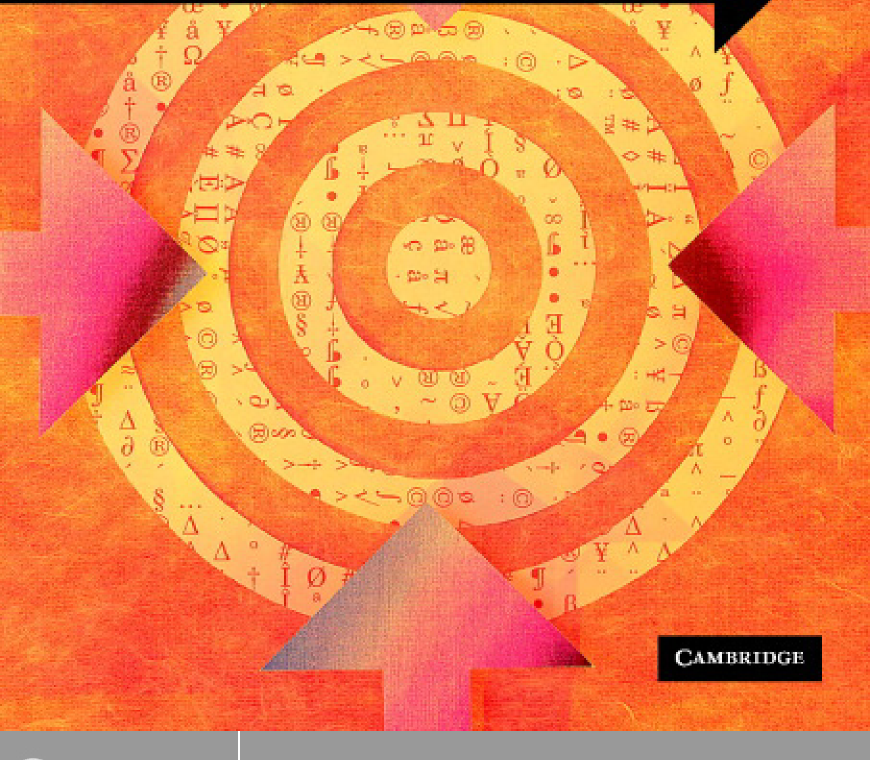
David Rainey

Product Innovation

Leading Change through Integrated Product Development



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Product Innovation

Increasing pressure to produce new products faster and more cheaply is resulting in huge efforts to streamline and restructure the traditional new-product development (NPD) process. The purpose of this book is to describe, assess, and apply the latest constructs, methods, techniques, and processes to enable managers, professionals, and practitioners to be more effective in designing, developing, and commercializing new products and services. It provides guidance and support in formulating and executing NPD programs for business practitioners and MBA students. The book is written from an integrated product development (IPD) perspective, linking all aspects of marketing, costing, and manufacturing into the development process even before the first prototype is built. It covers the advanced tools necessary to achieve this, such as virtual prototyping and fully integrated business systems, and explains the changes needed to organizational structure and thinking.

David L. Rainey has over 30 years of experience and leadership in industry and academia. He is a Professor of Management and the Chair of the Hartford Department of the Lally School of Management and Technology at Rensselaer Polytechnic Institute, Troy, New York. He is a leading, internationally known authority on global enterprise management, sustainable development, technological entrepreneurship, and product innovation.

I would like to dedicate this book to my wife, Elizabeth and my sons, Jonathan, Christopher, and Timothy. Without their love and support, I would not have been able to devote the time and energy to the book.

Product Innovation

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David L. Rainey

Lally School of Management and Technology
Rensselaer Polytechnic Institute

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Preface

Product Innovation: Leading Change through Integrated Product Development defines and discusses a comprehensive, state-of-the-art framework for managing product innovation and the related new-product development (NPD) process in complex and challenging business environments. Product innovation involves the conceptualization, design, development, validation, and commercialization of new products and processes that provide superior solutions to the needs and expectations of customers, stakeholders, and society. Product innovation is an essential strategic approach for creating competitive advantages in the dynamic, global business environment.

Globalization; social, political, and economic pressures; technological innovation; and turbulent market conditions and trends have shortened product life cycles and created demands for better, cheaper, cleaner, safer, and more-effective products. Product innovation involves developing new solutions that provide positive benefits to customers and stakeholders. Product innovation is the fundamental management construct[1] used for creating new products, reinvigorating existing products, and solving product-related difficulties with customers and stakeholders.

With a dramatic surge in NPD programs, leading business corporations across the world are improving their NPD processes, capabilities, and approaches to enhance integration and to become more proactive in meeting the realities of changing business landscapes. Entrepreneurs usually launch their businesses based on the introduction of a new product or service. Existing businesses perpetuate themselves by commercializing new products to complement, improve, or replace existing products and product lines.

Product innovation and new-product development involve difficult journeys for most companies, especially those with limited resources. There are many problems, pitfalls, barriers, uncertainties, and risks due to the ever-changing landscape of demanding customers, concerned stakeholders, and government mandates, and the turbulence in the business environment.

The successful development and commercialization of a new product or service[2] are the principal objectives and desired outcomes of product innovation. Product innovation is driven by the strategic context of the organization and the necessity to improve business prospects continuously in the light of the changing business environment. Anticipating change, and expeditiously responding to the dynamics of the business environment via product innovation, are important precursors for achieving sustainable competitive positions and exceptional performance.

Changing business conditions and trends require a higher level of management sophistication to keep pace with a rapidly evolving world. Innovation and leadership are essential means for turning challenges into opportunities, mitigating existing problems, and inventing the world of the future.

Product innovation is the theoretical construct linking the strategic context with NPD programs. Product innovation addresses the why, what, who, and how. It is the overarching framework for planning, developing, implementing, and evaluating new products, and for translating opportunities into realities using state-of-the-art processes, practices, methods, and techniques. Product innovation focuses on integrating the capabilities and resources of the organization into an agile and creative entity for developing new solutions that exceed customer and stakeholder expectations. Product innovation is the broad perspective (strategic) on creating new products. New-product development involves the specific processes and methods (tactical) for achieving results and success.

NPD methodologies have evolved over last 20 years from simple, sequential, slow-paced, uncoordinated methods to highly integrated, fully articulated processes using sophisticated management techniques to achieve creativity, learning, speed, quality, performance, reliability, and value creation. New-product development uses process-management or project-management methods for identifying, analyzing, selecting, developing, and launching new-product opportunities.

Integrated product development (IPD) is the prevailing product-innovation approach used by most global corporations. IPD is the concurrent development of new products and processes using cross-functional teams that enable collaboration and coordination between all of the participants within the organization and are strategically aligned with the needs of customers and stakeholders. IPD has evolved over the last decade to include many sophisticated management processes and practices such as "design for six-sigma," enterprise management, stakeholder-based (social, economic, and environmental considerations) methodologies, lean business management, mass customization, and the concepts of the balanced scorecard. Today, customers, stakeholders, and society expect and demand superior products and services that meet the needs of all constituents.

The book uses a multi-dimensional approach for developing new products and services in a business environment of rapid changes and high expectations. The basic methodologies incorporate an integrated perspective linking the external dimensions and the internal capabilities for formulating and implementing flexible and effective NPD programs.

The NPD framework discussed in the book is based on an enterprise-management model used to describe and analyze the business environment and the essential dimensions of customers, markets, stakeholders, competitors, supply networks, related industries, and the infrastructure. Enterprise management involves the integration of strategic management and the operational aspects of an organization with all of the external constituents and forces influencing the business. It is an embedded system that encompasses the whole, both internal and external, and the present and the future.

The purpose of the book

The purpose of the book is to describe, assess, and apply the constructs, methods, techniques, and processes for enabling managers, professionals, and practitioners to be more effective in designing, developing, and commercializing new products and services. The book is meant to serve business practitioners and MBA students. It is intended to provide guidance and support in formulating and executing NPD programs.

The methods and approaches can be adapted for real-world NPD situations or may be used by students in developing a theoretical NPD program to fulfill the requirements of a graduate-level course pertaining to the subject of the book. Regardless of the use, the constructs focus on the practical aspects of new-product development. The topics are presented in a style that allows the reader to concentrate on the subject matter. Footnotes are used to provide the scholarly underpinnings, to explain certain topics in more detail when necessary, and/or to offer differing points of view from other authors.

The book focuses on NPD processes that are most appropriate for incremental innovations. It incorporates enterprise management and stakeholder-based thinking with the conventional focuses on customers, markets, and competition to provide a richer level of sophistication by incorporating the multifaceted forces impinging on NPD opportunities and challenges.

The overarching objective of twenty-first-century NPD thinking is to maximize the value proposition. The value proposition is the critical perspective of product innovation. Customers seek value when purchasing products and services and want the benefits derived from innovative solutions. They want solutions not products. Similarly, the constituents of the enterprise seek value and expect a balanced portfolio of positive outcomes. Product innovation is not a zero-sum game where customers and producers win and stakeholders and society lose. It is about creating new products that are sustainable solutions for the future.

The book is divided into four parts.

Part I introduces product innovation, the strategic logic of new-product development, the underlying strategies for developing new products, the organizational aspects, and an overview of a "standardized" NPD process.[3] The principal organizational model involves the development and application of the cross-functional team with participants concurrently developing new products based on internal and external resources.

Part II focuses on the "fuzzy front-end" of the product innovation including idea generation, concept development and selection, and the definition phases of the NPD process.[4] The fuzzy front-end is the conceptual level that analyzes and determines the viability and suitability of the new-product candidate(s) and sets the stage for the design and development of the new product(s). It includes the preliminary assessments for determining whether to invest into the new-product opportunity(s), and how to map out a game plan that identifies specific details of the product and process to guide the organization.

Part III explores the methods and techniques used to design and develop the product/market, marketing, production, and financial dimensions of the NPD process. It covers the essential elements used during the NPD process and articulates the core objectives, strategies, techniques, and programs involved in deciding the appropriate courses of action pertaining to the developing new products. Part III provides the methods and techniques for making the conceptual-level decisions as well as the design and development decisions during the later phases.

Part IV discusses the operational level of new-product development. It includes the design and development, validation, pre-commercialization, and product launch. The last chapter provides concluding remarks and some insights into the future direction of integrated product development.

The book offers guidelines and templates for planning, developing, implementing, evaluating, and leading NPD programs. It introduces a "standardized" NPD process to explain, examine, and explore the intricacies involved in commercializing new products. The standardized NPD process includes the fundamental elements that most new-product plans and programs should have. However, it should be noted that not all of the elements of the standardized NPD process are appropriate for every situation. Indeed, it is the responsibility of the practitioners to determine the essential requirements for their situation and tailor the NPD process to suit their business conditions.

The overall objective of this book is to provide a systematic framework for developing new products using a process-management approach. Flow charts, templates, and suggested techniques are provided to guide the practitioner through the process. From the user's perspective, the challenge is to adapt or modify the standardized approaches to fit a specific situation. Within each chapter, boxed text offers real-world examples.

The process of creating a new product is exciting, demanding, and rewarding; it requires enthusiasm, creativity, and dedication. Product innovation is multifaceted, requiring input and collaboration from every function of the organization, and each and every participant. It involves many internal and external participants, including potential customers, suppliers, and interested stakeholders.

Successful NPD programs generally have five essential facets: the **Plan**, the **Program**, the **Process**, the **People**, and the **Product**. The plan provides the *direction*, the program provides the *vehicle*, the process is the *pathway*, the people are the *means*, and the new product is the *destination*. New-product development provides the mechanisms to make the transition from the present to the future; from an idea to reality; from challenge to reward.

The creation of a blockbuster movie epitomizes the process. It starts with a vision. The foundation for a movie may be based on a book, a concept, or a previous movie. The producer organizes the key participants; secures resources; and selects the screenwriters, the director, and the actors. The screenwriters adapt the story line, setting the stage for the overall direction. The director plans, organizes, develops, and implements the process to create the film. The director is the linchpin between the producer and the participants. The actors perform their roles according to the story line, adding their own creative talents to enrich the outcome. There are numerous editors preparing the final copy, extras providing realism for the scenes, technicians facilitating the production of the end result, staff supporting and handling the minute details of the process, and back-office personnel managing the practicalities of the production.

In addition to the internal participants, there are also external players. The producer generally works with a major studio to orchestrate the release and marketing of the movie. The studio provides the distribution mechanisms to theaters and ensures that the advertising and promotion campaign is synchronized with the release of the movie.

The actors not only turn words into actions, but also often expand their participation by providing feedback and comments to colleagues during the filming and editing. This indirect involvement allows them to contribute to improving the final product and to learn more about the entire process, not just their roles. It requires the entire team of players and other participants to make a successful movie. Even a single below-par performance can have a significant effect on the overall outcome. David Mamet, the Pulitzer-prize-winning playwright, said, “The greatest performances are seldom noticed.”[5] Success is not measured in terms of the parts but is based on the whole.

Like new-product development, movie making is risky business. Even the Oscar-award-winning director Steven Spielberg would agree. Spielberg directed “1941,” a box-office failure, following his great success with “Jaws.” Movies, like new products, may fail to achieve expected outcomes even though the participants followed the script exactly, with the right direction and appropriate resources. Success is never guaranteed.

Product innovation is driven by the *enthusiasm of success*, not by the risk of failure. However, even with the best methods and practices, failures occur. The fundamental premise of integrated product development is that outstanding execution, based on a well-articulated game plan and an effective NPD process, increases the probability of success. The main approach for product innovation is to orchestrate the resources and participants into an integrated force using a coherent framework that provides leadership, direction, organization, evaluation, management, and control.

The complexity of today’s technologies and products requires a systematic approach. Similar to Mamet’s comments, individual performances are not as important as the seamless involvement and collaboration of the integrated team within the management system.

The book explains how the cross-functional team manages the NPD process. The NPD process focuses on the alignment of internal functions of the organization with the external business environment and its customers and stakeholders to plan, develop, implement, and evaluate new-product programs.

Planning steps include: establishing a common purpose; setting objectives, goals, and targets; breaking the NPD process into elements; securing the resources and management commitments; organizing the effort; and mapping out a game plan.

Development steps include: analyzing the needs; generating ideas and concepts; selecting a new-product candidate(s) for development; designing the product(s); selecting appropriate means to produce the product(s); and developing a marketing campaign to support the product launch.

Implementation steps include: obtaining management approvals; securing the finance; ensuring the proper execution; and managing the uncertainties, risks, and rewards.

Evaluation steps include: obtaining feedback about resource utilization and organizational achievement; measuring performance in terms of targets and goals; determining that the NPD program is on track; and taking any necessary corrective actions.

Product development can be characterized as a process of interrelated decisions, proceeding from opportunities, ideas, and concepts to commercialization in a systematic way. Through analysis and insights, all participants gain confidence along the path to commercialization.

An effective NPD process provides direction, enabling management to align the people and resources of the organization strategically and to energize creativity. Strategic alignment provides the mechanisms for collaboration between the essential players. Creativity is achieved through the individual and team contributions using out-of-the-box thinking. It is the open-ended part that leads to new-product solutions and improvements in the NPD process. The systematic approach ensures that information is evaluated and used effectively to reduce uncertainty and risks. As knowledge increases, uncertainty tends to decrease, enhancing the probability of success. Likewise risk is not the enemy, but an essential part of the process. The basic premise is to manage risk, not to avoid it. A superior process is one that is clearly mapped out and understood by all the participants.

Product innovation is about the future and creating a more-favorable strategic position. It is about leading change, not just responding to it. Product innovation is about achieving distinction, creating sustainable products, and obtaining an enduring competitive advantage in the context of a challenging business environment.

Notes

1. Constructs are models or frameworks used to describe, define, explain, analyze, understand, manage, and control management systems, processes, approaches, and solutions. They are intended to mirror reality and provide practitioners and decision makers with the essence of the complexities of the business situation.

2. The book covers the development of products and services. For the sake of simplicity and readability, the term product(s) means products and services.
3. The "standardized" process is a generic process which incorporates the essential elements of the prevailing methods used by various large corporations. It is a compilation of the real-world NPD processes.
4. Numerous authors use the notion of a "fuzzy front-end." Anil Khurana and Stephan Rosenthal discussed the construct in detail in their *Sloan Management Review* article: Integrating the fuzzy front end of new-product development, *Sloan Management Review*, Winter (1997), 103–120. Rosenthal also described front-end processing in *Effective Product Design and Development: How to Cut Lead Time and Increase Customer Satisfaction* (Homewood, IL: Business One Irwin, 1992).
5. D. Mamet, *True and False: Heresy and Common Sense for the Actor* (New York: Pantheon Books, 1997, p. 79).

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Edward Arnheiter is a professor of management in the Lally School of Management and Technology at Rensselaer Polytechnic Institute. He teaches courses in operations management, supply chain management, and lean business management. He wrote Chapter 9 in the book.

Lou Gingerella is a Professor of Management at the Lally School of Management and Technology at Rensselaer Polytechnic Institute. He teaches courses in financial and managerial accounting and financial management.

Richard Picard is a Product Manager at the Wiremold, Inc. He is a graduate of Rensselaer Polytechnic Institute.

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I have tried where necessary to give full details of the sources for all data and information and am grateful to the authors. If I overlooked providing the appropriate citation, I apologize and thank the source.

Part I

Product innovation and strategic logic

Innovation involves changes and improvements to technologies, products, processes, and services that result in positive contributions for customers and other constituents of business organizations. An innovation is a creative new solution to the prevailing conditions and trends, and fulfills the expressed and latent needs and wants of customers and stakeholders.

Innovation management involves the means, mechanisms, and methods for leading change through developing new technologies, products, and processes. It includes changes in business models and organizational structure. Innovation management is imperative for improving product portfolios, enhancing and developing new products, and achieving customer and stakeholder satisfaction in the fast-paced world of globalization, technological change, and pressures from the business environment.

Innovation is pivotal for sustaining the prosperity of most organizations. If cash flow is the life-blood of a business enterprise, then innovation is the prescription for reinvigorating the organization to compete more successfully in a demanding world.

Product innovation concentrates on improving the strategic position and product-delivery capabilities of the organization through creativity and leadership. Product innovation includes several essential aspects.

(1) Examining the needs for new products, processes, and services.[1]
(2) Determining the proper direction and fit for new products.
(3) Establishing the appropriate game plan of the entire management system for developing and commercializing new products.
(4) Selecting new-product opportunities for investment.
(5) Enhancing the organizational capabilities to create successful new products.
(6) Creating the new product and executing the new-product development (NPD) program.

Product innovation is a dynamic construct requiring managerial and organizational leadership and skills; it is a far-reaching term. It involves taking the initiative to make incremental or even dramatic improvements to the existing product portfolios, replacing some of the current products with new ones, or developing new-to-the world products for the benefit of existing or new customers.

In this book, product innovation focuses on process-management methodologies for evolutionary changes to create new or improved products rather than revolutionary changes via technological innovation. Product innovation is a means of managing the destiny of the organization instead of reacting to the pressures of the markets and business environment. ***Leading change through integrated product development*** (IPD)[2] is the most important perspective. IPD provides the organization with the ability to improve its positions in the served markets as well as in new markets by creating new solutions. It presents opportunities to enhance the business environment in a favorable way.

The twentieth century witnessed many spectacular innovations, from the airplane to microprocessors and the Internet. Based on the successes of their new products and technologies, companies like Boeing, Intel, Microsoft, General Electric, Toyota, Siemens, Nestlé, Proctor & Gamble, and many others improved their methodologies and capabilities to develop new products using sophisticated NPD processes. The emphasis has shifted from thinking about the features of the new product to managing the process within a management system to ensure that the core needs and requirements of customers and stakeholders are fulfilled to the greatest extent possible and to ensure that everything within the process occurs as synchronously as possible.

The twenty-first century is in its infancy. Technologies, products, and processes are becoming more sophisticated. Customers want even better quality and more value. Product life cycles are shrinking. Speed is becoming the overarching metric. Leading change through innovation is about creating a better world with products and technologies that people can trust and that have positive impacts on the business environment. Customers, stakeholders, and society expect improved solutions with overwhelming benefits as well as significantly reduced negative consequences and impacts. The general solution includes better products, more-effective processes, and more-capable and more-creative people.

IPD is the mainstream approach for developing new products. Its origins were established in the aircraft industry and automobile industry during the late 1980s and early 1990s.

Part I provides an introduction and overview of product innovation. It describes and discusses the driving forces in the business environment that induce changes, and the strategic direction of the company for compelling new-product development. The most important discussions focus on the standardized NPD process. Part I includes the following chapters:

- **Chapter 1 Introduction to product innovation and new-product development**
- **Chapter 2 Strategic logic of product innovation**
- **Chapter 3 The new-product development process and organizational aspects**

Part I lays the foundation for the main premises discussed through the book. It introduces the enterprise-management model, which serves as a basis for formulating, analyzing, and implementing strategies for new-product development. The book presents an integrated perspective for developing new products using a stakeholder-based approach.

Notes

1. The book covers the development of products and services. For the sake of simplicity, the term product(s) means products and services.
2. IPD incorporates all of the internal (technical, marketing, product, financial, and management) dimensions and the external (market, stakeholders, supply networks, related industries, and infrastructure) dimensions into a comprehensive framework that focuses on the concurrent development of all of the dimensions and elements of the NPD process. IPD is discussed in more detail in Chapter 1.

1 Introduction to product innovation and new-product development

Introduction

Overview

Product innovation is the overarching management framework for making incremental changes and improvements to products, services, and processes.[1] It includes the conceptualization, design, development, validation, and commercialization of new products for customers and markets in concert with the prevailing conditions and trends.[2] Product innovation involves the creative responses and solutions for meeting the needs and expectations of customers and market(s), the driving forces in the business environment, and the strategic requirements of the organization. Product innovation runs the gamut from improving existing products to discovering entirely new ways of satisfying customers and stakeholders. From an internal perspective, product innovation depends on the knowledge, experience, capabilities, resources, and the prevailing technologies of the organization. From an external perspective, product innovation focuses on customer and stakeholder needs, wants, and expectations. Customers desire excellent products and services with exceptional value, outstanding benefits, high quality, and assured reliability. Meeting such specifications is the exciting challenge of product innovation.

Product innovation is challenging because of the complexities of the business environment, the changing needs of customers and markets, the effects of competition, and the difficulties associated with understanding the present and forecasting the future. However, the complexities of product innovation are simplified in most organizations because there are common pathways to define and describe the processes and methods used for developing new products, and the organization has an information system to support the required analysis and decision making. Product innovation requires contributions from strategic management, engineering, marketing, finance, production and operations, supply networks, distribution channels, and customers on a concurrent basis to ensure that the process encompasses the essential requirements for achieving successful outcomes. A diversity of knowledge, skills, creativity, and insights is an essential precursor for success.

Integrated product development (IPD) is the most widely adapted product-innovation methodology used to link systematically the external business environment – and its opportunities, challenges, and concerns – with the internal dimensions[3] of the organization – and its capabilities and resources – to create innovative solutions based on improved products and services. IPD is the concurrent development of new products using cross-functional teams that are strategically and tactically aligned so that every participant is involved in the process from inception to commercialization. IPD is the new-product development (NPD) construct (process) used by most leading corporations to manage their NPD programs.[4] There are many case studies and much empirical data to suggest that IPD is the most effective product-innovation methodology.[5]

IPD employs process-management techniques that integrate capabilities and requirements into seamless flows of activities for ensuring creativity, quality, thoroughness, and speed. Successful outcomes (new products) are realized through an effective NPD process that facilitates the flow of activities and outcomes from inception to commercialization using the knowledge gained from previous NPD programs and the skills and capabilities of the participants.[6]

IPD depends on the entire enterprise to achieve success. The enterprise consists of all of the internal participants, and the suppliers, the distribution channel, the customers, the stakeholders, related industries, and strategic partners. These dimensions[7] are discussed in detail in the first three chapters since they are central to the fundamental premises of IPD. Indeed, the strategic alignment of all participants during the planning and implementation of the NPD process is the very essence of IPD. It is the concurrent planning, development, and implementation of the NPD program, the process, and its elements that defines and distinguishes IPD. Furthermore, it is the ongoing evaluation of the activities, outcomes, and prospects for success that provides the wherewithal to discern the merits of proceeding, adjusting, or terminating NPD programs or new product opportunities and gives IPD its most crucial characteristics. Using the principles and methods of IPD, management and participants have a reliable sense of the prospects of success. An effective NPD process gives the decision makers the confidence that they are exploiting the best opportunities and developing sound solutions.

The prime objective of IPD is to produce cost-effective designs for both products and processes which meet or exceed customer and stakeholder needs and expectations, providing exceptional value for all constituents. The organizational goal is to maximize the performance of the people and the management system and to minimize the negative impacts of new products on the external business environment. IPD is a structured framework that provides management and practitioners with a clear understanding of the interrelationships between product development elements and their impact on the product creation process, and the realities associated with the supply networks, external stakeholders, customers and markets, and competition. The intent of IPD is to reduce dramatically the time and resources required for successfully introducing products to the market(s).

The concept of product innovation includes NPD programs involving improvements to existing products and the product development process of research and development (R&D) programs that create new-to-the-the world products based on new technologies. The technology-development side of R&D often involves technological innovation used to discover and create the underlying technologies. The theories and methods involving technological innovation are beyond the scope of those pertaining to product innovation.[8] The greater the departure from the prevailing technologies and market conditions the more likely it is that the type of innovation management process changes from product to technological, and from incremental to radical. The strategic process of selecting between product and technological innovation is a complex topic, and is discussed in Chapter 7.

The main premises of the chapter and introduction to the book

The premises presented in this chapter and subsequent chapters of the book pertain to IPD and NPD processes that are based on process-management theories, methods, and practices. They examine the strategies, approaches, methods, and techniques used to develop new products systematically in the demanding world of the twenty-first century.

The discussions are geared toward sophisticated practitioners and graduate-level students (as well as advanced undergraduates) who need to understand and manage the entire NPD process. The models, methods, techniques, processes, and practices are intended for an audience that aspires to actually use them in the world of product innovation. They are also devised to provide a sense of balance for those practitioners who are experts in a technical field but lack the breadth of knowledge about the whole NPD process, and its implications and requirements.

This chapter explores the basic definitions and implications of product innovation, IPD, and the NPD process. It provides background concepts on the evolutionary trends of business models and new-product development and sets the stage for understanding the driving forces of change in today's complex business environment. Furthermore, the chapter includes the fundamentals of the NPD process and the basic types of new products. The aim of the chapter is to provide an overview of the essential elements of product innovation.

Chapter 1 includes the following topics and main learning objectives:

- Understanding the meaning and purposes of product innovation and new-product development.
- Exploring the overarching pressures and driving forces for product innovation in a corporate setting.
- Linking product innovation to product management and the product delivery system.
- Identifying and assessing the types of new-product programs.
- Describing the fundamentals of IPD.

- Examining the primary elements of the NPD process.
- Exploring the fundamentals of NPD processes, methods, and techniques.

Product innovation and new-product development

Overview of product innovation

The primary objectives of product innovation are to create value, to obtain a competitive advantage, and to achieve long-term success through the development and commercialization of new products and services. The principal drivers of product innovation are customers, markets, stakeholders, and the other constituents in the business environment. The focus is on meeting their needs and expectations as they evolve.

Product innovation is a subset of the strategic-management system. Strategic management provides the direction, strategies, objectives, and the overarching decision-making process to determine what options should be addressed and how to create an atmosphere within the organization for discovering opportunities and responding to the challenges. Product innovation provides new solutions to old problems; creates new opportunities to exploit existing capabilities, resources, and assets; ensures sustainable outcomes through the systematic replacement of obsolete products; and builds new capabilities and resources for sustaining the future.

The business environment includes the social, economic, political, regulatory, ecological, market, and technological forces that impinge on the organization causing changes and providing opportunities and challenges. Social and economic forces have significant effects on stakeholders and other constituents of the organization. Political and regulatory factors establish mandates that drive the need for new products and specify requirements that must be included in the NPD process to ensure that all legal requirements are fulfilled. Ecological factors are critical for satisfying the basic underpinnings of the natural world and for maintaining a sustainable position in the future. Market forces generally influence the viability of existing products in the market place. Changing market conditions and trends establish new provisions that may not be satisfied by existing products. Such changes have effects on the life cycle of current product offerings, creating opportunities for new products. Technological forces provide new ways and means of dealing with customer and stakeholder needs and providing the mechanisms to create the products that customers demand, expect, or would like if they were available. All of these forces provide opportunities to create new solutions for satisfying the needs of the business environment, thus fueling product innovation and the NPD process. Each of these forces is discussed in more detail in the subsequent chapters of Part I.

Figure 1.1 depicts the elements of a simplified view of the main forces impinging on product innovation and the subset of relationships.

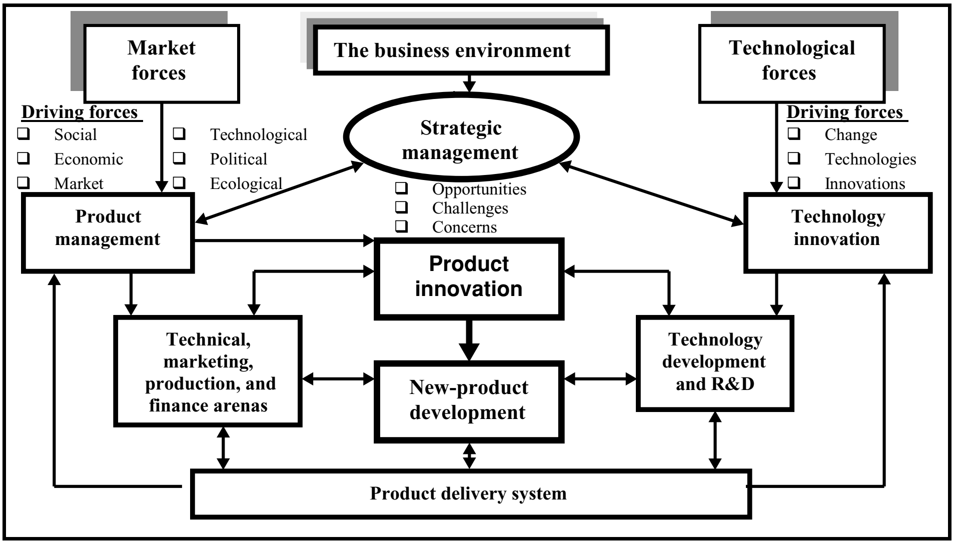

Figure 1.1 Simplified model of the primary elements of product innovation

Technological innovation includes technology development and R&D activities. These involve creating new technologies, developing the next generation (technology platform) of existing technologies,[9] improving existing technologies and new-to-the-world products and processes thereof, discovering new technologies to improve existing products, and finding new opportunities to exploit the technical capabilities and resources of the organization. Most of these topics are beyond the scope of these discussions since they are related to technological innovation.

Product management involves the technical and marketing functions for delivering products and services to existing customers and markets using the organization's product delivery system. Product management provides information and data to support requests for new products. Depending on the organizational structure, it may have a direct role in leading and/or managing product innovation and new-product development.

In most organizations, current products and services constitute the primary functions and modalities of the product delivery system. The product delivery system consists of the resources and capabilities to produce, market, and deliver the product lines and the related support services for satisfying customers and generating cash flow. The product delivery system includes all of the elements of the value chain necessary to produce and deliver products to customers successfully.[10] The product delivery system is critical to the ongoing success of any organization. It is the flow of products and services to customers that provides the cash flow for sustaining the life-blood of the organization. However, most products and services have a limited life cycle or attractiveness in the served markets. Products and services have to be refreshed, reinvigorated, or replaced on a periodic basis to avoid deterioration of market positions or obsolescence.

Product innovation examines the need for innovative products and processes, and the requisite NPD programs. It determines the role that new-product development plays in providing the mechanisms to create change.

The NPD Process

The NPD process is a horizontal construct that links activities and actions for converting inputs into outputs in a systematic way. The NPD process incorporates phases and reviews that ensure a comprehensive progression of accomplishments for creating a new product(s) based on the strategic direction and the operating capabilities and requirements. The NPD process follows a logical flow from the strategic phase, through the development phases, to the product launch.

The NPD process is a prescribed pathway that practitioners use to formulate and implement an NPD program. This book discusses an NPD process that can be described as a "standardized"[11] (generic) process. The NPD process includes **phases**, **steps**, **activities**, and **reviews**. The phases are the major areas that include the description, analysis, and development of the action items and are typically followed by a management review and/or approval prior to moving to the next phase.[12] Generally, the phases include the following:

Phases and reviews of the generic NPD process

- ***Phase 0. Strategic Logic and Alignment***
- ***Phase 1. Idea Generation***
- ***Phase 2. Concept Development and Selection***
- ***Phase 3. Program Definition***
- ***Phase 4. Design and Development***
- ***Phase 5. Validation***
- ***Phase 6. Pre-commercialization and Launch***

The phases and reviews provide a standardized format for executing the NPD program within the management system. They give management the ability to review and evaluate outcomes without interfering with the normal flow of activities and accomplishments or constraining the creativity of the practitioners. Reviews are flexible activities that may be simple discussions or involved presentations and debates. They are dependent on management style and the criticality of the elements under discussion and awaiting approval.

The phases allow the participants to carry out the specific requirements of the program with flexibility. The activities within the phases are generally accomplished using parallel streams, providing the means to minimize the time and effort spent on individual activities. The format of the book follows the NPD process. Figure 1.2

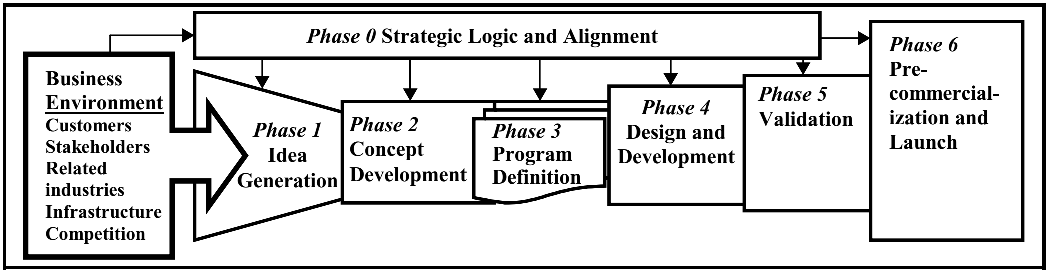

Figure 1.2 The standardized NPD process

provides a general framework for the NPD process. The overarching goals are to develop the new products successfully and to satisfy the needs of the business environment.

For an NPD program, the basic approach is to identify the required phases, steps, activities, and reviews, and to map out a pathway (in series and in parallel) that builds value, minimizes time, and ensures thoroughness. A key to success is to implement as many of the activities as possible on a parallel basis.

The NPD process provides the mechanisms (through phases and reviews) to simplify the flow of the activities into less-complicated, easily understandable steps so that everyone knows what to do. Given that NPD programs tend to be related and have similar requirements, the execution of the NPD process provides answers to the following:

- Why is the new product being developed?
- What is required to develop it?
- When does the new product have to be available in the market?
- Who is responsible for the NPD program and the activities?
- What are the outcomes required to meet expectations and how are they measured?

The NPD process provides structure for ensuring that activities are linked with the upstream and downstream requirements and participants. Decisions are made on the basis of what has to be done and when it has to be accomplished. The NPD process depends on the organizational capabilities and resource management. People perform tasks and get results and they need to have the capabilities and resources to achieve those results.

The framework for product innovation

The framework for managing new-product development provides linkages between the chapters and the flow of the content of this book. The NPD framework provides a unified approach to guide the way to the ultimate results. It is based on the opportunities and challenges in the business environment and the strengths and weaknesses of the organization.

Executive management establishes the vision and its commitment to product innovation and the NPD process. New-product opportunities are framed in the context of the overall social, economic, market, political, and technological realities of a complex and rapidly changing world. These elements are developed further in Chapter 2.

The NPD framework is based on a wide array of technological, financial, and market-related considerations. The main aspects of proper integration are:

- Creating value for all of the external constituents and internal participants.
- Developing a network of value relationships with customers, stakeholders, related industries, and supply networks that are part of the system and are integrated into the NPD process.
- Establishing the management system and processes for the effective planning and implementation of NPD program(s).
- Creating cross-functional team(s) that understand the interactions required for achieving success and managing creativity and complexity.
- Allocating resources adequately across the organization based on the process requirements.
- Incorporating change-management mechanisms and infusing information and knowledge into the process.
- Managing uncertainties, complexities, and risks.
- Evaluating performance on an ongoing basis.
- Linking the NPD process and the results of the NPD program to the creation of value.

These aspects are covered throughout the book.

Figure 1.3 provides an overview of the flow of the book and how the chapters relate to product innovation and the NPD process.

The overarching driving forces for product innovation

Profound changes in business-management constructs

Based on the dramatic changes in the business environment and sensational improvements in products and technologies over the last few decades, management theories and models have evolved from simple frameworks focusing on the performance of the existing product delivery system to more-elaborate management systems focusing on strategic positioning for the future. While it is obvious that executive management has to think about reinventing the business to keep pace with the changing business environment, the notion of continuous change is a burgeoning concept that is implicitly understood by leading business executives, but the implications and impacts are not always fully appreciated. Innovation is an absolute necessity to avoid becoming obsolete.

Traditional management models were simplistic hierarchical organizational structures with senior management creating the strategic direction and functional management (through the chain of command) providing tactical decision making. The

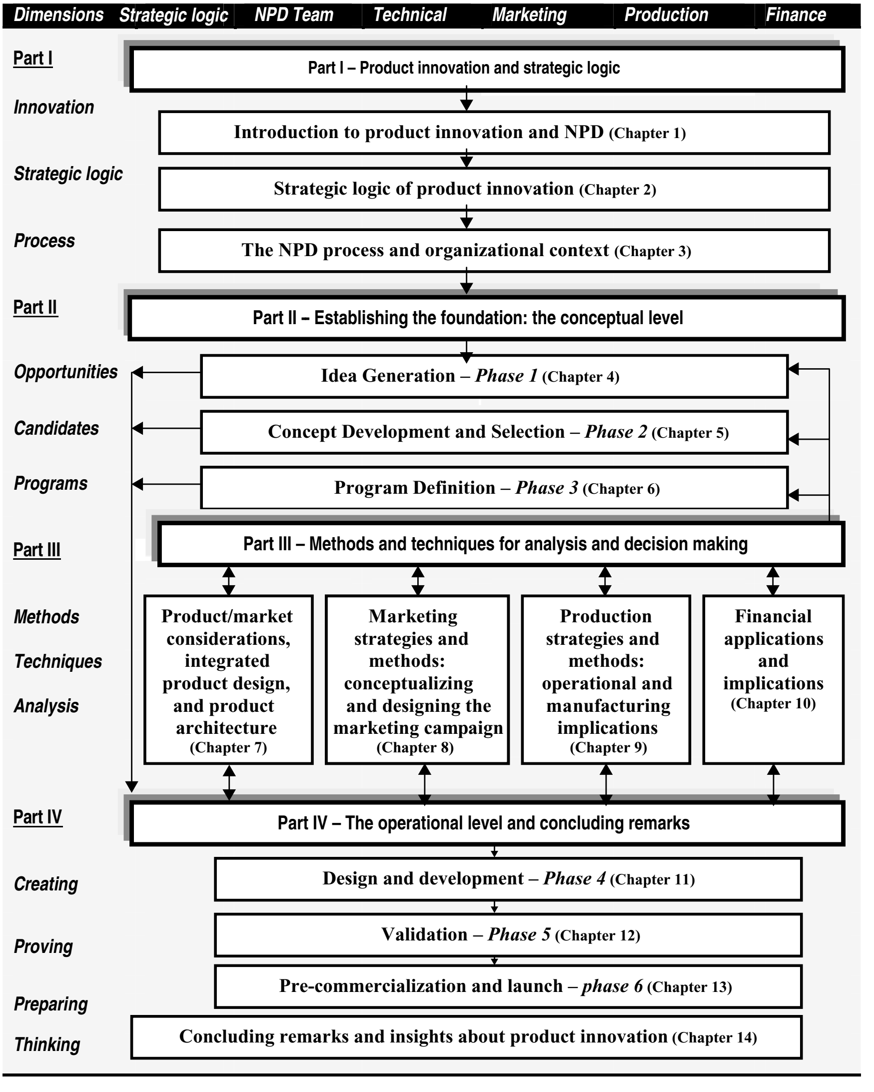

Figure 1.3 The general framework of the chapters of the book

hierarchical models worked reasonably well as long as management had sufficient time to acquire information, analyze the situation, and make appropriate decisions. In the relatively slow-paced world of the early twentieth century, the hierarchical organizational models functioned adequately because most businesses had similar time-consuming approaches that burdened analysis and decision making with slow-paced information flows and interfaces. Moreover, the driving forces of change were less powerful with the implications of change gradually unfolding over many years; therefore, the requirements for interactive systems were not pressing.

However, the business environment changed radically during the early 1970s. With the oil crisis of 1973 and a similar situation in 1979 – along with high inflation, stagnation, and high interest rates – the business environment became more turbulent and less predictable. The rate of change increased significantly as business entities around the world expanded their reach to find new opportunities and exploit their competitive advantages in new markets. Change became an ever-present phenomenon, creating opportunities, challenges, and concerns (threats).

Based on the changing landscape, the early vestiges of globalization took hold. Competition expanded dramatically as powerful producers in regional markets sought opportunities in distant locations. The US automobile industry illustrates the phenomenon. The insular "Big Three"[13] companies were ill-prepared to respond to the onslaught of the Japanese and European automobile companies with superior product quality and enhanced benefits. World markets had radically changed, demanding products and processes commensurate with the new realities of high quality, excellent performance, and better value. However, General Motors, Ford, and Chrysler were unable to keep pace with such changes during the late 1970s and early 1980s and their fortunes suffered. In the global business environment, success is measured based on world-class attributes, not local capabilities and practices.

Faced with the realities of global events and global impacts, strategic business-planning models of the late 1970s drastically changed conventional management thinking. Strategies, objectives, philosophies, principles, and management systems became more important than organizational structures and operational tactics and activities. Management reached out to identify and incorporate new opportunities and to respond to threats. Management models evolved from organizational structures to management systems that included strategic thinking, strategic management, and the construct of the value chain. Total quality management (TQM) and similar constructs were key drivers in the evolution toward a more-horizontal structure, replacing the vertical approaches of the hierarchical organizational models. The focus was on continuous improvement and the capability to manage continuous change.

During the 1980s, Michael Porter's famous "value chain and value system" were truly revolutionary perspectives on management systems.[14] Porter changed the basic management models from focusing on organizational linkages in decision making to a process-management orientation of managing deliverables and achieving high performance. His models embodied the philosophies of quality, customer satisfaction, and value. Porter focused on the system and its essential elements and examined the interrelationships between suppliers, producers, value networks, customers, and competitors, and how those relationships created value and provided linkages with customers. While new entrants and substitution were explored, the dominant perspective was on the prevailing situation. Porter's model of the "Five Forces" became the dominant perspective for managing the product delivery system.[15]

During the 1990s, management systems became even more sophisticated as business leaders made significant improvements in aligning corporate and business strategies, integrating operations, managing innovation, and improving overall business performance. The management system became the pivotal construct. The management system is the integration of all of the essential elements of the internal and external dimensions for managing in the present as well as in the future.

Concurrent with improvements in management systems, strategic-management models expanded to include a much broader perspective for managing businesses, especially for global corporations. The overall management system consisted of:

- Strategic business management focusing on developing and implementing corporate strategies and initiatives for change.
- Product-delivery management (operating system or operating management system) focusing on near-term performance and results.

Strategic business management and product-delivery (operating system) management are well-known subjects that have evolved over the twentieth century. They are geared toward the long term and short term, respectively; they are still evolving. Strategic management involves determining the strategic position of the organization in concert with the external factors influencing the business. Strategic management concentrates on business development, innovation management, managing change, and building sustainable strategic positions for the future.

The basic premise of this book is that product innovation is a strategic-management approach for leading change.[16] In addition, strategic management is about leadership and leading change – not just developing products, processes, or technologies!

A brief overview of the evolutionary trends in business-management constructs

Business enterprises (corporations) have evolved dramatically over the centuries. Initially most commercial entities had a single product based on an established process. Such organizations were straightforward, and change was rare. Today, management systems are complicated, having multifaceted levels and dimensions that require ongoing adjustments and change. Change is expected and managing change has become an exigency in managing any organization.

Figure 1.4 provides a basic overview of the hierarchy of historical business models.[17] Whereas there has been an evolutionary trend from the simple to the complex, each of the general constructs still exists today.

- ***Singularity*** (historical). The prevalent historical model involves the production of a single product (usually a material). It is typically driven by supply and demand of a commodity. It involves process-oriented operations using basic technologies. Mining is an example.
- ***One-dimensional product concept*** (nineteenth century). The one-dimensional (1-D) product concept model focuses on the producer's perspective of products and production. It is based on the assumption that customers will buy whatever is available. Standard products are the general offerings based on production techniques using

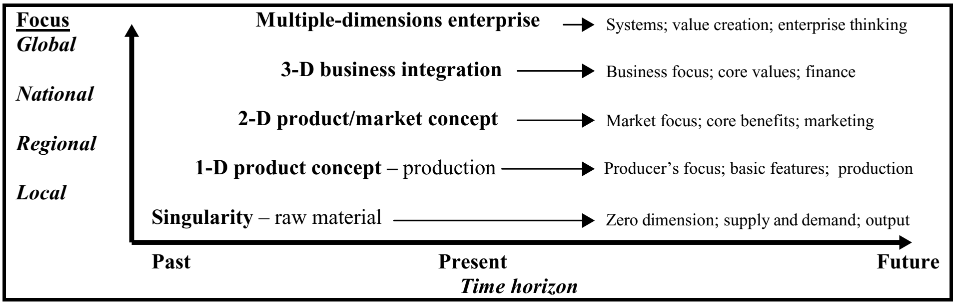

Figure 1.4 The hierarchy of business models

basic or even innovative technologies. Pistols and rifles of the Colt, Winchester, and Smith and Wesson days are examples.

- ***Two-dimensional product/market concept*** (mid twentieth century). The prevailing management model changed after World War II, when producers in the United States were able to meet customer demand, but not necessarily their expectations. The product/market concept is a two-dimensional (2-D) model, addressing customer needs and understanding the benefits desired. The market-share leaders developed innovative technologies and products to gain a competitive advantage. US cars made during the 1960s are examples.
- ***Three-dimensional business integration*** (mid 1980s). Driven by the dramatic improvements in products and technologies by the Japanese and others during the late 1970s, global companies realized that they needed an integrated perspective of their businesses, linking suppliers, distributors, and customers with the product delivery system. Porter's value system depicted this construct, which focused on value creation, organizational capabilities, and product delivery. Competitive advantage is obtained through leading-edge technologies and providing customers with superior performance. Canon's entry into the copier business and its success against Xerox, the market leader, is a great example.
- ***Multiple-dimensions enterprise*** (late twentieth century/early twenty-first century). Enterprise-management models link not just suppliers and customers, but every entity involved with the management system on a global basis. The focus is on integration and innovation, and leading change using product and technological innovation and strategic relationships with multiple partners, alliances, and networks. Toyota is a good example of a corporate model.

Table 1.1 provides insights into the essential aspects of the multiple-dimensions enterprise model. While the key factors pertaining to the two- and three-dimensional models are well known, the critical aspects and perspectives of the multiple-dimensions enterprise models are still evolving. The basic aspects are defined further in Chapter 2.

Table 1.1 *Key perspectives of 2-D, 3-D, and multiple-dimensions enterprise models*

	Salient aspects	External perspective	Internal perspective	Essential metrics
Multiple-dimensions enterprise model	• Global perspective • Leading effects • Managing change • Value creation	• Globalization • Value networks • Value proposition • Interfaces • Opportunities	• Integration • Innovation • Leadership • Focus and fit • Entrepreneurship	**Value creation** **Total satisfaction** **Creativity** **Learning** **Risk mitigation**
3-D business integration model	• Management system • Strategies • Vision/mission • Objectives	• Product/markets • Attributes • Supply networks • Business environment	• Knowledge • Relationships • Technologies • Capabilities • Resources	**Cash flow** **Quality** **Effectiveness** **Responsiveness** **Cost**
2-D product/market concept model	• Product lines • Product delivery • Product development • R&D	• Customer satisfaction • Demand • Applications • Liabilities	• Engineering • Marketing • Production • Finance • Assets	**Profitability** **Efficiency** **Productivity** **Cost**

The enterprise is the entire organization (corporation) with all of its external relationships and linkages. It is the high-level strategic-management system of the corporation and all of its strategic business units and their product delivery systems along with all of the physical and virtual relationships with supply networks, partnerships, alliances, and other value networks. The enterprise includes its customers, stakeholders, suppliers, distributors, related industries, and the external infrastructure. Leaders of multiple-dimensional enterprises have to understand the underpinnings of change and determine the effects of those changes. A comprehensive understanding of the business environment, and its conditions and trends, provides insights into managing change and developing appropriate strategies for being the market leader.

The most profound factor is creating value. From an enterprise perspective, customer satisfaction is important, but it is only one aspect of creating sustainable value. The value proposition is described and discussed in Chapter 2.

The organizational capabilities are embedded in the people, not the functions. The central internal perspectives and organizational aspects are the integration of the capabilities and resources, innovations for the future, and leadership of the people. The prime strategic directive is to determine the focus for the organization and discover its fit into the world of opportunities. Such opportunities are driven from a global perspective, as well as at local and regional levels. Moreover, they are based on creating opportunities from an entrepreneurial point of view and from the outcomes of technological and product innovations. In the dynamic world of the twenty-first century, it is about creating opportunities, not just finding them.

The most crucial metrics are value creation, total satisfaction, creativity, learning, and risk mitigation. The most appropriate measure of any activity, operation, or strategy is the value that it creates. The bottom-line of the enterprise is value. If creative people are measured in terms of productivity, they are most likely to be viewed as underperforming. However, when examined from a value-contribution perspective, the result may be different. If the focus is on the short term, creativity and other valuable outcomes may not be given significant attention and reward.

Learning is also an overarching measure. How quickly can the organization change? How much time will it take to develop a new product? The learning metric relates to the responsiveness of the organization to proactively invent its future. It is linked to the organization's ability to be creative and to become the architect of its future.

In a rapidly changing world, knowledge expands and then quickly becomes widely distributed. Leading-edge methods, practices, and approaches become commonplace, and then obsolete.[18] Learning is pivotal in maintaining a competitive position. Rapid learning sustains the knowledge base, which is an essential ingredient for success. If the twenty-first century is about high-technology solutions and sustainable performance from a global perspective, then people are the most important resources of the organization. Learning not only enriches those resources, but also creates leading-edge capabilities that are difficult for others to emulate.

Risk mitigation is discussed at the end of the chapter. It is a common theme woven throughout the NPD process. Without risk mitigation most NPD programs would be viewed with uncertainty because of the high inherent risks.

The logic for leading change

The logic for leading change is embedded in the complexities of the global business environment. The main underpinnings forcing change are globalization, time compression, and technological integration.[19]

Globalization is the overwhelmingly significant factor. It is the notion that the world economies are shifting toward a borderless economic structure in which nation states are less relevant and global corporations vie to satisfy customer demand based on standardized (global) products, using more-homogenized approaches. Space and time are compressed and geography is not a critical factor. For instance, a single event anywhere can have profound effects on everything. The effects of the terrorist attacks of September 11, 2001, that resulted in the destruction of the World Trade Center in New York and the damage to the Pentagon in Washington, DC, are among the most far-reaching in history. Since that time, the United States and its allies have fought wars in Afghanistan and Iraq in an attempt to reduce the threat of similar attacks. People are less secure about their safety and have made profound changes in their travel plans and lifestyles. Businesses are spending more on security and are changing products to incorporate new requirements based on the current realities of the world. Globalization means being directly or indirectly linked to everyone and everywhere.

The Internet is the great example of a significant global change. It has dramatically expanded the communications infrastructure between entities and individuals on a global basis via a very low-cost and ubiquitous media. It epitomizes globalization! The Internet makes it much easier to acquire knowledge and information and to change dramatically the competitive situation.

With global linkages being so pervasive, it is difficult to establish a dominant position that can be sustained over time. While there are numerous examples of dominant strategic positions such as Microsoft's software and Intel's microprocessors, the case history of the twenty-first century may have more stories like Motorola's dominance in cellular telephones being usurped by Nokia, and then in turn by other competitors. Globalization also means that an organization may be the biggest, but not the best. Moreover, strategic advantages may evaporate quickly as new technologies are accepted. General Motors is the largest automobile manufacturer but it does not have the best market capitalization or the largest number of market-share leaders in the various segments.[20] The most important implications of globalization are the ramifications of markets and customer expectations. The universal product (the Model T, VW Beetle, or the DC-3) is a rare phenomenon. Even leading-edge products and technologies have short life cycles. Intel's Pentium products are replaced at least every two years.

Mass customization is a relatively new concept that is useful when thinking about global markets. Each customer wants the product his or her way! In the fast-food business, McDonald's has retained the mass-production notion of "we do it all for you," but it is searching for ways to differentiate itself in defense of its market share. It is trying to discover new approaches to provide customers with exactly the right product at the right time! Mercedes has changed its mantra for the supply process of automobile manufacture from "the right product at the right time in the right quantity and quality at the right place" to "each customer receives his customized car at the agreed due date."[21]

The most intriguing challenge is the consequences of time compression. The linkage between the time dimension and globalization is a key driver of innovation. Because of the expanded means of communicating and disseminating information, knowledge, and know-how, proprietary positions quickly become part of the public domain. Superior positions fade quickly. Companies like Lucent Technologies within a few years went quickly from the pinnacle of success to trying to reinvent itself.

Time compression is an essential force in the world of the twenty-first century. As product life cycles become shorter, the cycle time to develop a new-product (improvement, replacement, or new-to-the-world) has to be improved. The automobile companies have made significant improvements in their NPD cycle. Kim Clark reported that the average development lead-time during the mid 1980s for the Japanese automobile companies was 43 months; the American and European companies were at 62 months.[22] Today, the average development cycle for a new automobile model is between 24 and 36 months.[23]

The implicit question is what leads and what follows, time compression or the strategies to reduce cycle time. The question is interesting; the answer is unimportant! It is an ongoing process, and, to a large extent, the question supports the premise of this discussion! The main implications of time compression reinforce the importance of invention, innovation, and leading change. Organizations have to become very good at leading change because change is an inherent part of managing an enterprise. The choice is to lead change or to be inundated by it. If you accept the notion that time compression will continue, then the entities that can manage change will survive and prosper and the incapable will shrink into oblivion.

Technology provides the means to change systems, products, and processes. Technology integration is an essential part of managing the enterprise. It implies that various technologies may be necessary to produce an innovation. It also means that technologies have to be embedded into and become part of the system.

Technological innovation is the dynamic part of the system with continuous improvement and ongoing change. Assuming that the technological underpinnings remain constant over time is a risky proposition. Indeed, Intel's investment into its Pentium technologies is an example of the technology-platform concept with the new generation being related to the previous. The Pentium strategy has been successful for approximately a decade. However, there are new (different) technologies on the time horizon. Sun is working on a "clockless" microprocessor.[24] What happens to Intel if the alternative approach becomes the dominant technology? If you do not create the next technological wave, someone else will!

Integration is built on the premise (fact) that technologies are linked and that any given technology is useless without the support of related technologies. The automobile is a good example. James Womack, Daniel Jones, and Daniel Roos called the automobile, "the machine that changed the world."[25] The automobile was the dominant product of the early half of the twentieth century, influencing everything from "drive-throughs" to the mobility of the population. However, the modern automobile is not the mechanical device that Daimler-Benz, Henry Ford, Alfred Sloan, and others created. It is a combination of very sophisticated technologies, from fuel injection using computer technology to global positioning system (GPS) navigation. It represents the fusion of countless technologies that have been integrated, refined, improved, and rapidly changed over the last century.

While the list of profound effects might include every conceivable variant, it is sufficient to say that the key drivers for change are people, technology, the business environment, and how society and businesses manage opportunities and challenges.

Integrated product development

A brief overview of traditional NPD methods

The traditional NPD methods were relatively slow paced because each activity was completed in series rather than in parallel. The "sequential approach," as it was called, allowed each functional unit to contribute to the overall process independently of many of the other participants. The upstream activities were executed based on the inputs available at the time, without much regard for downstream considerations.

The typical NPD program flowed from R&D to design and engineering, marketing, production, testing, and commercialization. The approach was viewed as efficient since it tended to minimize the resources devoted to the NPD program at any point in time. However, there was very little collaboration and the information and data from upstream activities were handed over to the downstream participants without much direct involvement or ongoing commitment. The notion of "technology transfer" had great importance because it involved transferring the responsibility for the development from one functional group to the next group and providing them with all of the information and knowledge. However, failure to interface properly during the transition leads to an inadequate understanding of the situation or missing ingredients in the design and development constructs.

Whereas the sequential approach may have been efficient, it was not always effective. The process was time consuming and fraught with uncertainties because each functional area operated semi-autonomously without a complete sense of the entire program. The ability to evaluate the probability of success was limited during the NPD process, because the picture was fragmented and a complete view was not available until near the end. In many cases, only after a significant investment was made and most of the work accomplished was there sufficient information available to make a judgement about the viability of the NPD program. That point was often so close to the end of the NPD program, that there were few options for change or termination without significant cost or time implications. Moreover, there tended to be many mistakes due to the lack of downstream inputs and meaningful reviews. Design engineers would perform to the best of their capabilities, but would fail to achieve good designs because they lacked the necessary contributions of downstream participants from production or marketing. For instance, the product design often incorporated specifications and requirements that proved to be difficult to obtain or accomplish from a production perspective. Downstream players would be similarly disadvantaged because they would not know the reasons why certain selections were made. The lack of coordination would slow the process and create the need for additional activities to correct the inconsistencies and mistakes. The failure to truly integrate the process cost time and money and reduced the probability of success.

The lack of understanding of the entire process by the participants also contributed to the many mistakes. Even with highly skilled and dedicated personnel, the fragmented process contributed to ineffective coordination and poor communications. The focus was on the specific tasks rather than the overall objectives of the NPD program and the strategic implications.

Basic overview of IPD

The concept of IPD evolved because customer expectations necessitate continuous performance improvements, requiring faster, better, cheaper, and lower-risk NPD programs. Shortening life cycles means that products have to be regularly updated to be competitive and the updates must occur more frequently. Given the proliferation of available products and services and the fragmentation of markets, new products generally have to be tailored to meet the specific needs of each market segment.

The Boeing 777 Development Program was an early innovator of IPD. When Boeing managers reflected on the performance and cost implications of their traditional sequential process that had been used on a previous design program (Boeing 767), management realized that significant costs were added to the production of the plane over its life cycle due to the lack of coordination during the design phase. Phil Conduit, General Manager of the Boeing 777 program, commented on the previous design methods, "One engineering person out of three exists to fix mistakes made by the other two."[26]

The Boeing 777 program is an example of how a company made the transition from the sequential or, as Boeing called it, the “over-the-wall” approach to IPD.

IPD focuses on speed to market, superior product performance and reliability, reduced development cost, low unit cost, and greater flexibility. Speed is essential because customers want solutions to their needs or problems quickly. Time means money. Moreover, there are always competitors putting pressure on existing products and services. Senior management and product managers have to make rapid determinations about the feasibility and acceptability of the new-product opportunities, review the expected requirements and results, and forge effective game plans for the NPD programs.

The centerpiece of IPD is a descriptive, analytical, and structural framework that provides managers and practitioners with a means to integrate all of the requirements and resources on a real-time basis. IPD enables managers to make informed decisions because the upstream and downstream players are involved on a concurrent basis. It integrates the concepts, approaches, methods, and techniques used by practitioners into a single methodology. It allows the participants to understand what is required, how the elements are integrated, and who is to perform what roles and take on which responsibilities.

The central challenge of IPD is the understanding and articulation of current and future customer needs and requirements, and how to translate opportunities into realities. The underlying aspiration of IPD is to achieve outstanding product/market quality and performance and enjoy product longevity in a dynamic business environment.

The essential aspects of IPD

The basic philosophy of IPD is the synchronization of the activities of the participants from start to finish to maximize value and outcomes, and minimize the time, effort, investment, uncertainty, and risk. Organizations are continuously improving their NPD processes to increase product value, quality, and performance, and to reduce defects and burdens. In simple terms, the NPD process integrates the essential elements: markets, technology, finance, and management. They must co-exist. If one of the elements is missing, the new-product opportunity is incomplete or it may evaporate altogether. Figure 1.5 depicts the essential elements of an NPD opportunity.

The Iridium telecommunication project is a good example of the necessity for an integrated approach. The venture had the investment money and they were successful in developing the system of 66 satellites, plus spares. However, they used the sequential development approach for handling the technical aspects of the system before they truly addressed the marketing issues. When they initiated the marketing campaign, they realized that the market for their system was insufficient to warrant the investment. They failed and lost billions of dollars. See boxed text in Chapter 6.

The most important basic elements of a new product are underlying technologies, the related technical aspects that it employs, and the market segments that it serves. This

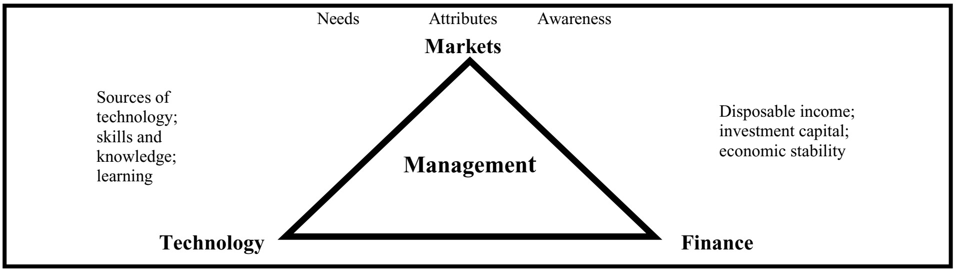

Figure 1.5 Essential elements of an NPD opportunity

view suggests that the new product is defined in terms of its product/market position and the underlying technical structure. Financial implications and management approaches are also pivotal. The financial elements relate to the internal and external funding sources. The organization must be able and willing to invest in the development of the new-product. The potential customers must be aware of the new product, have the disposable funds to purchase it, and be convinced that it is worth their time and money.

Internet start-up companies that failed are good examples of incomplete frameworks from a financial perspective. Initially investors were willing to fund the companies and their activities. But, the lack of paying customers caused the opportunities to disintegrate and investors rapidly withdrew their financial support.

Management is the integrating component. It ties the elements and activities together. It provides the leadership and direction. Management formulates the strategies, implements the action plans, manages the processes, and evaluates the results. However, it is more than just management. It is about leadership. Management provides the inspiration and the guidance to ensure that participants travel down the pathway to success. Product innovation requires creativity and a dogged mindset about achieving desirable outcomes regardless of the obstacles. The NPD process is glued together by the leadership and the team(s) who lead the process toward achieving the objectives, the targeted results, and success in the markets.

The framework of IPD

The traditional approach did contribute to new-product successes, but the pathways were long and difficult. There were missing links:

(1) A comprehensive framework within the strategic-management system for managing NPD which provides a clear approach for decision making and determining NPD program status and assessing the probability of success.
(2) An integrated view of the interrelationships between the key internal participants and the constituents in the business environment.
(3) A systematic process for achieving and measuring results on a timely basis.

An integrated framework incorporates the essential elements of an NPD process that combines the market, the product, production, marketing, and financial dimensions in the light of the external forces. The framework provides practitioners with a clear understanding of the interrelationships between the NPD elements and the complexities of the strategic-management system and organizational structure. It includes the critical internal and external requirements that are necessary for achieving successful outcomes. The focus is on synchronous development of all of the important activities to the greatest extent possible. The framework provides the policies, guiding philosophies, principles, the means to identify and execute the requirements, and ways to eliminate barriers.

Steven Wheelwright and Kim Clark articulated the concept of a framework for a development strategy in their book, *Revolutionizing Product Development*. Their book articulated some of the key principles of IPD.[27]

Our research on and experience with firms that have superior development capabilities suggest that a much more comprehensive framework for a development strategy provides a far more secure foundation for an individual project. This framework addresses the four main purposes of development strategy:

- Creating, defining, and selecting a set of development projects (NPD programs) that will provide superior products and processes.
- Integrating and coordinating functional tasks, technical tasks, and organizational units involved in development activities over time.
- Managing development efforts so they converge to achieve business purposes as effectively and efficiently as possible.
- Creating and improving the capabilities needed to make development a competitive advantage over the long term.

Their model deals with the strategic aspects of technology assessment and forecasting, and market assessment and forecasting, which form the foundation for the technology and market strategies. The framework links strategies with product plans and the individual NPD programs. Wheelwright and Clark suggest that the integration of marketing, manufacturing, and design functions leads to speed, quality, efficiency, and effective problem solving. They argue that, "the ability to identify opportunities, mount the requisite development effort, and bring to market new products and processes quickly is critical to effective competition."[28]

The NPD framework includes identifying and characterizing the dimensions of the NPD process, positioning new-product opportunities in the light of market realities, building flexibility into the process, managing accelerated NPD programs, determining the mechanisms that management uses to guide the product development through the organization, and defining the metrics for monitoring performance. The framework provides a logical flow of the key elements of an NPD program and establishes a systematic process for managing the complexities involved in any situation.

IPD focuses on integrating the organizational capabilities and resources into an effective team that can manage and execute the process for developing a new product and achieve superior results. IPD also means improving the NPD process and enriching the people involved so that they are ready for the next opportunity. The management system must have the capacity to formulate, analyze, and implement an NPD program, to enhance the process for the future generations of new-product programs, and to ensure that the organization and its key participants capture the learning and knowledge for sustaining the activities. The basic premise is that the need to create new products is a continuum; therefore, the process must be systematic and holistic.

Principles of IPD

IPD relies on the articulation of guiding principles to all of the participants so that they understand the underlying drivers and philosophies. The fundamental principles offer both guidance and direction. The IPD principles are as follows:

- ***Have a holistic approach***. New-product development is an interdisciplinary process that obtains concurrent contributions from all of the participants and necessitates that as many activities as possible be performed on a parallel basis. (It is not just the responsibility of engineering or marketing.) All of the activities must be integrated into an NPD process that is logical and systematic. Parallel processing is essential for holistic development.
- ***Ensure strategic alignment of the NPD process***. Strategic alignment infers that the NPD process must be part of the overall business strategy of the organization and linked to the strategic-management system. It requires ongoing management involvement and the simultaneous commitment of the resources deployed by the organization and its supporting entities. The entire enterprise must know where it is heading and each part of the organization must be headed in the same direction. The organization must have clear objectives and targets that are well understood and form the basis for decision making. A hierarchy of well-defined and communicated objectives provides the integration necessary to guide the NPD program.
- ***Use cross-functional teams***. Cross-functional teams provide a flexible organizational structure for managing the NPD process; controlling the resources, contributions, and outcomes; and balancing the perspectives throughout the development cycle. The team approach provides the mechanisms for integrating the participants and activities over time. Because all individuals are participating on a concurrent basis, the information and knowledge necessary for making informed decisions are inherently available to participants because they experience the entire process.
- ***Focus on customer and stakeholder satisfaction***. Customers and stakeholders are important participants in developing a new-product. Their needs, wants, mandates, and expectations are critical specifications. Understanding customer requirements is a fundamental challenge. Customers have expressed and latent needs and wants. Several mechanisms should be used to obtain and verify their desires.
- ***Use resources efficiently and effectively***. Given that new-product development can be an open-ended process with numerous options, resources should be concentrated

on specific targets where critical mass can be achieved. Critical mass suggests that resources are decisively committed in sufficient quantities to achieve success in specific market segments. Since resources are always limited, organizations must focus their attention on the primary aims and targets of the NPD program. Priority must be given to the attainment of the essential objectives.

- ***Understand and manage the timing of the NPD program***. Success is often more dependent on the correct timing of the NPD program than on the fine-tuning of the details. Timing means seizing the initiative by choosing the appropriate time and place to commercialize the new-product.
- ***Prepare and communicate simple yet comprehensive plans and instructions***. Strategies, policies, plans, and objectives should be as simple as possible. The organization must understand the purpose of them and the reasoning behind them. Management should articulate the reasons as well as the directives. The logic of why an activity is necessary provides compelling reasons for the actions. Communications are often cited as the reason for failure; therefore, efforts to reduce confusion must be utilized. Effective communications can be the source for achieving success. Coordination and cooperation are primary internal mechanisms.
- ***Maintain flexibility***. The rapidity of changes in the market place or in the business environment requires a flexible approach. Maintaining flexibility enhances the organization's ability to respond to changing conditions and trends. Flexibility means committing resources as required, but shaping the outcomes in such a way that there is the ability to meet changing requirements.
- ***Focus on key performance areas***.[29] In today's business environment, there are many key drivers beyond purely financial rewards. Product performance, quality, value, speed, and responsiveness are critical for success. Managing development time and investment are also critical. Successful organizations achieve outstanding results in all areas.
- ***Measure performance continuously and continuously improve***. Performance evaluation is the process of assessing, analyzing, measuring, and reporting performance against the objectives and targets. An effective performance evaluation system provides the means to track realities with expectations. The process includes testing outcomes with respect to customer and stakeholder expectations in order to determine the appropriateness of the progress. Performance evaluation provides a mechanism for understanding what changes might be necessary, thus providing opportunities to make such changes in a timely manner.

The principles of IPD are interrelated and offer insights into the organizational aspects and the NPD process, not just the product. A high level of management sophistication is necessary to contend with the complexities of the global business environment.

The overall objectives of IPD are to design and build new products; to improve the process for product development; and to build a creative, capable, and innovative organization. People succeed in an NPD situation when they know the process and understand the expectations.

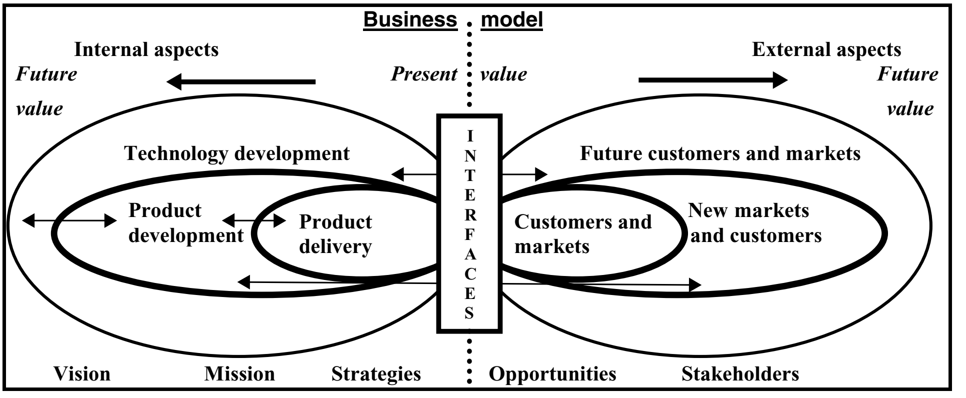

Figure 1.6 A simplified perspective of product delivery and IPD

IPD and the product delivery system

Overview

IPD necessitates many interfaces with the external and internal aspects of the business environment, the strategic-management system, and the product delivery processes. Such interfaces are important linkages of the strategic logic, which translates the present activities, with the future direction. Meeting the needs of customers and stakeholders drives the product delivery system. Organizations deliver existing products and develop new ones on a real-time, concurrent basis. There is a direct connection between the existing product delivery system – and its customers, markets, and stakeholders – and product innovation and its focus on meeting the future needs of customers and markets with new products.

The organization's business model provides the strategic alignment linking present products and the product delivery system with those of the future. For most companies, only a small portion of an organization's resources and people are dedicated toward product and technology development. However, such resources must be allocated carefully to ensure that existing and potential customers and markets are connected across time.

The product delivery system is firmly situated in the present with most of the actions and their implications completed within months. The cash flow from accounts' receivables tend to take the longest time. Product development is typically situated in the near future, usually within one to five years. Most new products are developed to improve the effectiveness of the product portfolio and the attributes of the products.

Figure 1.6 portrays a graphical representation of the product delivery system, product development, and technology development as they relate to the business environment.

Product innovation focuses on the requirements of the product delivery system, and the customers and markets that it serves. It also seeks out new customers and markets to enhance the reach of the organization and its success.

New-product categories

The development of a new product requires a well-thought-out process to ensure that the key dimensions and elements have been addressed and incorporated into the process. Usually, the product and the intended market are directly linked and define the opportunity. The perspective of the product/market opportunity rather than the product and its market provides an integrated view of the situation. The notion of the product/market combines the technical aspects, the market requirements, the marketing campaign, the production aspects, and the financial implications with the form, fit, and function of the product.

A new product is the summation of its benefits, functions, and features from the views of the customer and the producer. It includes the tangible and the intangible aspects. The tangible aspects are the physical features and benefits while the intangible aspects include the psychological perspectives. The tangible aspects are normally easy to visualize and understand because they are demonstrable. The intangible aspects are more esoteric. The intangible aspects may be the fun and enjoyment that the product creates or the prestige that it provides. A BMW automobile is more than transportation or a mechanical apparatus. It is speed, performance, and mobility. Its essence is joy.

A simplified view of NPD types can be illustrated using a two-dimensional matrix of the categories based on market-driven factors, opportunities, core capabilities, and technology. The market-driven factors represent the majority of the new-product opportunities.

Table 1.2 provides a simple construct for understanding the main categories of new-product development. The literature suggests that core capabilities and market opportunities drive most NPD programs. Organizations have to develop new products that are related to their existing product delivery system because they have to replace the obsolete products, cure defective ones, or continuously improve the effective ones. However, as the world changes, new capabilities have to be developed to exploit new opportunities and challenges. Therefore, new solutions have to be discovered and better products created to keep pace with change. Technology-focused new products attempt to stay ahead of the dynamics of the business environment through more radical solutions for meeting the needs of customers and stakeholders.

Most of the NPD programs are market focused, leveraging existing core capabilities and resources. New-product development in this category is relatively straightforward to execute, requiring only a modest investment, using existing assets that focus on existing customers, and generally has low risk.

Table 1.2 *Simplified view of new-product types or categories*

	Market focused	Technology focused
Core-capabilities focused	**Type I – incremental improvements** • Cost reductions • Revisions to solve problems • Addition of features and functionality • Quality/performance improvements	**Type III – radical improvements** • New generation • Enhanced platform • New platform • Fusion of technologies
Opportunity focused	**Type II – incremental changes** • Repositioning of existing product • Derivative for existing market • Derivative for new market • New product line	**Type IV – radical changes** • New-to-the-world • Improved technology platforms • Radical technologies • Disruptive technologies

The market-focused category represents initiatives to improve current products through changes and enhancements or to expand the business potential by establishing new markets for existing products or new products for the existing and/or new markets. The former is simple, while the latter requires higher investments because there is more uncertainty in terms of products and markets, a longer development time, and a higher risk.

Technology-focused NPD programs are complex and involve a significant investment of time and money, and significant levels of uncertainties and risks. Such programs require an extensive amount of detailed analysis from inception to launch.

"Type-I" new products are simple improvements for enhancing the capability of the product delivery system to satisfy existing customers. Given that the price of a product has a powerful influence on its success in the market, cost-reduction programs are common. Lower costs translate into a more-favorable pricing strategy and/or better profitability and greater value to customers. Another prevalent type of improvement focuses on solving problems or eliminating defects and burdens associated with existing product(s). The numerous product recalls per year are a testament to the fact that products are often launched with significant problems that require attention. If the defects are serious, an NPD program may be necessary for systematic improvement of the product. This type of improvement is usually absolutely necessary in order to avoid customer dissatisfaction and product liability. Adding a new feature is also a common reason for a new product type being developed. The coffee-cup holder in automobiles is an example of a simple improvement based on changing customer lifestyles. As getting coffee from Dunkin Donuts or Starbucks became popular, the necessity for the coffee-cup holder became obvious and pressing (at least in the United States).[30]

"Type-II" new products include derivatives for existing and new customers and repositioning of existing products for new customers. Derivatives are related to the prevailing

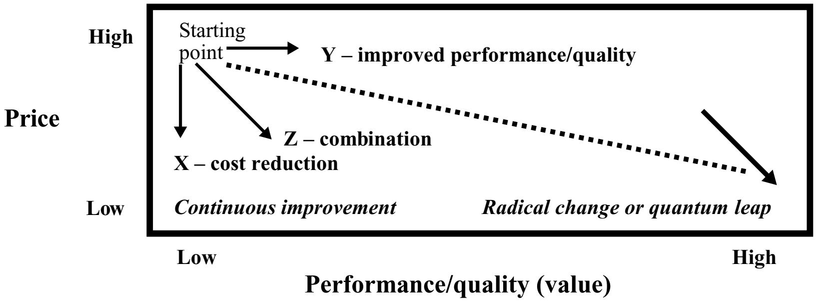

Figure 1.7 Performance-to-price ratio

technologies and usually require only minor modifications. They are variations that are linked to the previous product/market situation or an extension of it.

Both type I and type II may be viewed as improving the value and benefits of the products for existing or new customers. Generally, they both focus on ways for improving the product delivery system. They fit into the grand scheme of continuous improvement.

Performance-to-price ratio is a key metric for measuring customer value. Shifting the performance-to-price curve shown in Fig. 1.7 to a lower price point "X," a better performance point "Y," or both, "Z," can improve products. Customer expectations include improved performance-to-price ratio for most products. Moreover, the general expectation is more performance for a lower price. This is depicted in Fig. 1.7 as outcome "Z," the combination approach.

"Type-III" new products employ improved technology to expand the technical base for the products. New-generation programs involve major developments in the underlying technology to provide new capabilities and applications of the technology. The new products developed from the new generation, or from significant improvements to the existing technology platform, usually require considerable investment, effort, and time to achieve commercial success. They are radical improvements to the existing technological base.

The more-prevalent but less-sophisticated approach for making radical improvements involves the fusion of two or more existing or new technologies into a new configuration. Often the new technology is simply the marriage of current technologies. Early automobiles were combinations of bicycle parts, wagons, and simple motors. The phenomenon continues, with many of today's new products being hybrids.

The Toyota Prius

The Prius, Toyota's hybrid automobile, is an example of the fusion of technologies. The hybrid combines Toyota's lean-burn internal combustion engine technology with an electric motor. The new product delivers high fuel conversion (more than 50 m.p.g. [21.3 km/l]) as well as extremely low emissions. Radical improvements mean significantly better products as a result of using enhanced technologies or combinations of technologies.

The ultimate test of the Prius will, of course, be its viability in the market. In this respect the Japanese market is providing encouraging results. In Japan, the Prius has been available since 1998, and demand has been strong. Certainly, the circumstances of the Japanese market differ from other markets in developed countries. Fuel is more expensive in Japan, and qualified Toyota repair shops are numerous, providing comfort to customers who are concerned about hidden problems which are often associated with new technology.

The US market is promising, especially due to increasing fuel prices. For a new product, the fact that only a few other people own it can hinder market penetration, even if the new product is better. Once a certain proportion of people own the product, then it can gain much wider acceptance. To accelerate the trend towards wide consumer acceptance, Toyota is losing money on Prius sales. It sells for around $20,000, and Toyota is believed to be losing several thousand dollars per vehicle. That is the investment required to establish a new-to-the-world product. Toyota plans to increase volume significantly, lowering the costs per unit and increasing profitability. Moreover, the lower initial volumes allow Toyota to gain experience in the market place without taking significant product-liability risks. At the current level of sales, if a recall is required, or a major defect is discovered involving warrantee claims, the company has thousands of cars to worry about rather than hundreds of thousands.

"Type-IV" new products represent radical changes to the technologies and the means of delivering products to the markets. New-to-the-world products based on new technologies offer features and benefits not available in the current markets via existing products. They use innovative technology for solving the market needs in a radically changed manner. Type IV is depicted in Fig. 1.7 as the radical change or quantum leap in value. New fuel-cell-based automobiles fit into this category. They have the opportunity to change everything related to the automobile. The advanced versions use hydrogen, not gasoline. They are expected to be zero-emissions vehicles.

Constructs of radical improvements and radical change are similar to Clark and Wheelwright's types of product/process development projects. Their model used the following types of new-product/process developments:[31]

- ***Breakthrough development projects*** (new-to-the-world product). Such projects involve creating the first generation of entirely new technology, product, and/or process. They are 'breakthrough' in the sense that the core concepts and technologies break new ground for the organization.
- ***Platform or generational development projects*** (new-generation products). These are the platform or core development projects that typically have a design life of several years and establish the basic architecture for a set of follow-on derivative projects.
- ***Derivative development projects*** (derivative new products, improvement and repositioning of existing products). They tend to be substantially narrower in scope and resource requirements than platform projects. They refine and improve selected performance dimensions to better meet the needs of specific market segments.

The Segway Human Transporter (HT)

Many new-product innovations are born out of market necessity. For example, coffee-cup holders were added to cars primarily because of on-the-go lifestyles and long commutes, and the explosion of the video rental market was driven by the availability of low-cost video cassette recorders (VCRs). Other innovations are motivated by catastrophe, such as cholera epidemics leading to the idea of collective public health.[32]

Then there is Dean Kamen's much-publicized radical innovation in personal transportation, the Segway Human Transporter (HT). The Segway HT utilizes self-balancing technology, something originally envisioned by Kamen when he saw a wheelchair struggling over a curb. Self-balancing would elevate people who couldn't walk, so they could view the world at eye level. Kamen also believed self-balancing technology could improve the lives of people with full mobility.

Using dynamic stabilization technology, Kamen's company, DEKA Research and Development, developed a two-wheel, single-axle vehicle that allows riders to stand upright, and move forward or backwards simply by shifting their weight. Lean forward and the HT moves forward. Lean back and the HT decelerates. If the rider continues to lean back, the HT moves in reverse. Leaning harder increases speed. The HT steers by twisting a handle grip, changing the speed of one wheel relative to the other. Essentially, the HT avoids tipping over by applying an appropriate restorative torque whenever it is needed. Another smart feature of the design is that when decelerating, the motor operates as a generator, charging the batteries. When the driver wishes to stand still, the motor torque may be constantly cycling between positive and negative.

The engineers involved in the development of the Segway HT were pushed continuously during the three-year development program to think of radical concepts. To promote different ideas, Segway developed a company culture where even failures were encouraged. The company actually created a special award for the most spectacular failure. This celebration of failure and the culture of open communication helped overcome a major challenge associated with many start-up projects: how to move from ideas to execution. To help keep the HT project on schedule, it was made clear at team meetings whether the focus should be idea generation and brainstorming, or whether it was necessary to make decisions and move on.

Regardless of how well the Segway HT sells, its technology should reduce the cost of solid-state gyros, brushless motors, and other critical components useful for spin-off applications, such as new wheelchair technology. The HT has a range of around 11 miles (17.7 km) and a top speed of 12.5 m.p.h. ([20.1 km/h] electronically limited).

Sources
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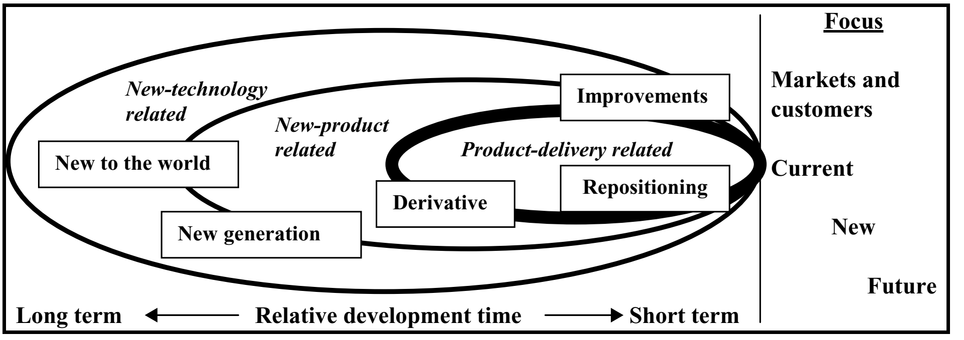


Figure 1.8 New-product categories in perspective

The new-product categories provide a means of quickly estimating the time and effort required for achieving the commercialization of the new product. They also provide a sense of the risk-to-reward relationship. Incremental NPD types require less time and money to commercialize because they are usually based on the existing product/market situations that are well known to the organization. Incremental improvement types are generally simple and can be produced and marketed on a short time scale (one to two years). The risks are usually low. Incremental-change types are intermediate (two to five years) in time horizon taking more time and effort to bring to completion. The risks are slightly higher because there may be greater uncertainty about customer preferences and market expectations.

The radical types normally require significant innovations in technology, market aspects, marketing, design, production, and finance; thus, they usually involve a much longer time frame (five to ten years). New-to-the-world and new-generation types tend to require substantial time, effort, and money to launch since they involve a more radical view of product/market situations. They often involve changes to the infrastructure. Because of the longer time horizon, they have higher risks and, therefore, there has to be a commensurate higher level of reward. Figure 1.8 depicts the relative positions of the new-product categories.

The scope of the NPD programs and the time horizons usually increase dramatically as the objective moves from continuous improvements to the existing product/market situation to the quantum or radical jumps in new-to-the-world innovations. Product innovation generally pertains to the new-product developments that follow the principles and methods of process management as described in this book. It pertains directly to the type-I and -II product innovations. It may apply to some type-III product innovations, but the more significant the change mechanisms the more the management approach switches from process management constructs to project-management methods. Most importantly, if the NPD programs require significant changes in the technologies then technological innovation becomes the prevailing construct. In such situations, the premises and methods described by Wheelwright and Clark, and other scholars, are more appropriate for the NPD programs involving quantum or radical change.

The circle of management perspectives of the NPD process

Process management

Process management provides the mechanisms to integrate activities into meaningful outcomes. Process activities should have an "owner" who is responsible for execution, provides authority for the actions, and has the control mechanisms to ensure that the activities are completed properly. The process owner may be one of the participants or a member of the senior management team. The authority may be a guiding document, a protocol, the plan, the program leader, or executive. Control is an essential part of process management. Its purpose is to ensure the efficient, effective, and consistent flow of activities; it is not intended to stifle creativity and achievement.

Process activities can be classified into three categories:[33]

- ***Value-adding activities***. Activities that provide value to the customer and stakeholders during the transformation of inputs to outputs.
- ***Waste-generating activities***. Activities that produce rework or additional-work activities in the future because the processes were not followed properly or because key participants were not included in the decision-making process.
- ***Essential or mandated non-value-adding activities***. Such activities do not create value but are necessary to comply with the customer desires, stakeholder requirements, mandated process requirements, or regulatory mandates.

The NPD process management provides the mechanisms and structure for ensuring that activities are linked with the upstream and downstream requirements and participants. Decisions are made on the basis of what has to be done and when it has to be accomplished. Figure 1.9 provides an overview of the essential process-management considerations for NPD.

The NPD process depends on organizational capabilities and resource management. People perform tasks and get results; they need resources to achieve those results. Process management is concerned about managing change and mitigating risks. The prime focus is on value creation, organizational capabilities, and resource management. These topics are discussed in the next subsections.

The NPD process includes methods for discovering ways and means of making the process fault resistant. The use of flow charts and check sheets helps to avoid mistakes by ensuring that all of the requisite elements are covered.

Process management involves the execution of the overall strategies and action plans for achieving the new-product objectives. It is the means of bridging the gap between the plans and implementation. It guides the organization and the people on how to use the

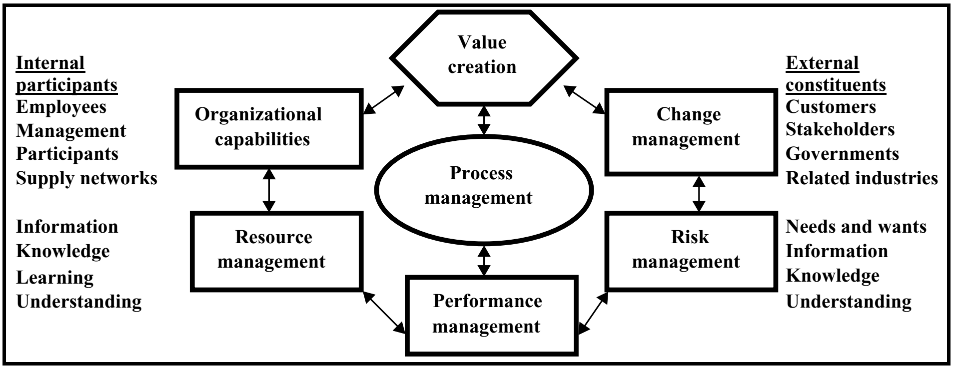


Figure 1.9 The essential process-management considerations for new-product development

principles, practices, methods, and techniques in structuring and managing new-product development. Process management includes determining the key inputs (plans, people, resources, and information), managing the process, executing input/output activities, obtaining results, and evaluating performance. The basic approach is to transform inputs, as described above, into valuable outputs through value-adding processes.

Process management includes tangible and intangible inputs and outputs. Resources and people are the direct inputs. Plans and information are the intangible inputs that may be unique to a given program. The intangible inputs include the guidelines and principles for new-product development, the methods and techniques used to determine the course of actions and to make choices among the alternatives, and the structure and protocol of the program. The intangible inputs also include the decision-making process within the organization and the control mechanisms to ensure proper execution, balance, and consistency of the results.

The tangible outputs are the direct results achieved by the process. They include solutions to problems and outcomes for meeting customer and stakeholder expectations.

The intangible outputs include the feedback and lessons learned during the execution of the process. They are used to improve upstream activities, to eliminate problems and difficulties, and to exploit better ways of executing the program.

Process-management methodology includes enhancements to the existing and subsequent programs, and the minimization and/or elimination of all forms of waste. Inefficient activities contribute to non-value-added or economic waste. The wrong focus or incomplete inputs lead to potential market-related problems due to the lack of information or appropriate level of detail. Lessons learned can provide a source of knowledge for improving the processes in terms of environmental considerations and technical aspects.

Minimizing environmental waste from a design and development perspective improves the long-term viability of the new product in the market place. It reduces the potential for difficulties in the future. The feedback and lessons learned are also

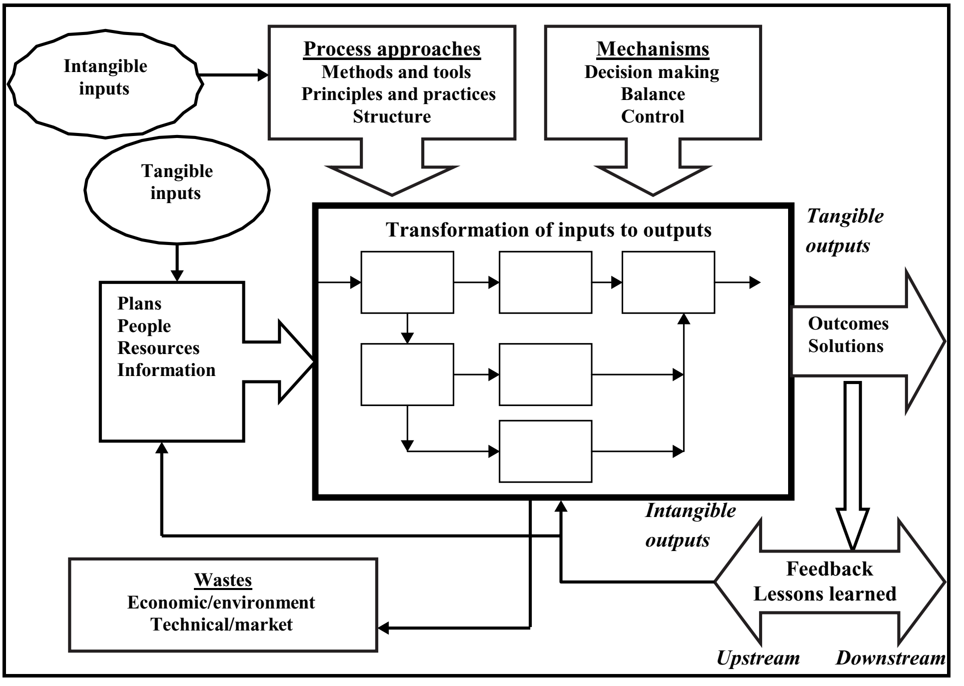


Figure 1.10 Process-management model

provided to downstream participants so that they may benefit from the experiences and knowledge gained during the upstream activities. Process management requires mechanisms for ensuring that decisions are made on a timely basis and that the process remains under control. Figure 1.10 provides a sense of the relationship between elements within the process.

Value creation

The basic purpose of developing new products is to create value for the organization, its customers and stakeholders, and all of the constituents involved. Existing and potential customers seek value and positive results. Meeting customer needs and providing exceptional benefits are the foundation of value creation and new-product development. It is critical to know what is important to the customers. In generating value, the NPD process must enhance the positive aspects and reduce the negative ones. It must increase the benefits and decrease defects, burdens, and costs associated with any product. A burden is any activity or action that adversely affects the value proposition for the customer or stakeholders. In others words, burdens increase cost, decrease quality, reduce flexibility, or increase time delays, all of which lower customer satisfaction. The value proposition is discussed in greater detail in Chapter 2.

3M and the development of its flexible development process

3M is organized into more than 40 business units in 6 markets with revenues of $16 billion, net income of $1.43 billion and R&D expenditures of $1.1 billion.[a] It has 71,699 employees, in over 60 countries, split about evenly between US and international locations.

The Minnesota Mining and Manufacturing Company (3M) was founded in 1902. It was started by five businessmen who wanted to exploit the mining of what they believed to be corundum deposits. While that venture failed, their subsequent operation – the manufacturing of sandpaper – was very successful. 3M's innovative capacity produced many successes including waterproof sandpaper, masking tape, Scotch-brand cellophane tape, Post-it Notes and more than 50,000 other new products over its history. 3M created the products and customers discovered the applications.

Its innovative capabilities are attributable to its corporate culture and management philosophy that rely on customer involvement and employee contributions. 3M's management style promoted creativity and decentralized thinking. William McKnight, the Chairman between 1949 and 1966, encouraged delegated responsibility and encouraged people to take the initiative.[b] He was credited with 3M's famous "15% rule" which permeates the culture today, allowing its technical employees the flexibility to use 15% of their time to work on their own projects. 3M empowers its employees to seek high quality and performance with sustainable growth. Post-it Notes were developed under the 15% rule. Researcher Art Fry used an adhesive invented by another 3M researcher (the product had failed because of its inability to attach permanently) to create the "temporary" solution for marking pages and the like.

3M believes that the risks inherent in developing new products are mitigated by its diversity. It does not expect that every new product will be successful. The company is always on the leading edge of innovation and creativity. Its vision is to be the most innovative company in the world.

For example, in 1975 the company adopted its Environmental Policy and created the voluntary Pollution Prevention Pays (3P) program. The program has been an outstanding success, as suggested in the following statement, "In just over two decades, more than 4,600 3P projects initiated by employees worldwide have produced total savings of $810 million while eliminating 1.6 million pounds [725,000 kg] of releases to the air, water, and land."[c] The company led the way for the pollution-prevention thinking of the 1990s. It captured economic benefits from the savings, enhanced its environmental position by reducing waste streams, and improved its corporate image by exhibiting environmental leadership. As the 3P program evolved into 3P Plus, employees have been actively engaged in discovering new initiatives to continue the long tradition of research and innovation. While it takes management commitment to support the initiatives, employees at every level are sensitive to the notion that pollution prevention is everyone's responsibility.

[a] http://www.mmm.com/about3m/facts/3Mfacts.jhmtl.
[b] E. Gundling, *The 3M Way to Innovation: Balancing People and Profit* (Tokyo, London: Kodansha International, 2000, p. 58).
[c] 3M, *Environmental, Health and Safety Progress Report*, *1998–99* (St Paul, ME: 3M, 1999, p. 3).

Organizational capabilities

Organizational capabilities in the context of the management system provide the means for formulating and implementing strategies, controlling inputs and outputs, and achieving results through the development and deployment of people. A fundamental problem with many organizational approaches is that individuals are insufficiently informed about the context of their roles and responsibilities as they pertain to the strategies, objectives, and plans of NPD programs. Thus, participants are unable to act in accordance with the established guidelines and processes.

The principal organizational structure used for IPD is the cross-functional team. Cross-functional integration is an organizational structure established to achieve collaborative behavior in a highly interactive product innovation environment. It is a methodology that enhances the skills and capabilities of the NPD participants by forming interdisciplinary teams for program execution. The emphasis is on the achievement of overall results and excellence.

Rapid product development requires close coordination and cooperation among all of the participants. Cross-functional teams link downstream activities with upstream decision making. Knowledge of downstream capabilities and limitations allows the team to select solutions that are appropriate for the needs and requirements of the program. Organizational aspects will be further discussed in Chapter 3.

Creating a spirit of high performance and collaboration is pivotal for success. Team members establish the basis for performing the work, set the priorities, specify the design and development activities, assess the alternatives, and evaluate the results.

Resource management

The commitment of resources is a vital step toward achieving the NPD objectives. Great strategies and outstanding opportunities are wasted unless there is a commitment and competency to deploy sufficient resources to meet the needs and requirements. Management must determine and allocate the appropriate resources and ensure that there is a critical mass of such resources. The notion of critical mass suggests that resources are concentrated and available in sufficient strength and capability. Resources deployment for a new product should be concentrated on product/market segments that offer distinctive opportunities and must be decisively committed in a timely manner. Over extending the deployment of limited resources during the NPD process tends to dilute the effort and results in a piecemeal outcome.

Resources include the people, materials, the capital, and plant and equipment used during the development of a new product. They are the inputs and the outputs. Given that resources are limited, organizations must focus their strengths on the primary target(s) and not dilute outcomes by attempting to achieve too many objectives or complete too many NPD programs at one time.

Change management

The emphasis on speed (developing new products with improved quality, performance, and reliability and with reductions in unit cost, cycle time, and development investment) is essential. Products must be designed and produced within the time frame dictated by the external forces that initially led to the decision to pursue the new-product opportunity. The faster the development, the more it is in line with the up-front analysis, the forecasts, and the prevailing business environment.

In the real world, internal and external conditions change quickly. Generally, the NPD process requires a precise mapping of the flow of the activities from beginning to completion. However, care must be taken to provide the flexibility to meet unexpected situations or dramatic changes to the underlying conditions. Change is often viewed as a negative and there is usually resistance to change. In reality, change may be positive and provide new opportunities to excel. Change management focuses on how to keep pace with the dynamics of change in the business environment.

Risk management

Risk is an inherent part of any business process or activity. The risks associated with the production and marketing of existing products are usually well known and managed using established control mechanisms. The level of risk has to be monitored in terms of the context of the situation. There is a risk associated with simply maintaining the status quo. The risk of obsolescence may be comparable to the risk of taking an initiative. Risks are different from situation to situation, but nevertheless they are always present.

A new-product failure in the market can have significant implications if there are millions of units in use. Potential resolutions of such problems include a complete recall of the product, or correcting the defect at the customer's location. Even if a problem costs only one dollar per unit to fix, when multiplied by millions of units this becomes an expensive solution.

Product innovation involves risks and requires risk-management methods. Discovering and blazing new pathways are always risky. The challenge is to identify the risks, assess the impacts, determine the potential consequences, and mitigate the implications. Even with best practices there may be a level of risk that has to be tolerated. It can be argued that a certain level of risk is preferable; it keeps out the faint hearted. Risk and uncertainty are directly linked. The lack of information and knowledge increases the potential for making mistakes, missing important elements, making incorrect assumptions or decisions, or not comprehending important conditions and trends.

Risk can be defined in strategic (business), program (financial), product/market, and technical (product) terms. The greater the gap between certainty and uncertainty, the greater is the overall risk. Actual risks are difficult to determine and calculate. They depend on the NPD program and the business environment. Risk is discussed throughout the book and is a major element during each NPD phase.

The NPD process is structured to provide an understandable flow of inputs and outputs. However, even with a well-defined approach, there are a significant number of uncertainties. Generally, the level of uncertainty should diminish over time, but there are always external drivers that can change, with a unexpected consequences. Uncertainty and change are two of the main underpinnings that cause NPD programs to be inherently risky. Risks are the ever-present concerns that the results will not meet the expectations.

Risk management is the process of mitigating risk over the course of the program and reducing the probability of the occurrence of an adverse effect and/or the magnitude of a negative situation. Risk management deals with the program, the NPD process, the new product, and the organizational aspects. It includes the identification of risk factors, the analysis of the risk elements, and the mitigation plans to lower the associated risks. Risk management includes the strategic, program, financial, market, and technical risks associated with new products. Risks can be categorized according to a hierarchy of their impacts on the organization. Table 1.3 identifies the principal areas and implications.

There may be other areas of risk that should be addressed. Management should identify the key risk factors as early as possible and track the potential risk over the development period. Generally, a risk-management plan reduces the probability of unwanted events occurring as the program unfolds.

The benefit of using IPD and the NPD process is that management has the opportunity to reduce the uncertainty and risk over time by increasing the organization's knowledge about the new product and the development process, thereby reducing the possibility of an adverse event. The reviews at the end of phases tend to mitigate risks since the key elements of the program are examined and evaluated.

Performance management

Performance management is the systematic evaluation of the NPD process and the results of the NPD program from start to finish, examining the achievements of the organization on the basis of the established targets formulated during the early phases of the NPD process. It is used to determine the extent to which the organization is meeting the objectives and targets, and managing the risks and consequences associated with the development of the new product. It focuses on the product and the process! Performance criteria and metrics are used to determine the likelihood of success.

Performance management provides senior management with a mechanism for internally tracking and evaluating performance and ensuring that there is continuous improvement. It includes an assessment of the organization's performance against the needs, wants, and expectations of customers and stakeholders. The purpose is to reduce the variability within the process and to serve as an integrating mechanism for ensuring that there is consistency, balance, flexibility, and control.

Table 1.3 *Risk categories and the significant implications*

Area/type	Key factors	Implications	Examples
Strategic			
Program failure	The failure is so significant that it damages the reputation of the organization.	Customer and stakeholder confidence in the organization is seriously jeopardized and external **trust is lost**.	Firestone Tire's difficulties with sport utility vehicle tires.
Strategic gap	The organization fails to develop the new product or the product fails in the market place.	The strategic goals of the organizations may be jeopardized due to the gap between what was planned for and what was achieved.	Apple Computer had several failures – Lisa and Apple III[34]
Program or product difficulties	The program can have a negative impact on the image of the organization or on other products.	The program negatively affects the other products of the organization or diminishes the organization's future capabilities. Problems with the new product may ripple across the brand.	P&G does not use its name for products; it wants each brand to be independent.
Financial			
Financial investment	Financial investment includes the development costs plus the losses during the launch. Higher investment influences rate of return.	The risks include development costs overruns, lower revenues and profits over time, and lower than expected returns. The losses can have an effect on overall cash flow.	Gillette's Mach III Program cost three times more than estimated – impact on cash flow and profits.
Economic limitation (unit cost)	The unit cost of the product or the value provided to the market place does not meet expectations.	Unit costs are higher than acceptable. Customers are not willing to pay the price. The cost of the product and the associated services are too high.	With the introduction of the Lexus, BMW had to improve its costs.
Expense overruns	Expense overruns during the NPD process and launch increase the investment required to develop the new product. Expense overruns have an impact on cash flow projections.	For long-life-cycle products, additional expenditures during development translate into higher unit cost, which reduces the attractiveness of the product and may be a competitive disadvantage. Increases investment requirements.	The "Dot.com" companies learned too late that they had to spend much more on marketing.

Market			
Performance gap	The performance goals and product/market specifications have not been met. Quality goals are crucial. Defects reduce product viability.	The product is not capable of meeting its target requirements. It does not offer sufficient value and benefits to potential customers. Customers and stakeholders are dissatisfied.	The Iridium System had several major deficiencies, plus it was too expensive.
Market timing	Speed to market is essential for success. Delays during the NPD process are difficult to overcome.	For short-life-cycle products, delays to the market have a large impact on cash flow. Lost sales opportunities may never be recovered. The company may lose its leadership position.	The Boeing 777 was completed in five years; market share was at stake.
Technical			
Technical mistakes	Errors in design may lead to defects or problems that involve liabilities. Design defects are difficult to detect unless there are reviews.	Errors lead to product-liability problems. Mistakes take time and money to correct. Mistakes cost more money as the NPD process proceeds toward commercialization.	One out three engineers on the Boeing 767 project corrected mistakes.
Technical gap	The technology or the technical features are lacking or limited. The available technologies are not sufficient to meet needs.	The technical feasibility of the product may be limited to the current generation. The new-product opportunity is constrained by the technology or the lack of features or benefits.	Automobile models without "airbags" were difficult to sell.
Resource availability	The resources required to complete the program are not available. There is lack of capital, capability, people, materials, or facilities.	The program cannot be completed without acquiring additional resources. The program is delayed or cancelled or a partner has to be found. The resource problems affect other processes.	Chrysler (Intrepid) relied on partners to help design and fund the "cab forward."
Process/product safety	The technical requirements involve risks associated with material, waste streams and processes. Failure to meet health, safety, and environmental requirements may have a negative impact.	The liabilities associated with the materials, wastes, and processes are beyond the capability of the organization or its willingness to tolerate the risk. Health, safety, and environmental concerns may reduce the life cycle of the product or cause significant financial and managerial problems.	Environmental problems have limited the potential of many products – leaded gasoline, asbestos, oil-based paints.

Performance management needs to be dynamic and flexible in order to respond to the changing business conditions. It should reflect the realities of the various participants. The following are the primary intended purposes:

- Guiding the NPD process to ensure success, to keep pace with changing conditions and requirements, and to facilitate decision making.
- Mapping developments with respect to customers' and stakeholders' expectations.
- Benchmarking performance with respect to competitors, peers, or others in related areas.

Performance management is a process of assessing, both qualitatively and quantitatively, the organization's achievements. An effective performance-management process allows management to share information with the participants and to initiate corrective actions expeditiously. Performance management is designed to provide a consistent format for an authoritative overview of performance.

Performance management is also concerned with the prevention, detection, and correction of difficulties and problems that could affect the overall NPD process or adversely affect the success of the program or the organization. The emphasis is on improving performance through the establishment of suitable objectives and targets, and using the review and approval process to verify the accomplishment of the intended results.

Incremental versus radical innovation

With the dramatic upsurge in the development of new technologies and the rapid changes in the global business environment, product and technology life cycles have significantly diminished over the last decade. Such pressures have increased the emphasis on innovation management and the creation of new products and new technologies. While senior management generally recognizes the importance of innovation, the critical question pertaining to products and technologies is: what types of innovations are appropriate? The difficulties in making those determinations include selecting the right criteria and metrics, understanding the linkages between the technological aspects and the market underpinnings, and balancing the short-term and long-term business needs. The balance is based on the implications of the business environment and the core capabilities of the organization and its resources.

The typical selection process is a portfolio approach for allocating investments and resources between incremental and radical innovations. The portfolio approach indicates that investments should be made in the various categories to obtain a balanced or diversified portfolio. Incremental product innovation focuses on improvements and changes to existing products to enhance their value for existing markets and customers. It is generally a response to short-term pressures by customers, stakeholders, and competitors, or a concerted effort to stay ahead of the driving forces of change. Incremental improvements typically address the explicit or implicit needs articulated by external entities of the product delivery system. Such needs are relatively easy to identify because the forces of change within the business environment are well known to management and are at play every day. Product innovation in most business organizations is well defined and has a structure that is embedded in the management system.

Product innovation is often chosen because it seems to have a natural fit with the fundamental aspects of the management system and the prevailing conditions. Product innovation provides good solutions as long as the dominant technology and design characteristics do not change significantly. Moreover, the business environment has to be relatively stable so that the existing customer base continues to demand and accept standard products for satisfying its needs. Moreover, the organizational elements typically have well-identified mechanisms for managing product innovations. Marketing professionals have developed sophisticated methods for determining customer needs. Technical personnel understand the advantages and disadvantages of the prevailing technologies and products and have a sense of opportunities for improvements. Financial managers can easily determine the relationship between risks and reward, and calculate the benefits of change using conventional financial models and theories (i.e. net present value and internal rate of return calculation based on discounted cash flow). Manufacturing and operating personnel can quickly discern whether the organization is capable of meeting the production requirements.

Radical (technological) innovations represent more revolutionary changes to the underlying technologies and the management system. They are often disruptive to the existing system, necessitating new capabilities, assets, and resources. Radical innovation is a more-far-reaching and difficult phenomenon to understand and manage; it is driven by forces that may be outside of the normal purview of the product delivery system or even of the company.

Revolutionary changes are less prevalent than incremental changes, and are much more serious challenges; if managed correctly, they may represent a greater opportunity. They typically occur when the business environment becomes unstable or even turbulent due to social, political, economic, and/or technological forces. If the forces of change are driven by new technologies, the response has to be in kind.

In many organizations, the normal reaction to radical change in the business environment is to respond with product innovation. However, product innovation may not provide the right answer for determining how to deal with the winds of radical change. In such situations, product innovation may have to give way to technological innovation and the development of new-to-the-world products. Technological innovation focuses on developing or improving the underlying technology and knowledge base. It seeks dramatic solutions to the underlying difficulties in the business environment. In discovering answers, the organization has to search globally in non-traditional ways. Asking existing customers what they think about the situation or opportunity may not provide any definitive answers. They are not going to have a clue about the new technologies.

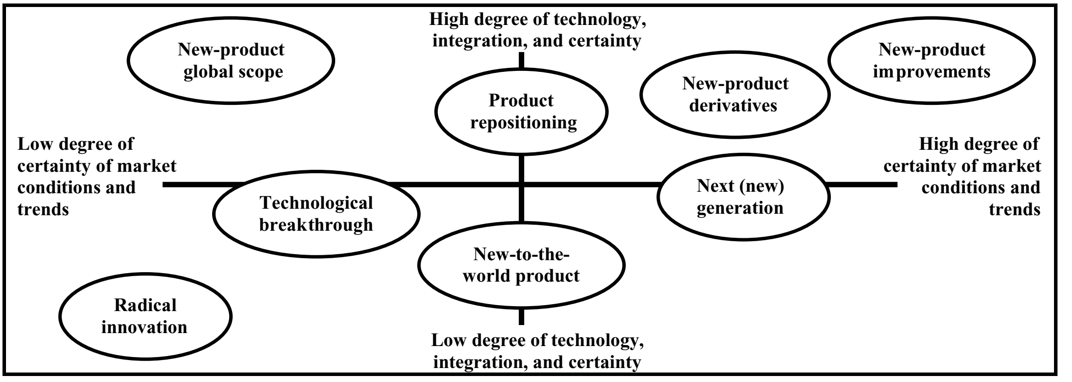


Figure 1.11 Relationship matrix of the basic types of innovations

Technological innovation requires understanding the underpinnings of wants and needs and looking to future customers for answers.

In *4th Generation R&D: Managing Knowledge, Technology, and Innovation*, William Miller and Langdon Morris suggest that the domain of discontinuous (radical) innovation occurs outside the circle of existing corporate infrastructures and the established knowledge of customers and suppliers.[35] They argue that discontinuous innovation is the domain of centralized R&D, since it is not encumbered with the product delivery system or incremental innovation. Whether management of technological innovation is the responsibility of the R&D function is not as important as the notion that technological innovation has to be managed at the executive-management level. The people involved have to have a broad view of the realities of the business environment and must have insights and perspectives that are not constrained by the existing products and services and the demands of the product delivery system.

Figure 1.11 maps out the basic types of innovations and their relationship to market conditions, technologies, and uncertainty. The essential point is that product innovation deals with known market and technology perspectives. Technological innovation is more difficult because of the unknown perspectives of the markets and technologies. Additional thoughts are presented in Chapter 7 for discerning the appropriateness of the innovation management model.

Summary

Product innovation has evolved from sequential approaches to sophisticated holistic systems with definitive elements and defined expectations. While the selection of a definitive NPD process is highly dependent on the nature of the business environment, generally there is an identifiable pathway for developing new products. The starting

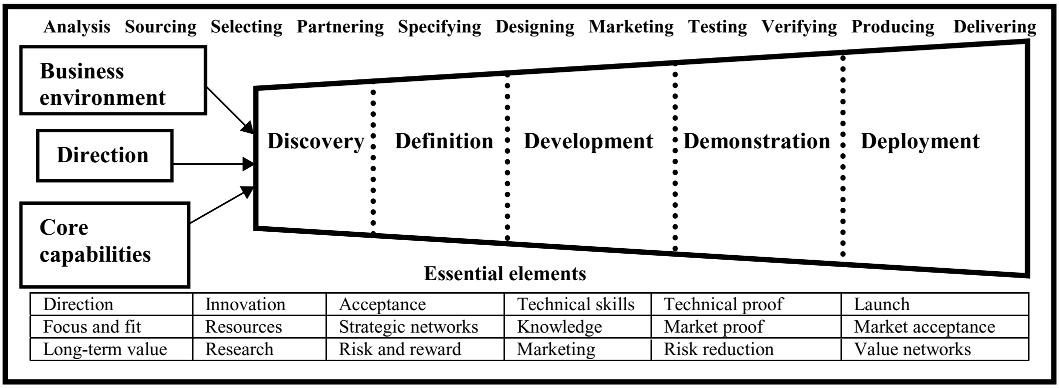


Figure 1.12 A simplified flow chart of the NPD process

point is assessing the business environment and the core capabilities of the organization. The results of the assessment provide insights about innovation and strategies for managing change. The foundation for product innovation is the analysis of the business opportunities and the strategic direction of the organization.

Figure 1.12 depicts a generic (simplified) version of the elements in the NPD process using IPD principles. Whereas Figure 1.12 suggests a simplified NPD process, there are many variations. A "standardized" version and several specific models are discussed in Chapter 3. The starting point often has the most variability. For instance, a discovery (ideas and concepts) could occur before analysis is done as in the case of scientists creating a new formula that no one expected. However, even in the case of a surprise, there are usually defined areas of research and development based on the strategic direction. Discovery is the initial step, but the research work that led to the discovery is usually preceded by strategic analysis of the business environment and core capabilities.

In most cases, the core capabilities of the organization and its opportunities are aligned. However, if they are not in alignment, then the resource base, capabilities, and knowledge of the organization have to be repositioned based on the needs of the innovations. Existing resources and assets have to be converted to meet the new requirements.

The NPD process incorporates multiple disciplines within the organization and relies on a framework to map the way from inception to completion. The framework follows a process-management approach for incremental innovation.

For the more involved and complicated new-to-the-world NPD programs, the organization may use project-management methodology or a combination of process-management and project-management thinking. Indeed, the combination approach might be used for the less-complicated programs as well. There are no preset rules.

External forces usually drive new-product development. Some of the key drivers are:

- Rapidly changing customer and stakeholder needs and expectations.
- Intense competitive pressures from world-class corporations.
- Fast-paced and dramatically changing business environment.
- New mandates from government and other stakeholder organizations.
- Dynamic technological innovations that are changing the essence of industries and competition.
- Enhanced capabilities and offering from suppliers, distributors, and related industries.

These drivers mean that the organization's products and processes must be capable of meeting the world-class standards.

To meet the demanding external expectations, there are critical factors associated with the NPD process that are essential for success. They include superior product performance, high quality, exceptional customer benefits, high value, low unit cost, rapid development cycle, and speed to commercialization.

Product performance is a fundamental requirement. It is the product's ability to deliver the features, functions, fit, and benefits in the light of the customer's perceived needs and wants or actual specifications. Performance is also relative. It is measured in terms of the price or cost to the customer. It is an essential determinant of value.

Total quality is a fundamental that is dependent on the perceived value provided by the product. Total perceived quality is the customer's view of the quality experienced. Providing outstanding value is a key to success. Providing exceptional customer benefits means providing an entire package of benefits, both physical and psychological. Customers purchase solutions not just products. Taking the perspective of the customer enhances customer satisfaction.

New-product development is a systematic process that focuses on developing new products and services using an established framework that maximizes results and minimizes the time, resources, and effort required to achieve the end results. It is based on an architecture that enables senior management and program participants to ensure that all elements of the process have been considered and that the design and development decisions have been validated using acceptable criteria and standards.

A significant NPD challenge is to ensure that product design and the market perspectives have been validated using real-world data and information. During each step of the process, the needs and wants of present and future customers and stakeholders must be understood and articulated and used as the basis for making key decisions about product features and benefits.

The process begins with a strategic perspective of the organization's vision, mission, objectives, and strategies; this covers all of the technical, marketing, productions, and financial decisions that have to be made to commercialize a new product. New-product development includes descriptive, analytical, and decision-making aspects that lead to a clear pathway for participants to follow. It integrates all of the essential elements into a management system.

The proper utilization of quantitative and qualitative techniques and methods is at the heart of an effective NPD process. The tools, techniques, and methods allow management to establish the information and data necessary to make informed decisions and to validate the decisions and outcomes.

Success depends on people and their abilities and skills. Building a knowledge-based organization is the crux of achieving superior results.

Notes

1. The book uses the term product(s) to include products or services.
2. Product innovation focuses on the outcomes (products or services), the mechanism (the NDP process), and the means (the people within an organizational context, their capabilities, and the available resources). A new product is any change, improvement, repositioning or new-to-the world product or service. The NPD process includes identifying new-product ideas and opportunities, understanding their implications, formulating new-product concepts, designing and developing the actual product(s), evaluating the potential and fit of the product, and launching the commercial results.
3. The dimensions include strategic management, engineering, marketing, finance, production, and operations.
4. IPD is a widely used term for developing new products using cross-functional teams and parallel processing of activities rather than the older sequential approaches in which functional departments would complete their assignments before their colleagues in the other disciplines became involved. Extensive amounts of time and energy were required to manage the sequential processes. Although there are many variations, most IPD models have a similar construct.
5. R. G. Cooper, Developing products on time, in time. *Research-Technology Management*, **38**:5, September–October (1995), 40–50. It is difficult to prove that one process is more effective than another, unless it is in the context of the development opportunity. Time to market is a good indication of effectiveness. The sooner the product gets to the market the better are the chances of achieving the desired cash flow. IPD, with its parallel processing, supports time-to-market objectives.
6. The discussions in subsequent chapters (especially Chapter 3) pertain to the NPD process. The NPD process is based on the principles of IPD. The terms are interrelated.
7. The term "dimension" is used to denote the main internal areas within most business organizations and the key external entities in the business environment. The construct used in the book highlights the involvement of the four essential internal function areas of technical, marketing, production, and finance. Using the construct of the enterprise-management model discussed in Chapter 2, the external dimensions are markets, supply networks, competition, related industries, stakeholders, and infrastructure.
8. The focus of this book is on incremental product innovation and the processes for designing and developing new products within the context of the prevailing conditions and trends. For an outstanding presentation of the implications of radical innovation please read: R. Leifer,

C. McDermontt, E. C. O'Connor, L. Peters, M. Rice, and R. Veryzer, *Radical Innovation* (Boston, MA: Harvard Business School Press, 2000). For an excellent discussion on non-linear innovation pertaining to business concept innovation read: G. Hamel, *Leading The Revolution* (Boston, MA: Harvard Business School Press, 2000).

9. Intel's microprocessor technology is a good example of the technology-platform concept. The Pentium in particular is an example of the generations of related technologies. The Pentium 4 is Intel's early-twenty-first century generation of microprocessor technology that has been undergoing a process of steady improvement over a decade or more.
10. The value chain includes inputs from suppliers, the production or service operations, the distribution channel, and the applications of the products by customers. This perspective will be further defined and developed in Chapter 2.
11. Because new-product development varies depending on the business environment, the industry, and the complexities involved, it is impossible to invoke the notion that there is a standard approach. The "standardized" NPD process is a generalization that provides the basic elements and a sense of what is critical in most NPD programs.
12. The construct of phases and reviews is more in keeping with the philosophy of IPD. The notion of a phase suggests that there is an ongoing flow from phase to phase. The process is a continuum, not a series of stages that begin and end. Likewise the notion of a review is also in keeping with the overall philosophy. A review suggests the completion of a significant phase that requires an evaluation, but it does not mean that the process is stopped at that point until management gives its input and allows the process to continue. This topic is discussed further in Chapter 3.
13. The "Big Three" companies were General Motors, Ford Motor Company, and Chrysler Corporation.
14. M. Porter, *Competitive Advantage, Creating and Sustaining Superior Performance* (New York: Free Press, 1985, pp. 33–47).
15. *Ibid*., p. 6. Porter's model of industry structure included the industry competitors at the center, and buyers and suppliers at the input and output sides of the industry dynamics. The relationships between the players depended on the power structure of the transactions. Suppliers might have the edge if resources were valuable and scarce. Conversely, buyers might have the advantage if there were many producers of equal quality and performance. Porter included the potential for new entrants and substitutes to reflect on the dynamics of change.
16. Technological innovation is also a key for leading change. It is a more-complex construct geared toward discovering and developing new techniques and mechanisms for achieving business success. Technological innovation generates business opportunities by dramatically modifying the underlying technologies and/or business model. New technologies trigger new business models that have to be in alignment with the global business environment.
17. The constructs are generalizations of various specific models that are used by companies. While there are many variations, the framework provides a useful view of the transformations in management models.
18. This phenomenon is described in detail in the supplement to Chapter 7. The Kano principles provide insights about the evolution of a leading-edge effect and how it dissipates over time.

19. V. K. Narayanan, *Managing Technology and Innovation for Competitive Advantage* (Englewood Cliffs, NJ: Prentice Hall, 2001, p. 43). While there are many discussions about the most important driving forces pertaining to the business environment, it is clear that globalization and time compression are primary factors. Time compression is particularly critical since shorter product life cycles mean that NPD cycles have to be reduced as well.
20. General Motors (GM) and Toyota sold approximately 8 million and 4 million cars in 2001, respectively. GM has a market capitalization of less than half that of Toyota. While market capitalization does not present the full picture about company performance, it does provide a sense of how some external entities view the value of the companies.
21. www.dialogdesign.de. Taken from a presentation by Carsten Humm and others at the Daimler-Chrysler plant in Stuttgart, Germany on June 7, 2001. Mercedes produces the C-Class, E-Class and S-Class automobiles at the Stuttgart plant.
22. The US automobile industry in an era of international competition: performance and prospects. In *The Working Papers of the MIT Commission on Industrial Productivity*, Vol. 1 (Cambridge, MA: MIT Press, 1989, pp. 28–31).
23. There are many ways to measure the time duration of the NPD process. It is clear that companies like General Motors, Ford, and Toyota are working on process development to further reduce development time. Such companies have cut many months out of the time to launch a new product.
24. www.sun.com/smi/Press/sunflash/9511/sunfalsh.951107.19779.html. "Sun changes the rules of the game with new systems that will launch users into a new age." Sun's press release stated:

    > This is a our most significant workstation announcement since 1989 . . . We're not talking about the kind of incremental improvements you get when you just increase the speed of a system's processor. Instead, we've completely re-engineered the architecture to optimize all system functions so that, together, the whole is greater than the sum of its parts.

    The point is not that the asynchronous microprocessor technology will win the battle, but that there are always alternatives that have to be considered.
25. J. Womack, D. Jones, and D. Roos, *The Machine that Changed the World* (New York: Harper Perennial, 1990).
26. D. Dimancescu, *The Seamless Enterprise: Making Cross-Functional Management Work* (New York: Harper Business, 1992, p. 31). The author details many of the decisions that Boeing management made during the development of the Boeing 777. His work represents an outstanding summary of the implications of IPD and the use of cross-functional teams.
27. S. Wheelwright and K. Clark, *Revolutionizing Product Development, Quantum Leaps in Speed, Efficiency and Quality* (New York: Free Press, 1992, p. 34).
28. *Ibid*., pp. 4–5.
29. This is a concept that Peter Drucker has been preaching for 40 years.
30. German automobile manufacturers like Audi are reluctant to "spoil" the purity of automobiles with additions that facilitate using the automobile for other than the intended purpose. This view is based on discussions with the head designers at Audi during a visit in June 2003.

31. Wheelwright and Clark, *Revolutionizing Product Development*, pp. 49–50.
32. The following are examples of difficulties that lead to great technological innovations.

Event	Innovations
Cholera epidemics	Collective public health and improved sanitation
World War II	Improvements in steel technology
	Improvements in aircraft, ship, and weapons technology
	Jet-engine technology
	Nuclear power
	Improvements in emergency medical care
AIDS epidemic	Protease inhibitors
	Increased research into the nature of viruses

33. Value-adding, waste-generating, and non-value-adding activities all take place within the ***value stream***. The concept of the value stream, and the elimination of wasteful activities within it, is discussed further in Chapter 9. The complete elimination of wastes so that all activities along a value stream create value is known in lean management as "perfection."
34. Read: D. Yoffie and M. Kwak, Apple Computer: 1999, *Harvard Business School Case, Number 9-799-108, 1999*. This report gives the tumultuous history of Apple computer and its great successes and failures.
35. W. L. Miller and L. Morris, *4th Generation R&D: Managing Knowledge, Technology, and Innovation* (New York: John Wiley, 1999, pp. 5–8).

2 Strategic logic of product innovation

Introduction

The strategic logic of the organization provides the rationale for product innovation. New-product strategies and programs are based on external and internal perspectives; the business environment, the market situation, customer needs, and competitive analysis make up the external perspective, while core capabilities, core technologies, development capabilities, organizational skills and knowledge, and strategic requirements constitute the internal perspective. The business environment, market requirements, and core capabilities are primary considerations in the formulation and implementation of market-related new-product strategies.[1]

The basic philosophy for developing sustainable new products is to create value based on the expressed and latent needs of the customers and stakeholders. The new-product development (NPD) process has to focus on finding opportunities and creating new products to delight customers and enhance long-term capabilities and prosperity.

Product innovation is established within the strategic context of the organization and its enterprise. The enterprise is the integration and alignment of the organization with all of its external constituents under the leadership of strategic management. It provides the overarching framework for understanding the opportunities and challenges in the business environment and the organization's capabilities and resources in the business context.

Strategic management determines vision, mission, and direction. Strategic direction provides the overall objectives, strategies, and action plans. The aim of strategic logic is to integrate the management system, its processes, and interrelated activities so that all initiatives and development programs flow seamlessly across the organization. A primary responsibility of executive management is to design, institute, and maintain an integrated management system that is easy to understand, operate, control, and evaluate.

Product innovation is a subset of the strategic direction and is one of the most important parts of the management system, especially with regard to future sustainability. Creating value for every constituent is the pivotal theme. Products and services provide benefits that satisfy the needs of customers and stakeholders. Successful products provide value to the business environment and ensure the longevity of the enterprise.

The primary purpose of product innovation is to aggressively pursue opportunities that fit within the strategic-management context and make valuable contributions to the overall success of the organization based on its core competencies, capabilities, resources, and strategic direction. Core capabilities and competencies are the strengths of the organization and provide the means to compete and thrive.[2] Core capabilities are the skills, knowledge, and talents of the people within the enterprise to create and implement programs, processes, and actions.

The business environment and the strategic direction of the enterprise drive product innovation. Corporate strategies set the stage for new-product strategies. New-product strategies likewise are determined through analysis of the business environment and are based on the most important dimensions: customers, stakeholders, supply networks, competition, related industries, and infrastructure. The choice of strategy depends on the situation; therefore, the strategies should fit the context and the resources of the organization. The most effective NPD strategies are those that fit the organization and its direction, capabilities, and knowledge.

Chapter 2 includes the following topics and learning objectives:

- Understanding how the enterprise-management model(s) facilitates new-product development.
- Defining and describing the strategic-management system and its relationship to new-product development.
- Exploring the value proposition and its relevance to new products.
- Formulating and articulating NPD strategies.
- Linking strategic management to the NPD process.

An enterprise-management model for new-product development

An overview of the enterprise-management model

The correct positioning of new products is critical for achieving success in the market place. An enterprise-wide view of the opportunities and challenges is necessary to assess the full dynamics of the business situation. The assessment must provide an understanding of all of the requirements of potential customers and constituents.

The enterprise-management model (EMM) for new-product development offers a comprehensive management framework for developing sustainable new products and improving existing ones. The model presents a multi-dimensional view of the business environment and highlights the key dimensions necessary for analyzing, planning, positioning, implementing, and evaluating NPD opportunities and programs. The model sets the stage for a descriptive, analytical, and structural understanding of the needs, opportunities, challenges, requirements, specifications, and the flow of the NPD process. The EMM is used to characterize new-product opportunities in sufficient detail so that management can be assured that very little has been overlooked. It attempts to minimize mistakes or oversights by systematically assessing all of the important aspects: social, economic, environmental, political, technological, markets, customers, competition, supply networks, related industries, and infrastructure.

The framework is more complex than conventional approaches due to the number of dimensions and elements that it includes, but as an integrated approach it includes the essential dimensions for effective decision making. The framework provides practitioners with an understanding of the process elements and the network of working relationships.

The EMM provides a global perspective and emphasizes the following:

(1) Market opportunities, customer needs and wants, product attributes, product and process specifications, marketing requirements, and technology issues.
(2) The interrelated effects of customers, markets, stakeholders, supply networks, related industries, infrastructure, and competitors.
(3) The use of integrated product development (IPD) thinking as a means for making sound business decisions about new-product opportunities.

The EMM includes the primary elements of Michael Porter's value system and its internal value chain, and the traditional economist's view of industry structure; it also includes the implications of stakeholders, related industries, and the infrastructure. Porter's value chain is the prevailing view of the essential relationships in the product delivery system.[3] The EMM and Porter's models examine product delivery, industry structure, and competitive aspects. They also include a comprehensive analysis of the suppliers, distribution channels, and customers as part of the system. However, the EMM extends beyond the conventional methods and includes additional dimensions that are both essential for analysis and crucial for selecting the right strategies based on a broader perspective. In particular, the EMM explores the roles of stakeholders (external constituents), the impacts of related industries, and the implications of the external infrastructure so that a more-comprehensive view of the opportunities and challenges can be ascertained. The EMM is in concert with the realities of using strategic partnerships and other external relationships to build credible mass for developing new products.

The EMM is a multi-dimensional array from a spatial perspective, with a temporal dimension covering the dynamics of the business environment over time. It is viewed from the new-product developer's perspective but could easily be transformed to a customer perspective as discussed in Chapter 8. The external dimensions include supply networks, customers and markets, stakeholders, competitors, related industries, and the infrastructure. The internal dimensions are technical, marketing, production, and finance. Each dimension represents a critical interface with the management system.

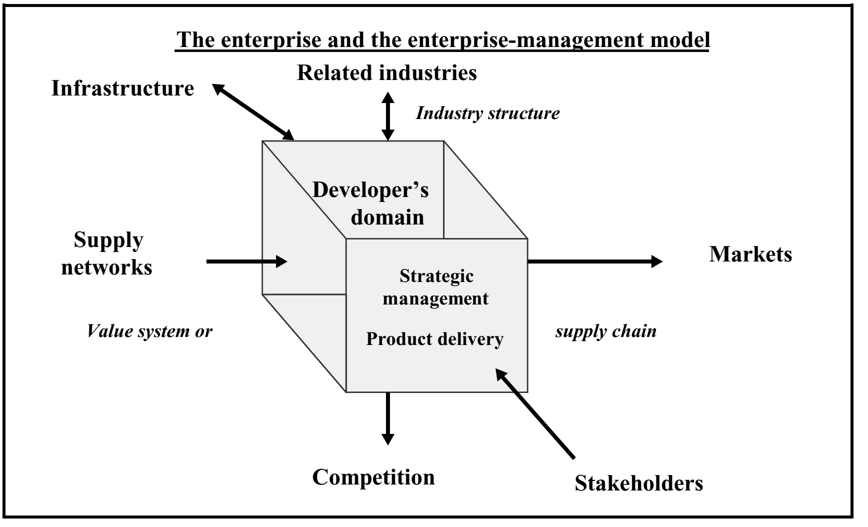


Figure 2.1 Enterprise-management model for new-product development

The EMM framework and the principal dimensions thereof are used extensively throughout the book. The dimensions provide the foundation for analysis and decision making.

The EMM provides practitioners with a comprehensive view of the strategic-management system as it relates to NPD programs and processes. The "standardized" NPD process introduced in Chapter 1, and described in Chapter 3, uses the principal external dimensions as well as the internal dimensions in determining strategies, discerning appropriate courses of action, and executing the necessary activities.

Figure 2.1 depicts the essential dimensions of the EMM. The enterprise-management level is the domain of executive management and includes the global strategic aspects of acquisitions and mergers, capital formation and utilization, and other financial and strategic positions. The primary considerations are the partnerships, alliances, and value networks that generate long-term success and strategic positions for generating opportunities in the business environment. While this book employs the EMM as the primary framework for managing product innovation, the strategic-management system is generally the level for discussions and decisions pertaining to new-product development and incremental innovation.

The strategic-management system includes all of the strategic business units of the company. There may be many such business units in a large corporation. The focus of the strategic-management system is typically on the intermediate term (more or less five years depending on the life cycles of technologies and products). The strategic-management system examines the needs and desires of the business environment and determines the most advantageous business strategies for meeting or exceeding the opportunities and expectations. It explores the requirements for strategic change and growth, and assesses the capabilities and resources of the organization for responding to the opportunities and challenges. The strategic-management system is often defined by its technologies and products, and the markets and customers that it serves.

The strategic-management level provides the linkages and alignment between the product delivery system (operating level) and the global view of the entire enterprise-management system. It is the integrating force between corporate management and the management responsible for execution of the strategies and programs. Strategic management is responsible for linking the management system with the business environment, thinking about innovation, creating innovative solutions for the future, and providing the strategic leadership for the organization.

The product delivery system is the core operating level. It concentrates on exploring and exploiting the existing conditions and trends, and on meeting the marketing, production, technical, and financial requirements of the organization. It is usually supported by product and process innovation capabilities for updating and improving product portfolios and product performance. The historical model for managing the operating level focused on the resources deployed within the system and the organizational elements engaged in converting resources into outcomes.

The EMM integrates the concepts, approaches, methods and techniques used by leaders, managers, and practitioners into a single methodology. It is a powerful construct that provides a comprehensive understanding of the underlying issues related to integration, innovation, and leadership. It offers a holistic view of the business realities, allowing the decision maker to find solutions to potential problems or issues.

The main elements of the strategic management system are defined and discussed in the next subsections. The intent is to provide a clear sense of the strategic aspects for assessing the opportunities and determining the appropriate strategic direction for selecting NPD programs. The focus of the discussion involves the implications of the strategic-management system in relation to product innovation.

The primary dimensions – the value system or the supply network

The primary dimensions include the producer or new-product developer (the strategic business units and their product delivery systems), the suppliers and their suppliers, the distribution channels, the customers and their customers, and those engaged in the recycling and disposal of retired products and waste streams. Porter called the key elements of the primary dimensions the "value system." The value system involves the flow of raw materials, parts, and components, etc. from the upstream suppliers to the producer who creates and delivers products and services through the distribution channels to customers and their customers, if appropriate.

The primary dimension is the essential part of the management system. There are many variations to the basic model. For example, Dell Computer uses the Internet and catalog ordering for customer interfaces, and ships its products directly to customers, avoiding the expense and other implications of using intermediaries in the distribution channels. Compaq Computer (Hewlett-Packard), on the other hand, sells most of its products through distributors and retailers. Both companies have Intel as a key supplier providing components for their products based on Intel's Pentium microprocessors. The supply networks are powerful relationships that provide valuable resources and capabilities to the management system and its beneficiaries.

In *Leading the Revolution*, Gary Hamel discusses the "age of revolution" and the "business concept." The aim of Hamel's business concept is similar to the EMM construct. The main exception is that Hamel's model lays out the flow from customer interface to core strategy and strategic resources, and finally to the value networks.[4] Hamel's model is not as definitive in the identification of the dimensions and elements. Moreover, it does not convey the importance of stakeholders and their needs and expectations.

Hamel's model links the core business strategy with the strategic resources of the organization through a mechanism called configuration.[5] The core strategy includes the mission, product/market scope, and the basis for differentiation. These are critical elements in the NPD situation and are covered as part of the Strategic Logic and Alignment Phase. The product/market is the primary focus of the new-product development, setting the stage for analysis and decision making. Likewise, strategic resources, competencies, assets, and processes provide the foundation for designing and developing the NPD program.

The EMM defines and links the interfaces between the internal dimensions of the NPD program with the external dimensions. The primary dimensions include the management system, and its markets and supply networks. It also includes the secondary effects of waste streams and end-of-life considerations.

The critical internal dimensions include the policies, the strategies, the selected NPD programs, the new and existing products and services, the NPD and business processes, and the prevailing practices of the organization. They are linked internally and externally by knowledge and information flow. Figure 2.2 shows the essential elements of the primary dimension.

The supply networks include the flow of inputs and outputs from suppliers to producers of products, and flow of products and services to their customers. The inputs and outputs include the materials, parts, components, products, and information necessary to provide effective solutions for meeting market and customer needs. As the upstream and downstream activities move from the producer's domain to the external dimensions, the variants from system to system increase dramatically. The supply networks include not only the primary suppliers, but also all of the second-tier, third-tier, and *n*th-degree suppliers.

Daimler-Chrysler's operation in Stuttgart, Germany – its Mercedes production facility – is an excellent example of a fully integrated supply network. Mercedes is linking

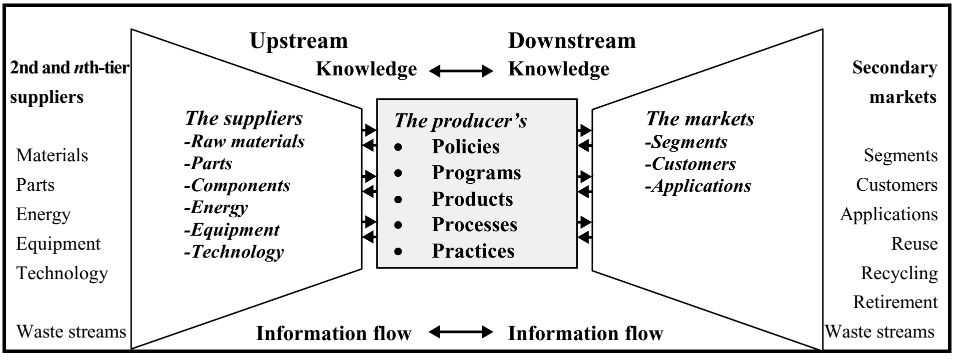


Figure 2.2 The primary dimensions – supply networks and markets

all of its suppliers and their suppliers seven deep into the supply chain so that Mercedes has accurate information about the flow of goods for the assembly of any particular customer's automobile. The system provides customers with the ability to select their own unique vehicle from the millions of options. The information system allows marketing professionals to give their customers specific delivery dates and confirmation details. Information control, in cooperation with every tier of the supply network, makes the entire supply chain transparent and provides real-time information about the supply status.[6] Mercedes can give accurate promised delivery dates, and can also track status to ensure that it meets its commitments. Mercedes' information and management system fits the notion of mass customization, providing each customer with the opportunity to create a unique vehicle.

From an NPD perspective the value chain includes the policies, processes, practices, products, and programs required for designing and developing new products. The producer's view of the market includes the selected market segment(s); targeted customers and their applications; and the secondary markets including the customer's customers, their applications, the reuse of the product over time, the recycling potential, and end-of-life aspects. In many cases, the customers for a new product flow through distribution channels. The ultimate customers are the "customers" of the channel entities. For example, Procter & Gamble (P&G) sells its products to retail outlets, which then sell the products to consumers. P&G sells Pampers through retailers like Wal-Mart, Kmart, Kroger, and A&P. The retailers enjoy the benefits of P&G's extensive advertising programs to attract consumers to their stores.

The integration of the primary dimensions requires the simultaneous coordination of a company's actions and activities. This includes defining the roles and responsibilities of the participants, collecting information about the opportunities and challenges, developing insights about conditions and trends, understanding the processes, and managing change over time. The strategic integration allows management and the practitioners to focus on the market segments that have the highest probability of securing successful

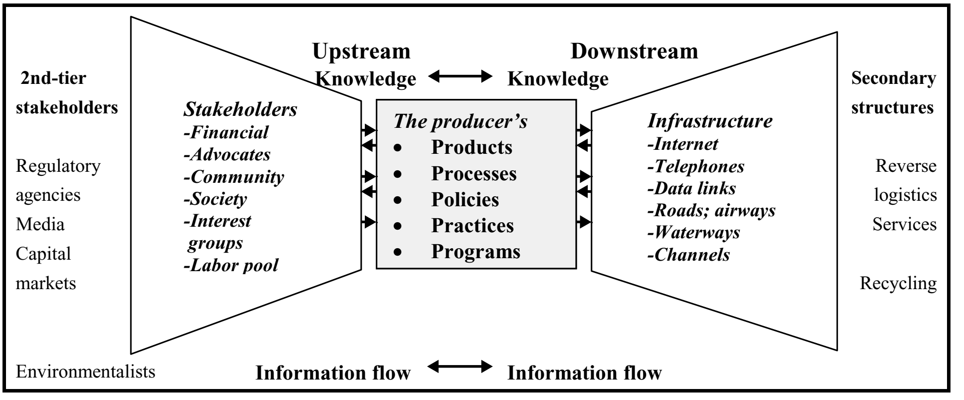


Figure 2.3 The secondary dimensions – external structure

outcomes, and to utilize resources in the most advantageous manner possible. It results in a concentrated effort on the targeted market segment.

The EMM goes beyond the primary applications of the product and examines secondary customers and their uses of the products. It explores how all of the market participants can promote the social, economic, and environmental strengths of the products. The market aspects include the repair, reuse, and recycling of the products. The prime objective is to maximize the creation of value by discovering as many secondary applications as possible for the products or the materials. This is not a radical concept. The second-hand market for used automobiles helps the production side sell new cars by creating outlets for the older vehicles. The aluminum can is an excellent example of a product that has been enhanced by the secondary market. Reynolds Metals created aluminum recycling in 1968 and became a major producer of recycled metal. Customers are pleased to buy and use a product that has a high residual value. The secondary processes reduce the cost of using the product by providing a residual value.

Customers who manage their resources have more assets to invest into inventing new opportunities for their businesses. Suppliers who help their customers improve the performance of the products, and support their applications, will be positioned to reduce the cost of ownership, increase reliability, and enhance quality.

The secondary dimensions – external structure

From the producer's perspective, stakeholders and the infrastructure comprise the external structure which is an important secondary considerations. Figure 2.3 provides a view of the critical elements of the external structure.

Stakeholders

Stakeholders are the supporting, challenging, confronting, and/or controlling entities that play significant roles during the development and life cycle of a product. Stakeholders include the local community, consumers in general, interest groups, environmental activists, governments, regulatory agencies, the international community, capital markets, and other constituents that play significant roles in the business environment.

The capital markets are significant stakeholders of corporations. They provide the funding sources for corporate debt structures and development programs. While capital markets are significant factors, a detailed discussion on sourcing capital and managing the related processes is beyond the scope of this book.

Stakeholders can play a positive role by supporting and facilitating the new product's development and commercialization, and improving the opportunities for the new product. For example, society may welcome and endorse new products that reduce or eliminate the hazards associated with toxic substances. On the other hand, some stakeholder groups may resist the commercialization of new products that have significant negative effects. Public pressure may make it more difficult and costly to pursue such new-product opportunities. For example, certain environmental groups create barriers for new products that use chlorinated solvents or those producing by-products that may contribute to global warming. Government agencies may promulgate new regulations requiring an environmental permit to operate the production facility. They may set constraints on operating conditions, establish rules for disclosures, and determine protocols for new product certification and approval. Such regulations may have a significant impact on the time and investment needed to complete the NPD process.

While customer satisfaction is extremely important, stakeholder satisfaction is also a primary objective. The stakeholder-based philosophy ensures that all external factors have been duly considered and satisfied. It is too simplistic to view only the customer as critical. Intel worked closely with the local community and government agencies during the development of the Pentium 4. The effort allowed the company to obtain the necessary permits within a few months.

The certification of a new product by a government agency may be one of the most time-consuming and expensive aspects of the development process. Clearly, the Food and Drug Administration (FDA) protocols requiring clinical trials have a major impact on the development of new pharmaceutical products in the United States, often necessitating more than five years of extensive safety and efficacy testing. Such examples are not intended to suggest that these requirements are burdens to the process, indeed they may be absolutely critical for long-term success. Airplanes, automobiles, and many other products that have safety issues require government certifications. The Product Safety Commission regulates product safety and issues recall notifications when there are serious product-related concerns about consumer well-being.

External infrastructure

The external infrastructure includes Internet communications, telecommunications, energy systems, airways, roads, waterways, and the atmosphere, etc. Infrastructure includes the support structures that provide the means and mechanisms to obtain resources, transport goods, communicate with support entities, and apply the products in a cost-effective manner. These networks and resources make valuable contributions that facilitate the movement of goods, information, data, waste, and energy to and from the supply and value networks. The infrastructure supports the flow of the product through the channels to customers. In every product category, the external infrastructure plays an important supporting role that sustains the viability of the product.

The infrastructure makes new products possible by providing the means for delivering the product or by reducing the cost associated with production or delivery. For example, electronic commerce provides a means for increasing the speed at which information and data are transferred, and transactions are performed. It reduces both the fixed costs of establishing the system and the variable costs associated with transactions. Communications integration via the Internet provides an enterprise-based system of carrying out activities regardless of where the participants are located.

The infrastructure also provides the means to eliminate the waste generated during the production of the products or during the applications. It supports products by providing solutions to product retirement/disposal issues. Reverse logistics provides a means for the recycling of used goods and the reuse of products and materials. The infrastructure offers producers and customers the opportunity to improve their ability to communicate with each other, transport goods and services, and solve problems, thereby reducing the cost of ownership, increasing speed and reliability, and enhancing overall product and system quality.

The infrastructure supports the value system activities and provides the means to link the key players. A closed-loop infrastructure facilitates the integration of all of the requirements to move the products forward and backward as quickly as possible. Just as inventory turns in a manufacturing facility improve performance by reducing assets, the intensity of the infrastructure provides the means of improving performance and reduces the need for new resources. For example, an aluminum can has the potential to be produced, filled, used, recycled, and remanufactured within a 90-day period. The infrastructure of redemption facilities, roads, and communications contribute to a short cycle time, allowing not only the reuse of the metal but a significant reduction in the amount of aluminum held in the system.

The industry dimensions – industry structure

The industry dimensions include the producer, its competitors, and related industries. These dimensions represent the industry structure from an economic perspective. The industry supports customers with additional product and service choices needed for

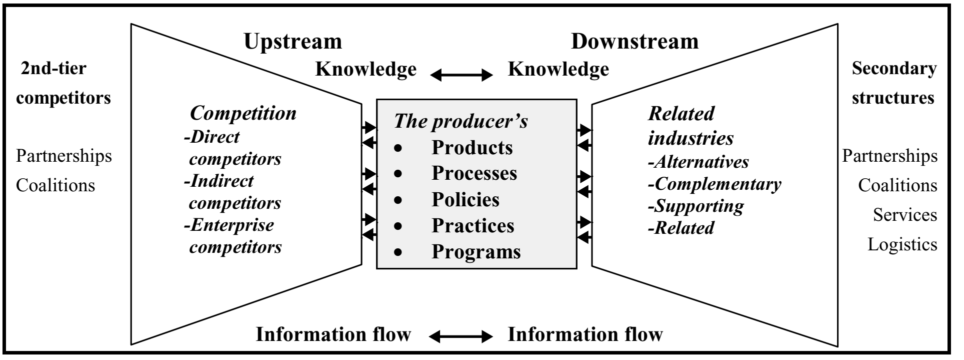


Figure 2.4 The industry dimensions – industry structure

making purchase decisions, for supporting the product applications, and/or for managing the implications of the product. The industry offers complementary, supplementary, or alternative products and services that provide customers with additional solutions for meeting customer needs or solving problems. It also allows customers to compare and contrast the options. Figure 2.4 provides the key elements of the industry structure.

Competition dimension

Competition represents the forces that are competing for revenues, market share, and new product success. Competition is often perceived as a negative force trying to take away market share or disrupting the stability of the competitive landscape. This is usually true for existing products, but it may not always be the case for new-product situations. Competitors may help to share the up-front expense of building awareness by providing additional sources of communications and information. If competitors expend their resources to help develop the market, this may make an NPD program feasible because each individual company's investment is lower than on a stand-alone basis. Moreover, customers may be uncomfortable having only a single supplier of a critical product. This is an important phenomenon in industrial or government markets.

The assessment and impacts of competition are discussed in more detail later in the chapter.

Related industries

Related industries often have an impact on the success of the new product in many ways by supporting product development and product launch. Typically they provide the complementary products and services that make the product viable by increasing its value. For example, Disney World depends on the airline industry to transport customers to Florida. The airlines want to see Disney succeed because its presence helps their businesses. Disney is dependent on Delta Airlines and others to provide the means to get customers to Disney World in Florida. Indeed, there is a strategic alliance between Disney and Delta Airlines to take full advantage of the opportunities available to the companies and to reinforce the benefits to the customers.

Related industries are fundamentally important to the new-product introductions. Personal-computer hardware relies on the introduction of new software. The new software demands faster processors, requiring more memory and greater capacity. Similarly, the movie industry depends on revenues from videotapes and other technologies such as DVDs. This in turn affects the service industries that offer rentals and the electronic goods manufacturers.

Strategic-management system: a product-development perspective

Overview of strategic management

Strategic management provides the strategic logic and direction for developing new products. It includes the upstream planning and analysis of strategic business issues and opportunities, and sets the stage for establishing the criteria for the NPD process. It establishes the basis for the decision making during the NPD process. Strategic management positions the organization to take advantage of its opportunities and to minimize its threats. The primary approach for product innovation is to leverage internal resources and capabilities while minimizing the impacts of weaknesses and building new capabilities through learning and experience.

Strategic management includes the high-level decision-making process for determining the new products to be developed, creating the NPD processes, selecting the markets segments to be addressed, and formulating and implementing the strategies and policies to guide the organization. Strategic management provides the leadership and general direction for new-product development.

Generally, senior management decides on or approves the new-product initiatives. In most organizations, the new-product initiatives are a result of interactive decision making rather than a single go/no-go decision. Senior management in dynamic organizations affirms the decisions made by the participants during the NPD process. Those decisions are built on opportunity assessment based on the conditions and trends of the external business environment and an assessment of the internal and external factors. The preferred approach is to generate opportunities and solutions by engaging the participants in analyzing, strategizing, evaluating, and decision making. It empowers participants to become energized through cooperation and understanding. It invokes a dynamic perspective on managing change with minimal resistance.

The opportunity assessment includes the following:

- An understanding of the existing business situation and strategic-management system.
- Identification of the core values, corporate culture, and vision.

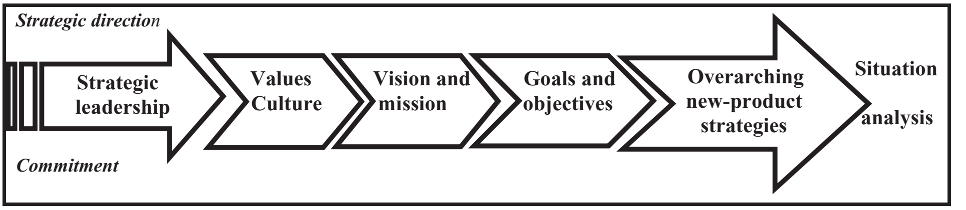


Figure 2.5 Strategic-management system related to new-product development

- Determination of goals and objectives.
- Assessment of the core competencies, organizational capabilities, and resources.
- Evaluation of the current products and their strengths and weaknesses in their markets.
- A situation analysis of the business environment and the external dimensions affecting the organization and its products and processes.
- A market analysis and competition analysis to discover opportunities, challenges, constraints, and concerns.
- Selection of new-product strategies.

Strategic-management system and its primary perspectives

The strategic-management system integrates the organization's processes and capabilities into a comprehensive framework for managing and directing business strategies including those related to new-product development. It includes the organization's philosophies and strategies with respect to the enterprise-management model and the NPD process. Senior management's primary role as it pertains to new-product development is to:

- Foster a perspective of the importance of new-product development.
- Provide the inspirational leadership and guidance necessary for achieving outstanding results.
- Set the primary objectives, policies, strategies, and process methodologies.
- Provide the resources and capabilities to execute NPD programs.
- Evaluate outcomes and performance on an ongoing basis and affirm decisions.

Management at every level in the NPD process has the responsibility for articulating the philosophies and values of the organization and for translating the strategic objectives into an operational language that is meaningful to NPD practitioners. The bottom line is that everyone participates, based on the shared knowledge, and is guided by a well-understood framework. Figure 2.5 provides an overview of the main elements of the strategic-management system as they pertain to new-product development.

The strategic-management system includes the fundamental elements of corporate values and culture, vision and mission, goals and objectives, and strategies. The overarching strategic direction is typically articulated through and by executive management. The voice of senior management is expressed both implicitly and explicitly using policies and guidelines, and the inspirational messages communicated through words and actions. Strategic direction can be formal and informal, centralized and decentralized. However, in the new-product situation, strategic leadership and commitment are essential elements of the NPD process that are often missing until much later in the development process after many crucial decisions have been made. Often, senior management begins paying attention only after significant amounts of money are being committed or spent. Hayes, Clark, and Wheelwright suggest that senior management has to play a more-active role from the beginning of the process.[7] Indeed, most NPD programs require significant commitments (decisions) during the early phases of a program which determine the product/market position, the principal benefits and functions of the product, the cost structure, and other key aspects of both the product and the NPD program. Various studies indicate that between 50 and 70% of the investment is committed to during the up-front phases.

The pivotal point depicted in Figure 2.5 is the situation analysis, which in many cases precedes the actual definition and determination of the programs for new-product strategies. There are many variations to the positioning of the analysis of the business environment. The situation analysis examines the underlying business situation in terms of opportunities, challenges, constraints, and concerns; and determines the organization's capabilities in terms of strengths and weaknesses. It provides the input for management at every level, especially at the strategic-management level, to make informed and well-thought-out decisions about new-product strategies and NPD programs.

The new-product strategies provide the focus, direction, and mechanisms for determining what the new products are going to be. NPD strategies are the broad programmatic areas that are selected for investments and set the stage for idea generation and concept development. The key elements are described and analyzed below.

Strategic leadership

Senior management articulates the values, vision, and expectations (objectives and targets) of the organization. It ensures that principles and philosophies are integrated into a management system with a high-level of commitment and leadership. Senior management is responsible for directing the organization towards achieving meaningful targets and providing the resources and incentives for encouraging people to achieve results. Senior management establishes the policies, plans, processes, practices, and programs for linking the opportunities and challenges to the strategic and operational aspects of the organization.

Values and culture

Success depends on people and their abilities, skills, knowledge, and commitment. Building a knowledge-based organization is the crux of management's responsibilities for energizing the NPD process. With the "quantum leaps in the speed of change,"[8] management must exhibit leadership by providing the people with values and beliefs necessary for ensuring that new-product opportunities are acted upon and the desired outcomes are realized. Corporate values set the stage for establishing the goals and objectives of the organization. Values provide the guidance participants need when making critical decisions about NPD programs. For example, corporate values provide insights and directions about risks, ethics, and other more open-ended, often difficult to define, subjects that have to be handled during the NPD process. An ethic might be the "precautionary principle," stipulating that the "organization will err on the side of safety and caution, thus reducing risks."

Values also provide insights and guidance about how to deal with the social, economic, and political aspects of the business environment. A statement of values allows participants to understand the ethical and social obligations of the organization. For example, Johnson & Johnson uses its "CREDO" to articulate the values of the corporation.[9] The most intriguing conception of the CREDO is the prioritization of the principles. The customers and stakeholders are first and the shareholders and profits are last. Johnson & Johnson's core values help to guide the organization in making difficult decisions. With the CREDO to guide them, management and employees have a solid understanding of the fundamental truths and expectations.

Culture helps to determine the capabilities of the organization. People are amenable to participate in teams, if the culture supports teamwork and the system rewards team players. The culture guides in the attitude to risk taking or risk avoidance. Typically, it is the culture that determines the aggressiveness and thoroughness of the organization. If risk taking is not rewarded, but punished when failures occur, then people tend to be timid. Conversely, if risk taking is rewarded even if the program is less than successful, people may exhibit more confidence during future NPD programs.

Vision and mission

Senior management defines the vision and stipulates the mission, providing strategic alignment and direction. Vision is the high-level, future-oriented construct that translates external forces, opportunities and challenges, and internal capabilities and desires into a new reality for the organization. It is the long-term perspective that may take years, even decades to realize. It is the wisdom for viewing the business environment in terms of "what it can be or will be" instead of "what it is."

Developing new products is one of many ways for realizing the vision. New-product development is a primary mechanism for improving or transforming the business situation into a more productive and rewarding reality. Clearly, there are other means to realize business goals and objectives, including acquisitions and mergers, divestitures, stock buybacks, etc., but product innovation is a means for creating wealth through competitive advantages in the market place by satisfying customers and stakeholders in improved and exceptional ways.[10]

As the organization matures, its mission often becomes less clear, especially as mergers and acquisitions impact upon the historical roots of the organization. To perform successfully, the organization and its members must have a clear understanding of where the organization is heading. ***The mission defines the long-term direction of the organization and how new-product opportunities fit the strategic direction***. It defines opportunities and fuels the passion for achieving outstanding results. It defines the scope of the organization. It establishes what product lines the organization has and what its areas of interests are. The organization's mission is normally based on its current focus and its vision, and concentrates on the organization's capabilities and the customers and markets that it serves or plans to serve.

Product innovation focuses on NPD programs that support the current mission, near-term objectives, and core capabilities of the organization. Technological innovations tend to focus more on the organization's vision, leading to significant changes in the products and processes, as well as the prospects for success and reward.

The search for new-product opportunities must be grounded on the realities facing the organization and management's view of the future. The organization's vision and mission statements offer guidance and direction for discovering new-product opportunities. They establish limits on the extent of the search for new-product ideas and give strategic guidance in terms of what fits and what doesn't. Communicating the organization's strategic thrust may be difficult. It is typically disseminated through goals and objectives, strategies, and policies.

Enterprise goals and objectives

The enterprise goals and objectives help to define what new-product areas should be explored. They also define what is to be included in the NPD process and what is to be excluded. They provide the criteria for determining what are appropriate new-product opportunities. ***Objectives focus on outcomes: where the organization wants to be at some time in the future! The selection of objectives is based on the overall mission and strategic direction***.

According to Robert Kaplan and David Norton, authors of *The Balanced Scorecard*, an organization must have a balanced set of objectives that include the fundamental requirements for achieving long-term success.[11] Their construct fits perfectly into an NPD situation where the focus has to be on more than just financial reward. Moreover, the "balanced scorecard" is in concert with stakeholder-based management frameworks that have balanced views of the most important objectives of an organization. Table 2.1 provides a matrix of the main areas described in the balanced scorecard.

The new-product objectives are a subset of the strategic objectives of the organization. They stipulate what categories and types of new-product developments are required to fulfill the strategic and growth needs of the organization. The new product could be a failure, but if significant learning was achieved, then the NPD program might be viewed as a success and new knowledge is gained. Indeed, organizational learning

Table 2.1 *The balanced scorecard from an NPD perspective*

Main category	Key objectives	NPD considerations	Targets (examples)
Financial perspective	Value creation Profitability Growth	Return on investment Cash flow and low unit cost Market size and growth rate	30% internal rate of return 50% gross margins 15% growth rate
Customer perspective	Price/cost Functionality Responsiveness Service	Superior value Customer satisfaction Stakeholder satisfaction Performance and benefits	2 × performance/price 95% delighted customers 0 complaints (defects) 100% serviced in one day
Internal perspective	Quality Productivity Leverage	High-quality business processes Supplier involvement	Six-sigma quality 10% reduction in time 90% related to existing products
Organizational learning	Learning Innovation Intellectual assets	Rapid development Knowledge Process learning	10% improvement 50% growth 2 or more patents

is a primary objective. This is especially true if subsequent NPD programs result in enormous rewards.

Generic NPD strategies

Overview of the formulation of NPD strategies

Organizations establish strategic direction by analyzing their strategic positions regarding the external forces and their internal competencies and capabilities, and through the strategic alignment of their resources with the needs and opportunities of the business environment. When addressing the external forces, the strategic approach is to take advantage of the opportunities and to neutralize the negative aspects. Kenneth Andrews, a leading authority in corporate strategy, defined strategy as:[12]

> Strategy is the pattern of decisions in a company that determines and reveals its objectives, purposes, or goals, produces the principal policies and plans for achieving those goals, and defines the range of businesses the company is to pursue, the kind of economic and human organization it is or intends to be, and the nature of the economic and non-economic contribution it intends to make to its shareholders, employees, customers, and communities . . . [It] defines the businesses in which the company will compete, preferably in a way that focuses resources to convey distinctive competencies into competitive advantage.

H. Igor Ansoff suggested that the formulation and implementation of strategies are realized by strategic management. He defined strategic management as:[13] “A systematic approach to a major and increasing important responsibility of general management: to position and relate the firm to its environment in a way which will assure its continued success and make it secure from surprises." The development of new-product strategies depends on how management views the consequences of business conditions and trends; such as changes, opportunities, threats, etc. The difference between an opportunity and a threat may depend on how and when the issue or situation is handled.

NPD strategies consist of decisions on how to select product/market segments that are attractive from a organizational perspective, to utilize the capabilities and resources of the organization in the most effective manner, to minimize the pressures of competition, and to gain sustainable competitive advantages. Product/market strategies for new products are normally narrow in scope and concentrate on the specific requirements to identify, select, design, develop, test, produce and market the new product within the constraints of the internal and external dimensions. Generally, they are highly focused on the objectives of the NPD program and the requirements of the new product.

The product/market strategy consists of a set of decisions that defines the direction of the NPD programs. A new product/market strategy includes the following:

- ***Selecting a target product/market segment***. If there is more than a single target, the choices should be ranked in order of importance. The potential early customers should be identified. Each additional product/market segment requires a thorough understanding of the related external dimensions, increasing the complexities of designing and developing the new product.
- ***Determining the objectives***. The objectives for each product/market segment should be fully defined and articulated in a manner that is consistent with the precepts of the balanced scorecard and value creation.
- ***Evaluating the primary dimensions***. The dimensions of the enterprise-management model should be addressed and the primary aspects of each should be identified and mapped out. For example, the most important competitors and their potential responses should be defined. Likewise, the critical aspects of the supply networks, infrastructure, related industries, and stakeholders should be well understood with an articulated game plan.
- ***Outlining strategic alternatives***. Based on the core capabilities and the opportunities in the business environment, alternatives should be mapped out and examined in detail.
- ***Making strategic choices***. The strategic statements should include the primary means of attack and the alternatives available should the primary target prove to be unattainable.
- ***Articulating the internal dimensions***. The internal dimensions should be defined and structured into action plans. This includes the marketing, technical, production, and financial plans.

This approach has powerful implications for new-product development. It focuses on the complete array of choices that have to be made. Objectives, targets, and strategies drive the strategic aspects of new-product development. The NPD process includes a thorough evaluation of alternatives before selecting the viable candidate(s) for development. The NPD process focuses on making choices about customer targets and market segments. Success is often obtained by concentrating the available resources on specific targets rather than the broad market opportunities. The construct suggests that the stakeholders, supply networks, related industries, competitors, and the infrastructure are selected based on the targeted customers and selected market segments. The core strategy includes the means used to develop and execute the NPD program. The strategies are supported by action plans that provide the details on how the program will be developed and executed.

Generic strategies

The generic strategies for new products tend to follow the prevailing generalized strategies for businesses and products. Michael Porter's generic competitive strategies provide a straightforward basis for selecting a new-product approach or strategy. Porter suggests that an organization can achieve a competitive advantage using one of the following generic strategies:[14]

- ***Cost leadership***. This strategy requires the organization to develop a new product that has significant cost advantages over competitive or related products. This can be achieved through leveraging resources, employing strict cost controls, outsourcing marginal activities, and using economies of scale. Lower costs mean more value.
- ***Differentiation***. This strategy implies that the organization creates a new product that is unique and not easily duplicated by any competitor. A new-to-the-world product often has the advantage of being the only choice available for some period of time.
- ***Focus***. This strategy requires the organization to concentrate its efforts on a given geographical area or group of customers where it can achieve an advantage. Typically, the focus strategy allows the organization to use its resources effectively in one area, achieving critical mass and high customer satisfaction.

Porter's generic strategies can form the basis for selecting the overall NPD strategies. Generally, new-product strategies must also deal with the fundamental product/market objectives. Those objectives include time to market, unit cost, performance, value creation, quality, and total investment. Mitigating risk is also a prime concern.

Timing is often a key consideration in determining the strategy to be deployed. The typical timing strategies include the following approaches:

- ***First to market***. This strategy suggests that the organization has the process capability to move quickly from start to finish. Usually it requires close linkages between upstream activities, such as research and development, and downstream capabilities to validate the products and other outcomes and to commercialize new products. It also requires high investment levels and the know-how to establish the linkages between customer wants and needs, and new products. The strategy often means high investments into creating market awareness and promoting initial product demand. This may be seen as a proactive approach.

- ***Follow the leader***. This strategy suggests that the organization has the ability to determine what the leaders are doing in terms of new products and to quickly improve on their designs. It requires an excellent competitive intelligence capability and an integrated management system that can respond to new product introductions by competitors. This may be seen as a reactive approach.
- ***Strategic delay***. This strategy employs delaying tactics to determine the strengths and weaknesses of the leaders and followers and improve upon their deficiencies. It implies that the organization studies such strengths and weaknesses and makes changes to the product architecture or formulations to improve its offerings in relation to the competition. It requires an extensive market research and intelligence capability for obtaining the information and data. The organization needs to have the technical skills and knowledge to evaluate competitive products and to effect improvements.
- ***Imitator***. This strategy implies that the organization has the ability to copy competitive products and make variations that are more cost effective than the competition. It requires a lean structure or cost-effective supply networks that can out-perform the other enterprises. Moreover, it often saves considerable amounts of money by copying, borrowing, etc. everything that it can.

Each of the timing strategies has advantages and disadvantages. Generally, the value of the timing strategy depends on the resources and capabilities of the organization. The actual strategies depend on time and position, suggesting a matrix view of Porter's generic strategies and the typical timing strategies.

The main advantages of being first to the market are obtaining market share and enhancing ones reputation as being the leader. There is no guarantee that the lead can be maintained. Indeed, the leader often stumbles, providing an opportunity for the follower to take over. A classic case was General Motors and its Chevrolet becoming the market-share leader in 1927 when Ford failed to update its product, the Model T.

The follower may try hard to take over the lead but occasionally the advantages of being first become a huge barrier to the other competitors. Intel has enjoyed an enormous advantage in the microprocessor arena because of its technological leadership and the ability to introduce new technologies, platforms, and products quickly. Its reputation and image as a quality producer is a difficult challenge to overcome.

However, the follower often gains from the lessons it learns from the leader. Such insights allow the follower to overcome the leader's mistakes and become the leader. Compaq Computer overcame IBM's leadership in the personal-computer market in early 1995, only to be replaced by Dell Computer in 1999.

Strategic delay depends on the actions of the leaders. Leaders may create a situation where the side-line player can never enter the game. The barriers to entry may continue to grow making entry into the market place more costly as time passes. For example, on a global basis there are only six to eight competitors in the primary aluminum industry. The process technology is both expensive (more than $1.2 billion for a 215,000-metric tonne/year facility) and sophisticated. On the other hand, strategic delay may provide the time to assess information about the markets and the actual needs of customers. The large array of small to medium-sized competitors during the early years of the personal computer business provided Compaq with the data and knowledge that it needed to make a grand entrance in 1983.

The imitator simply gathers information that is readily available and builds a business and product position on a low-cost strategy of imitating one or more of the leaders. A good example of this approach is the generic pharmaceutical producers who wait until patents expire and then start producing the same product that the proprietary pharmaceutical company has spent millions of dollars on in R&D.

However, the imitator may discover that the leader has perfected the product(s) to the point where there are no opportunities to cut costs or improve the products. Motorola's pagers are an excellent example of high-quality, low-cost products that leave little room for a competitor to mimic. Even if some entity could copy the pager, customers would probably still prefer to have a Motorola because of its reputation and image as a high-quality manufacturer.

The actual strategy employed is dependent upon the situation, the resources and capabilities of the organization, and its objectives. There may not be a best approach. The key to success is to evaluate the situation as soon as possible and to select an appropriate strategy. The essence of any strategy is to obtain a competitive advantage that can be exploited for a reasonable period of time and to follow the logic of the strategy. Management must think about how to sustain its initiatives over the life cycle of the product. It is recognized that competitive advantages tend to dissipate over time; therefore, strategy formulation requires ongoing attention and refinement.

Table 2.2 provides a summary of the interrelationships between generic strategies and timing strategies.

New-product strategy formulation

New-product strategies consist of moves to select product/market positions that are attractive and defendable from a competitive point of view. The prevailing approach is to combine the product and market aspects together in order to define the new-product situation from internal and external perspectives. The product/market perspective gives management the view it needs to articulate strategies that are balanced and reflect the entire business environment.

The new-product strategy includes an identification of the select product/market segment that is the initial target, a statement of the short- and long-term goals, a definition of the resources and capabilities required to execute the NPD plan, and the specific means to achieve the desired results and sustain the position in the future. It deals with how to attract the initial customers and to build market presence during the launch period.

Table 2.2 *Evaluation of generic strategies with regard to timing*

Timing	Cost leadership	Differentiation	Focus
First to market	The first mover often has the ability to reduce cost early by absorbing fixed costs as volume grows. It usually has a significant cost advantage over competition for some period of time. This is a powerful strategy for the leader in the industry.	The first mover can select attributes that provide benefits to specific market segments that are willing to pay for the benefits. This is useful in the situations where the new product is not as cost effective as existing products.	The first mover with limited resources might achieve a powerful position in one segment that can be used to exploit other areas. This approach allows the building of critical mass. This is powerful for the newcomer.
Follow the leader	The follower uses this strategy when it can avoid making early commitments to new product situations where it is not clear how to achieve the low-cost position and it is imperative to be a low-cost provider, such as with commodities.	The follower can avoid direct competition by offering a product form that the leader has not concentrated on. This allows the follower with limited resources to select attributes that serve select areas of the markets.	The follower can avoid direct competition by selecting areas that the leader has not concentrated on. This allows the follower with limited resources to select market segments that are not fully served by the leader.
Strategic delay	Strategic delay uses cost leadership when it can avoid development and start-up costs by capitalizing on the investments made by the leader. The first to the market often has to educate the market at its expense. This strategy allows the entity to learn from the mistakes of the leader and avoid them.	Strategic delay uses differentiation when it is not clear what the most effective attributes will be or when the organization does not have the resources or capability to determine what the customer requirements are.	Strategic delay is useful for the organization with limited resources that wishes to avoid direct competition but does not know until the market is established what the opportunities will be. This is useful for the weak player.
Imitator	The imitator learns from the leaders and followers and reduces costs at every opportunity. This is a good approach for the entity that can afford to wait and see.	The imitator can specialize and offer attributes that are both cost effective and specialized for given market segments.	The copy-cat can specialize and offer products that are both cost effective and focused for given market segments.

Table 2.3 *Factors for formulating new-product strategies*

Perspective	Market	Economic	Technical	Delivery
External	Geographic focus	Best value	Most features	Superior service
	Segmentation	Best price	Best quality	Rapid response
	Differentiation	Most benefits	Compatibility	Superior locations
Internal	Marketing mix	Lowest cost	Best technology	Efficient logistics
	Ease of use	High efficiency	Best reliability	Most effective value networks
	Innovativeness	Effectiveness	Most durable	

It also focuses on how to pre-empt competition and to strengthen the product/market position over the long term. The objective is to build on success to achieve a sustainable competitive advantage that is difficult for others to duplicate.

Strategic formulation includes thinking about how to develop and launch the new-product initiative given the strategic situation and the internal resources and capabilities. This means that different competitors could respond differently to the same opportunity.

Generic strategies are useful constructs from a theoretical point of view, but in the real world NPD strategies require explicit statements about the direction and means to accomplish the desired results. New-product/market strategies have to be specific in scope and provide a clear view of what has to be done and when. They tend to be narrower than general business strategies. For example, using Porter's construct, a company may want to become a low-cost manufacturer to achieve cost leadership. In the new-product situation, the low-cost strategy would have to be more detailed specifying market segments, locations, performance, quality, etc. Strategies focus on market segments and geographical areas and include the marketing, product, production, and financial resources to execute the program.

Table 2.3 is a two-dimensional view of significant factors that may serve as the basis of formulating a strategic position. It is a simple construct containing only some of the most significant points that would be included in formulating new-product strategies. In the real world, the number of potential parameters is usually very large, making its difficult to articulate new-product strategies.

Selecting strategic factors depends on the specific situation. The most powerful approaches are best price, highest value, best quality, unique features/benefits, and best performance. The "best-price" strategy is usually based on a low-cost position. This strategy allows the developer to increase the size of the market quickly and to build market share rapidly. Given that low prices and generally low gross margins reduce the potential for quick profitability, it is difficult for competitors to enter the market without incurring significant losses unless they have a superior cost structure. Competitors are forced to make additional investments to gain a foothold in the market. This tends to limit the number of potential competitors who are willing or able to make such investments into the new-product positions. It also increases their risks of not achieving a viable financial return.

The "highest-value" strategy is similar except that it concentrates on providing the greatest total value relative to the total impact to the customer. Typically there is a performance-to-price relationship for most product families. The highest-value strategy uses the value equation and finds the zone where there is the potential to offer more for less (exceptional value). For example, standardization may contribute to low material and production costs due to higher volumes, higher quality, and more reliability.

The "best-quality" strategy is an obvious and sometimes required approach. It tends to pre-empt customer concerns about new products by providing the best quality possible from the beginning. Potential customers who might be the first users of a new product are wary because there may be undiscovered (hidden) quality defects. Those defects are typically discovered by customers and cured by the manufacturer over time. This strategy identifies the potential sources of difficulties and, using analytical methods, ensures that the potential problems are solved during the development process. The key to the strategy is to build trust in the market place and to provide mechanisms that preclude difficulties.

The "unique-features/benefits" strategy focuses on one or more aspects of the product which competitors don't have or cannot follow. It is a differentiation approach that provides a means to a superior position. The sources of the uniqueness may be internal or external. For example, a superior ordering and product delivery system may deliver the product to the customer at a lower cost and more quickly than traditionally possible. Amazon.com is an example of how to provide better service at lower cost.

Situation analysis for new-product development

Overview

The purpose of the situation analysis is to understand the prevailing business situation in the light of new-product opportunities and challenges, and to determine the most advantageous avenues for new products based on internal strengths. The internal strengths and weaknesses of the organization are examined in the context of the external opportunities, challenges, constraints, and concerns. The situation analysis is periodically conducted as part of the strategic management (planning) process, providing the information for formulating corporate and/or business strategies. It may also be a precursor for selecting the actual new-product strategies. Whether the situation analysis is part of the NPD process or a precursor, it is a critical step in ascertaining the capabilities of the organization as they relate to the opportunities for new products. The identification of a gap between what the organization would like (has) to do and

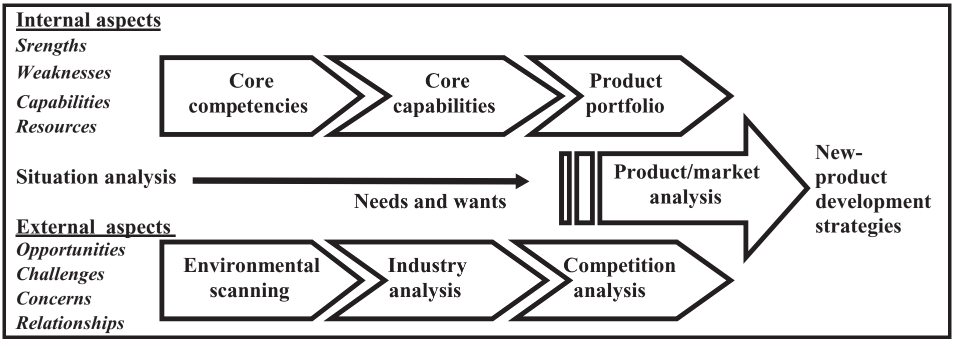


Figure 2.6 Key elements of the situation analysis for new-product development

what it is capable of doing is most crucial. The focus is generally on opportunities and challenges, and how well the organization manages customer needs and expectations, and stakeholder requirements. Figure 2.6 provides a flow chart of the key elements of the situation analysis.

The framework appears as a linear flow but the elements can be worked on in parallel. The internal and external assessments require interaction in order to determine the requisite perspective and insights. Product/market analysis is pivotal and is often performed concurrently with the other elements.

Situation analysis: internal aspects

Core-competencies assessment

Core competencies are the capabilities of the organization which it uniquely possesses and which are difficult for others to emulate. C. K. Prahalad and G. Hamel define core competencies as, “the collective learning in organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies.”[15] Core competencies are often the underpinnings of the organization’s competitive advantage. Prahalad and Hamel suggest that core competencies are relatively rare. An organization may have only a small number of core competencies. A prevailing thought of the 1990s was to focus on core competencies and invest into businesses, technologies, and products supported by the organization’s core competencies.

While core competencies are important for sustaining business success in the short term, the view that core competencies are the pivotal focus for determining NPD opportunities can lead to difficulties in the long term. As the business environment changes over time, new technologies and business practices may undercut the benefits of the core competencies of an organization. For example, the Internet has opened up new avenues for reaching customers and has expedited the communications methods for completing business transactions. Old competencies for handling the flow of information to customers may not be as relevant in the age of E-business. For example, Amazon.com

Table 2.4 *Core competencies related to new-product development*

Category	Area	Examples of leaders
General business	Superior system Financial services	Wal-Mart (management system) General Electric (capital management)
R&D/technology	Innovativeness Knowledge building	Du Pont (radical innovation) Bell Labs (major inventions)
Products	Superior quality management Rapid product development	Motorola (six-sigma quality) 3M (bottom-up development process)
Marketing	Marketing skills and programs Market research Support services	P&G (product improvements) S. C. Johnson & Sons (customer surveys) IBM (integrated product and service support)
Distribution	Rapid delivery Specialized delivery	Fed-Ex (information system) Dell Computer (E-business model)
Production	Low unit cost Unique processes	Nucor Steel (mini-mills) Toyota (lean business management)
Organizational	Superior management Flexibility/agility	Intel (Groves and Moore) Nike (virtual business system)

provides instantaneous access to information about its books and allows customers to purchase products using the Internet. This simpler business model may nullify the core competencies of the large book retailers. Even though such retailers fight back with their own Internet-based operations, they may not enjoy a core competence in the new field.

Table 2.4 provides some examples of core competencies. The information is presented simply to provide an understanding of the notion of core competencies and the examples are presented to provide insights about the categories. It is not inclusive.

Core-capabilities assessment

Organizations usually have specific capabilities and resources that provide the means to be successful with their existing product delivery system and offer advantages that can be exploited in new-product situations. Core capabilities are the fundamental strengths that organizations enjoy, but they are not necessarily unique to the organization.

The purpose of the core-capabilities and resource assessment is to determine whether there are sufficient resources in a specific area, both in quality and quantity, to formulate and implement an NPD program. The most critical broad questions are:

- Does the organization have the knowledge, skills, and capabilities necessary to carry out all facets of an NPD program?
- What are the strengths and weaknesses of the organization's core capabilities?
- What are the resource availabilities and limitations?

Table 2.5 *Core-capabilities assessment (examples of essential areas)*

Area	R&D	Technical	Marketing	Operations	Financial	Management
Phases						
Strategic	Technology	Competence	Market fit	Leveraging	Investments	Leadership
Ideas	Creativity	Brainstorm	Research	Processes	Value	Creativity
Concepts	Uniqueness	Quality	Forecasting	Supply chain	Screens	Linkages
Definition	Know-how	Economics	Programming	Make/buy	Funds	Adaptability
Design	Skills	Engineering	Promotion	Linkages	Estimating	Flexibility
Develop	Knowledge	Prototyping	Channels	Resources	Rewards	Knowledge
Validate	Techniques	Evaluation	Testing	Capacity	Risks	Learning
Launch	Feedback	Feedback	Sales force	Processes	Cash flow	Relationships

- Can the organization enhance existing capabilities and develop the requisite new capabilities to meet the requirements of new-product development?
- Does the organization have the expertise and capabilities to develop and market the potential newproducts?

The assessment is a general overview examining the adequacy of the core capabilities. The analysis includes a strengths and weaknesses assessment of the essential internal factors of the organization. It includes examining the organization's existing product portfolio, its technical and engineering capabilities, its market-related skills and knowledge, its financial resources, and its management capabilities. The assessment examines the following specific questions:

- Does the organization have the people to identify, analyze, and select new-product candidates and then create, design, develop, test, finance, produce, market, distribute, and deliver the new product?
- Does it have the organizational qualities to execute the NPD program successfully?
- Is there a management framework that facilitates new-product development?

Table 2.5 suggests some of the areas that might be analyzed via the NPD phases.

Product-portfolio assessment

The portfolio of existing products typically has a powerful influence on the choices for new products and the criteria used in the selection process. Existing product lines normally fit into a well-defined business or industry structure, providing the means to identify how products and services are related to the organization's mission, objectives, and strategies. The product portfolio includes the core products, related products, services, after-market products and services, and their relationship to new products.

New-product choices often depend on their fit into the existing product portfolio. Many new products are derivatives of existing products and the platforms from which they are derived. As discussed in Chapter 1, the categories of new products vary from simple improvements to existing products to radical innovations. A primary technique

Table 2.6 *Product portfolio from an NPD perspective*

Category	Areas or subsets		
Core products	Consumer	Industrial	Government
Related products	Supporting	Reinforcing	Complementary
Services	Core	Related to products	Supporting
After-market	Parts	Components	Services
New products	Market driven	Technology driven	Externally driven

used by many large corporations is creating a platform and developing derivatives from the base platform. For example, one of the Jaguar S-type models, which is produced by Ford, is built on the Lincoln LS platform.[16] The platform gives the producer the ability to create new models at a significantly lower cost.

The assessment of the product portfolio includes an evaluation of the existing products and a determination of the types of products. The examination includes an assessment of the need for related products that are required for supporting, reinforcing or complementing, and replacing the product lines. It involves determining the need for services, and after-market parts and components as well.

Table 2.6 lists the product-portfolio categories of the products and services as they relate to new-product opportunities.

The creation of product derivatives from existing platforms is a common technique for rapidly and more-economically creating new products. The derivative approach is common within the automobile industry. For example, Ford Motor Company recently announced plans to increase the number of nameplates it develops from a single platform. This will provide many more models from a smaller investment. The platform for the 2003 Volvo XC90 was largely derived from the Volvo 70 sedan base, using a few different suspension components and a wider track than the model 70. The XC90 is an upscale "sport utility wagon" along the lines of the Subaru Outback wagon.[17]

New-product opportunities often fit directly into the product portfolio of the business units and product lines. The new product may be larger or smaller, offer more or fewer features, and be more or less costly. There are infinite variations to the existing product lines which present opportunities for new products.

Table 2.7 offers a simplified assessment template for evaluating the product/market portfolio. It provides a list of the important capabilities from an NPD perspective, while the simplified approach offers a visual understanding of the strengths and weaknesses. The assessment can be made more comprehensive by expanding the use of comments. Indeed, one of the essential tasks for practitioners is to modify the templates provided so that they suit the definitive situation.

Product management is the approach used for managing existing products and services. The NPD questions ask: "How does the new product fit? Is it a replacement for

Table 2.7 *Internal assessment of selected product/market positions (template)*

		Strengths			Weaknesses	
Key areas	Comments	++	+	0	–	––
Product position						
• Favorable product position		☐	☐	☐	☐	☐
• Competitive features and benefits		☐	☐	☐	☐	☐
• Unique attributes		☐	☐	☐	☐	☐
• Patented or sustainable positions		☐	☐	☐	☐	☐
• Performance-to-price position		☐	☐	☐	☐	☐
• Aesthetics/appearance		☐	☐	☐	☐	☐
• Quality factors		☐	☐	☐	☐	☐
• Reliability and service capability		☐	☐	☐	☐	☐
Market						
• Market focus/segments served		☐	☐	☐	☐	☐
• Customer acceptance/loyalty		☐	☐	☐	☐	☐
• Brand-name recognition		☐	☐	☐	☐	☐
• Value proposition		☐	☐	☐	☐	☐
• Advertising and promotion creativity		☐	☐	☐	☐	☐
• Distribution channels/networks		☐	☐	☐	☐	☐
• Market research capability		☐	☐	☐	☐	☐
Engineering/technical						
• R&D capability		☐	☐	☐	☐	☐
• Resources		☐	☐	☐	☐	☐
• Inventiveness (patents)		☐	☐	☐	☐	☐
• Technologies employed		☐	☐	☐	☐	☐
• Skills and knowledge		☐	☐	☐	☐	☐
Manufacturing/procurement						
• Potential for low-cost production		☐	☐	☐	☐	☐
• Supply networks		☐	☐	☐	☐	☐
• Low-cost material availability		☐	☐	☐	☐	☐
• Availability of materials/parts		☐	☐	☐	☐	☐
• Cost/availability of required labor		☐	☐	☐	☐	☐
• Productivity of work force		☐	☐	☐	☐	☐

Note. The elements contained in the table are generic and are taken from a multiplicity of new-product experiences over time. The table is not comprehensive and practitioners and students should contemplate additions and deletions.

an obsolete or declining product? Is it an extension to the product line? What is the purpose of the new product?"

Most products follow a product-life-cycle scheme. After the new product is launched, there is typically a slow introduction stage, as customers become familiar with the features and benefits of the new product. If the product is successful, the product

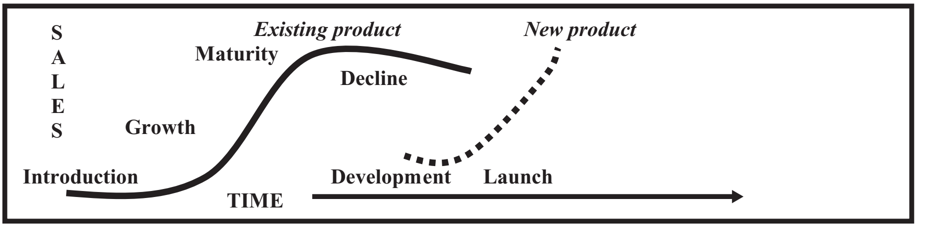


Figure 2.7 Generic product life cycle and the introduction of new products

sales grow substantially as more customers purchase the product and additional market segments are pursued. Eventually the product reaches the saturation point and it achieves its maximum potential. The demand flattens as the product matures and eventually the product's potential starts to decline, as other new products become more attractive to the customer. Technological obsolescence is a primary cause of decline. However, competitive forces and market expectations have significant impacts on the product life cycle and the product's position in the market.

Figure 2.7 depicts the standard product-life-cycle curve. It shows the generalized view.

Situation analysis – external aspects

Environmental scanning of the business environment

The dynamics of changes in the business environment are significant driving forces for product innovation. The NPD process must be framed in the context of the overall economic, social, political, legal, ecological, and technological realities. These external forces set the stage for new-product opportunities.

Changes in the economic conditions and trends provide the context for identifying ideas and concepts for satisfying customer and stakeholder wants and needs. ***Identifying new trends before they become apparent provides a profound mechanism for determining the vulnerabilities for existing products and the opportunities for new products***. The driving forces are often the precursors for identifying significant new-product opportunities. Threats to existing products can be viewed simply as challenges that, if acted upon correctly, represent opportunities for future rewards and new competitive advantages.

Table 2.8 covers the primary environmental business factors along with some of the key considerations for each factor. The elements provide a broad assessment of external factors in terms of conditions and trends and opportunities and threats. The most important perspectives of the assessment are the identification of the essential elements for analysis and a determination of their influences and impacts on the strategies and new products. The questions listed in Table 2.8 are intended to provide a sample of the questions that are typically asked. The actual list of questions is dependent on the

Table 2.8 *Scanning environmental factors – selected questions*

Primary factors	Conditions and trends	Opportunities/threats
Overall factors	What are the most significant driving forces? What are the causes of change? What is overall demand?	What changes are demanded? What is the degree of uncertainty?
Economic Business cycle Growth rate Inflation Stability	What are the general economic factors? Is the economy expanding or contracting? What is the inflation rate? Is there overall stability?	Are the current levels sustainable? What are the opportunities for growth? Are funds available at a low cost? Are there downward pressures?
Technological Technologies Rate of change Life cycles Inventions	What are the most important innovations? What are the rates of technological change? Are there new materials or substitutes? What are the sources of technology?	What technologies create new ways of operating? What are the impacts of the change? Are life cycles declining? What are the new inventions?
Government Public policy Regulations Product liability change Taxation	What are the new public policy issues? What are the regulatory mandates? Are there new product safety requirements? What are most important trends? Are there tax incentives?	What does government policy favor? What are the key areas of concern? What are the critical mandates? What are the major changes? Do the incentives work?
Political Interest groups Stability Legislation Regulation	Who are the most powerful interest groups? How stable is government action? What new laws are anticipated? What are the new rules from agencies?	What are the negative consequences? What are the changes? What are the impacts of new laws? Are there positive effects?
Social Stakeholders Demographics Mobility Attitudes	What are the social norms and trends? How is consumer behavior changing? Are consumers more or less willing to spend? Have people changed their views?	What are the favorable/unfavorable changes in demographics? Are there problems with “trust” in the product category?

industry and markets served and the strategic position of the organization doing the assessment.

The environmental assessment includes an examination of the prevailing conditions and trends and an evaluation of the related opportunities and threats. Under the conditions and trends, the primary external drivers are listed, described, and discussed in a comprehensive analysis. The focus is on significant changes that offer opportunities to develop new products or create threats to existing products that warrant attention.

Description of industry		SIC code	
Principal needs and wants served			
Identify the major competitors			

1. Potential growth rate of the industry

High growth, +20%						Low growth, 0 to 10%

2. Ease of entry of new firms into industry

No barriers						Virtually impossible to enter

3. Intensity of competition among firms

Extremely competitive						Almost no competition

4. Degree of product substitution

No barriers						Difficult to enter

5. Degree of dependency on complementary or supporting products and services

Highly dependent						Virtually independent

6. Degree of bargaining power buyers and customers possess

Buyers dictate terms						Selling firms dictate terms

7. Degree of bargaining power suppliers and vendors possess

Suppliers dictate terms						Purchasers dictate terms

8. Degree of technological sophistication in industry

High level of technology						Very low level of technology

9. Rate of innovation in industry

Rapid innovation						Almost no innovation

10. General level of management capability

Many capable managers						Very few capable managers

Figure 2.8 Industry analysis

The purpose of the assessment from an NPD perspective is to determine the drivers of change and sources for new-product opportunities. For example, a change in the laws and regulations pertaining to the use of materials such as chlorofluorocarbons (CFCs) under the Clean Air Act Amendments of 1990 created the need and opportunity to find replacements for fluids used in refrigeration and fluids used as industrial cleaning agents. This opened the door for a large number of new products. Higher fuel costs might drive the need for more-fuel-efficient automobiles. Toyota's introduction of the Prius, with its hybrid gasoline engine–electric motor, may be "ahead of the curve" for very efficient automobiles, given the growing problems with the availability and cost of gasoline.

Industry analysis

The aim of the industry analysis is to highlight the structural aspects of the industry and to identify the principal needs and wants of the industry and major competitors. Figure 2.8 depicts Michael Porter's model for industry analysis.[18] Porter's model identifies many of the essential elements for analyzing industry conditions.

Porter's construct offers insights about opportunities and challenges, and also the feasibility of selected actions. For example, item 4 examines the possibilities of product substitution. It explores the barriers that may exist to new or different products. The model is most useful for the broader aspects of strategic planning, but it does provide insights for the new product situation as well.

Competition analysis

Successful new-product introduction depends on identifying latent or existing customer needs and wants. This includes examining how competitive products fulfill or fail to meet customer expectations. Competition analysis is very broad. It also examines solutions (new products) that other entities might offer which could satisfy the customer needs.

Competitor analysis is a subset of competition analysis. It pertains to actual competitors rather than the broader view of competition. It starts with identifying the most significant competitors who are likely to be a factor during the design, development, and launch of the new product. The primary purpose of competitor analysis is to discover ways to satisfy customers more effectively than competitors. Simply knowing who the competitors are or might be is only part of the picture. It is critical to have a profile of the competitors and an understanding of their expected actions and responses to any NPD initiative.

The initial step is to identify and describe the key competitors as they relate to the new-product categories the organization plans to explore. Whereas this might include an exhaustive list of competitors who are part of the industry structure and serve some the same markets that the organization serves, typically competitor analysis focuses on the primary competitors or those that are most relevant to the potential new-product endeavors. The following are key questions pertaining to the overall strategic position:

- Who are the most significant current and potential competitors in the selected product/market segments that are the targets for new products?
- What are their visions, missions, objectives, and strategies?
- What are their strengths and weaknesses in relation to the organization's NPD plans?
- What are their core competencies and core capabilities?
- What are their current and anticipated product/market strategies?

Competitor analysis depends upon obtaining accurate data and information about each of the candidates. Such data and information is generally available from secondary sources like business articles, trade journals, investment houses, case studies, etc. Primary sources – such as company reports, Internet web pages, brochures, etc. – are also widely available providing rich sources of information about the competitors. A basic literature search should include an assessment of the past company history and financial record of each competitor and the current profile of the capabilities and positions. The purpose of the research is to determine the competitors' current strategies and, capabilities, and the likely future strategies that would impact upon the NPD programs.

Trade shows and industry conferences are fertile sources of information, especially about pending new-product introductions. New products are often exhibited at industry shows just prior to introduction.

Competitor analysis includes generally the same elements as the assessment of the organization's internal capabilities. In the NPD context, the analysis focuses on products and markets served. It also addresses the core capabilities of competitors as they relate to product delivery and product development. Therefore, the aim of the following questions is to examine the competitors from a new-product perspective and not from an overall strategic one:

- What are the advantages and disadvantages of the products of the key competitors?
- How do they differentiate their products?
- What are the key differences and similarities?
- What are the most likely competitive responses to the new-product opportunities?
- How do they market and distribute their products?
- What are their main methods for marketing communications?
- Who are their strategic partners? What are their relationships?
- What are their supply networks?
- What manufacturing processes do they use?

Competitor analysis can require an enormous amount of time and effort; therefore, it is useful to either prescribe the key elements for analysing competitors or identify a process or mechanism that facilitates ongoing competitor analysis which feeds into a database. Table 2.9 is a simplified competitor analysis template.

Product/market analysis

The purpose of product/market analysis is to identify the primary opportunities that are available to serve customers in new and exciting ways. Markets are generally characterized in traditional ways such as industry structure, government classifications such as the Standard Industry Code (SIC), or from a stock-market perspective. Usually, the federal government, through the Department of Commerce, defines market structure.

The organization often focuses on a set number of market segments based on its capabilities and resources or where it enjoys differentiated advantages. New products and services are typically targeted at one or more market segments. Most NPD programs focus on the existing market segments. This is especially true for improvements to existing products and derivative products of existing technologies. New-to-the-world products and repositioned products may serve either existing or new markets. This introduces the need to examine the characteristics of those new markets, or segments thereof. However, the general methodology is the same, whether it is for existing markets or new markets.

Market definition is a primary consideration requiring thoughtful examination. Definitions that are too broad or too thin can lead to faulty conclusions by distorting the

Table 2.9 *Competitor analysis: strengths, weaknesses, and perspectives (selected)*

Competitor/background information		Key strategies/anticipated strategies		
Main categories	Key elements	Strengths	Weaknesses	Perspectives
Strategic	Vision and mission strategies Capabilities/assets			
Product/market	Product portfolio Markets served New products			
Marketing	Marketing program Customer loyalty Pricing strategy Distribution channels Capabilities/skills			
Production	Processes/capacity Cost position Resources/facilities Skills/knowledge			
Financial	Financial position Cash flow Profitability Returns Investments			
Management	Leadership Innovativeness Aggressiveness Capabilities Risks/rewards			

picture of the true opportunities. The market (segment) can be characterized as the total number of potential users of the products (potential market) and the proportion that are currently using the products (served market). For example, Mercedes is thinking about introducing its “A” model to the United States. The “A” Series is the extremely small sedan designed to overcome vehicle congestion in large cities. Its most significant feature/benefit is its small size which facilitates finding parking spaces. The potential market might be considered as all large cities in the United States. The served market might be the targeted cities that have acute parking problems. Figure 2.9 shows the distinction between the available and the served market.

The market analysis provides a broad assessment of the key market factors and their potential to contribute to a new-product opportunity. This broad assessment gives definition for the determination of what markets and segments to address. The assessment

Table 2.10 *Market-attractiveness assessment: broad assessment of key factors*

Market definition		Customer characteristics	
Category	Elements	Conditions and trends	NPD questions
Market factors	Size Potential Growth rate Seasonality Life cycle Stability	How large is the market? What is its potential size? How fast is it growing? Is demand seasonal? What is the stage of its life cycle? Is demand stable?	What is the demand? What are the needs and wants? What are the major forces influencing demand? What is the demand curve? What is the long-term potential?
Market aspects	Variety Differentiation Legal Regulatory Price sensivity Scale/volume	How is the market segmented? How are products differentiated? What are the legal requirements? What are the regulatory mandates? What are the economic factors? What are the market shares?	Are there wants and needs not being served? Are there regulatory barriers? What are the absolute requirements? What is the available share?
Buyer behavior	Satisfaction Purchasing patterns Pace of change	How is the product purchased? What are the change mechanisms? Who are the buyers of the product?	What determines value? What are the essential benefits sought? What are the required features and functions?

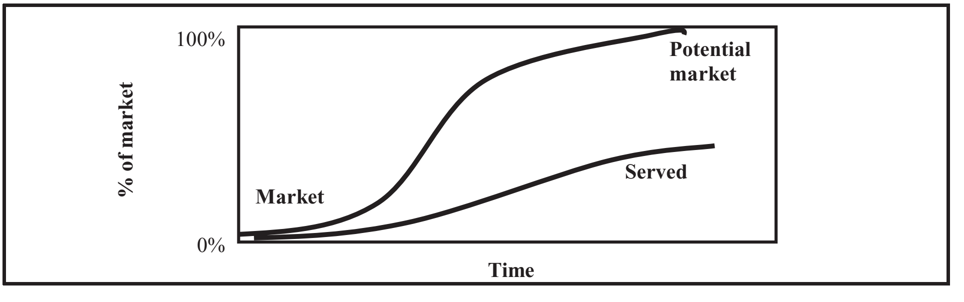


Figure 2.9 Available and served market

examines the prevailing conditions and trends and their importance to NPD plans and opportunities.

Table 2.10 is a template for conducting market assessment. It examines the essential elements – highlighting the conditions and trends – and evaluates the importance of each element.

Table 2.11 *Strategic planning and the strategic alignment process*

Categories	Elements	Significant factors for product innovation (questions)
Values and culture	Core values Beliefs and ethics	What are the core values that will guide the NPD process?
Vision statement	Needs and wants Opportunities Challenges	What are the enablers for new-product development?
Mission statement	Competencies Capabilities Resources	What are the **internal** drivers for new products?
Critical factors for success	People Resources Processes Technology	What are the most critical factors for success?
Goals and objectives	Strategic Business-related Financial New Product	What are the goals and objectives that have to be achieved?
Strategies and policies	Market focus Product position Framework Leadership	What are the directions and expectations for new-product development? What are the guidelines for NPD?

Generally, the market analysis is performed on market segments to determine the viability of a new product. The purpose of the broad market analysis discussed in this section is to identify the potential and requirements of the overall market, this sets the stage for the development of new-product ideas and concepts, and the evaluation of any opportunities.

New-product leadership

The wants and needs of the markets, the external forces, and the capabilities of the organization are key determinants of the opportunities for new products. NPD strategies are primarily dependent on the strategic situation. The strategic-management process provides the link between the external forces and the internal resources and capabilities. There are no opportunities unless there is a means of understanding their potential and mechanisms to take advantage of them.

The strategic alignment provides the logic pertaining to the fit of new-product opportunities with the strategic plans of the organization, its product portfolio, and its organizational capabilities. Table 2.11 provides a template for summarizing the most important elements in the strategic-alignment process.

The strategic alignment establishes the basis for the NPD strategies deployed by the organization. It provides the guidance for the Idea Generation, Concept Development and Selection Program Definition, Design and Development, Validation, and Pre-commercialization and Launch phases.

The value proposition: the overarching business perspective

Challenging the notion of profit maximization

During most of the twentieth century, profit maximization was viewed as the basic objective of business enterprises. While the postulate of profit maximization provided a sense of focus and direction, this internally focused perspective of the purpose of businesses led to a skewed view of the business world. The single-minded notion of maximizing shareholder value became a driving force behind decision making. While profitability is a critical factor in managing successful companies, maximizing profits is difficult to define and achieve. Assuming that the meaning of profitability can be stipulated, there are still the problems associated with determining how to achieve it. For example, profits can be improved in the short term by reducing expenditure pertaining to long-term opportunities or development programs. For instance, corporations can cut R&D expenditures to save money. Reducing or eliminating R&D activities typically improves short-term profits by cutting expenses, but the short-term profit maximization often translates into long-term problems. Such actions often jeopardize the future of the organization.

During the early part of the twentieth century, with the relative slow pace of change, the focus on short-term profitability had only a marginal impact on the long-term fortunes of the company. Management could easily respond to the technological challenges over time because it generally had many years to scale up R&D and NPD programs to stay in touch with the needs of the markets.[19]

There is sufficient evidence to suggest that the focus on profits was a critical strategic factor since it provided the financial resources required for making the appropriate investment at a later time. In reality, cash flow was more important than profits. Maximizing cash flow and profitability are still the underlying business perspectives used by many companies for achieving financial objectives; they remain the prevailing mantra.

The validity of the concepts of profit maximization and maximizing shareholder value should not be considered from an historical view. The question pertains to their importance in twenty-first-century management thinking and the overarching strategic proposition of the business. While profits and shareholder-value maximization intuitively appear to establish the foundation for management thinking about the purpose of a business enterprise, the dominant notions of the last century are increasingly more difficult to determine, measure, and achieve. With the rapidity of change and the reduction of product and technology life cycles, ***the focus on profit maximization is not the only overarching perspective***. Profits and cash flow are critical but they are derived from positive outcomes across the enterprise. The rise of globalization, time compression, and the dynamics of technological innovation have dramatically changed the driving forces that impact upon businesses.[20]

Corporations require innovative products and technologies for meeting the demands of their challenging business environment. They need to out-perform their peers and to achieve extraordinary outcomes. Globalization means that there are very few independent effects or events and that richer levels of knowledge and capability are necessary in order to be successful in an integrated world. Time compression is a profound phenomenon that is shrinking product life cycles. Techniques such as virtual development provide dynamic solutions for enabling collaboration and coordination between all participants regardless of perspective and location. Integrating the technical, market, and management aspects of product development and other related programs can create significant opportunities for improving outcomes. Technological innovations have become commonplace. Many new technologies, such as wireless communication, have rapidly evolved from analog to digital and beyond with dramatic changes each year.

With such profound changes, profit maximization and the related concepts have become impossible to articulate. The rapid growth and decline of such companies as Lucent Technologies and Cisco Systems serve as examples of the difficulties associated with trying to maximize profits, shareholder value, or market capitalization. Achieving such objectives is meaningless unless they are sustained over the longer term. In reality, exploiting opportunities has to be based on a perspective of sustainable development that leads to ongoing success. The theory of profit maximization has become less relevant given the complexity of the twenty-first-century business environment.

The logic of twenty-first-century enterprise thinking

As a management objective, focusing on profit maximization is not just less relevant, ***it could be harmful!*** The logic for such a hypothesis is based on the foundation that profit maximization does not always lead to success. The twentieth-century business enterprise was based on an ethnocentric assumption that if a company served its customers well, it would generate profits and become successful. While the concept of customer satisfaction is still relevant, it is too simplistic to explain the complex requirements of the modern business environment.

The product delivery system of supply networks, value networks, and customers is central for achieving customer satisfaction. Successful product delivery systems generate cash flow, but long-term success is not always guaranteed. Product-liability difficulties or problems with stakeholders can drain future funds, and have an impact on cash flow and valuation. The narrow perspective of customer satisfaction and generating profits does not include all of the constituents facing the business.

The solution is the broader view of managing the business environment. Enterprise-management thinking, as described earlier, provides that higher level of sophistication by incorporating all of the forces impinging on the organization. The power of enterprise thinking is that it is inclusive of all of the essential dimensions in managing and leading an organization.

The overarching objective of the twenty-first-century century company is to maximize the value of the enterprise. In the process of maximizing the value of the enterprise and all of its constituents, successful companies generate cash flow and profits that sustain their future. With sufficient cash flow, the enterprise can reinvest in innovations that provide opportunities and rewards. The linkages with the constituents ensure that approaches are balanced for all involved. The purpose of a business is not just to increase shareholder value; it is to maximize the value derived by everyone and every entity involved. Value maximization transcends the older views of the purpose of a corporation.

Defining the value proposition at the enterprise level

The value proposition is the critical perspective of the enterprise, the strategic management, and the product delivery system. It is the prime metric for innovation. Customers seek value when purchasing products and services. They want the benefits derived from the products or services, and solutions to their needs and wants. Similarly, the constituents of the enterprise seek value and expect a balanced portfolio of positive outcomes. Indeed, they require outcomes that are positive and expect that no entity or individual suffers because of the transactions, products, or processes. It is not a zero-sum game where customers and producers win and stakeholders and society loses. Air pollution from automobiles is an example. For instance, sport utility vehicles (SUVs) are very successful products which delight customers. However, the poor fuel economy and the high emission levels are impacts that society suffers and in the longer term may have an impact upon owners as well.

The value proposition can be expressed in terms of the value equation. ***The value equation examines the benefits of the enterprise in terms of the investments made***. Figure 2.10 depicts the general form of the value equation from an enterprise perspective.

While this equation provides a comprehensive view of the value proposition, it is difficult to map out all of the implications of what is meant by value. The prevailing view of most professionals and managers is the simplified ratio of performance (ΣBenefits) to price (ΣInvestments or ΣCosts). According to this view, value is improved by increasing performance or decreasing price, or both. Performance is improved by enhancing the benefits, both the tangible and intangible ones. Benefits include tangibles and

$$\begin{array}{cccccc} & \underline{\textbf{Leading}} & & \underline{\textbf{Lagging}} & & \underline{\textbf{Limiting}} \end{array}$$

$$\textbf{Value ratio} = \frac{\sum\textbf{Benefits} \rightrightarrows \begin{matrix}\textbf{\textit{Tangible}}\\ \textbf{\textit{Intangible}}\end{matrix} + \sum\textbf{Effects} \rightrightarrows \begin{matrix}\textbf{\textit{Tangible}}\\ \textbf{\textit{Intangible}}\end{matrix} + \sum\textbf{Knowledge}}{\sum\textbf{Investments} \rightrightarrows \begin{matrix}\textbf{\textit{Time}}\\ \textbf{\textit{Money}}\end{matrix} + \sum\textbf{Defects} \rightrightarrows \begin{matrix}\textbf{\textit{Quality}}\\ \textbf{\textit{Liability}}\end{matrix} + \sum\textbf{Burdens}}$$

Figure 2.10 The value equation from an enterprise perspective

intangibles. Tangible benefits are the direct outcomes that meet the needs of customers, stakeholders, or other constituents. Intangible benefits are the psychological effects. For instance, the tangible benefit of an automobile is mobility; the intangible benefit may be the pleasure produced by owning or driving the car. For most of the twentieth century, the general approach was to increase performance at a rate greater than the associated increase in price.

The sum of the benefits represents the leading effects that are sought at the inception and delivery of the product. The leading effects are the primary benefits that are usually apparent and are need based. For example, Michelin's radial tires were a great success because they improved the wearability and reliability of the tires, and reduced the burden of replacing tires as often. The value of the benefits is established by the investment of time and money to acquire the benefits. Money might be viewed as the tangible aspect, since it represents the ability to acquire actual resources, property, or physical goods. Time might be seen as intangible, since it cannot be captured or stored. Time may be just as critical as money in the calculation of the investment, given that time can never be recovered. The leading effects are usually apparent when determining whether projects, programs, or products are worthwhile.

Lagging effects and defects are a little more difficult to ascertain; they are often discovered on a much longer time frame. Lagging effects are considered to be positive and defects are considered as negative. A lagging effect is actually a benefit that was not contemplated or apparent during product development. For example, customers may discover applications for a product that were not originally planned. The odor-absorbing benefits of Arm & Hammer baking soda were not originally articulated by the producer, Dwight and Church. Customers originated the use of the product as a cleaner for refrigerators.

During the early 1980s, it became apparent to producers and customers alike that defects were a significant cost that had a negative impact on value. The total quality management (TQM) revolution was driven by the need to improve the quality and value of products and processes. Six-sigma quality programs were developed in recognition of the fact that defects are very costly to the customer and the producer.

Concurrent with the TQM phenomenon, the personal-computer era marshaled in the concept of improving benefits and reducing price at the same time. Intel led the way

Table 2.12 *Examples of burdens and their implications*

Example	Entities affected	Problems incurred	Implications
Asbestos	Workers suffer various diseases; companies forced into bankruptcy; society consumes resources to solve problems; courts litigate cases; governments have to protect society; interest groups monitor situation.	Health-care system affected with higher rates of specific diseases; resources dedicated to repairing damage; caution has to be used to ensure that a product does not contain asbestos.	Huge programs to replace asbestos in buildings and products; safe handling and disposal requirements; lingering effects of illness; ongoing new discoveries of existing problems; governments ban certain products.
Pollution	Society is damaged by the negative effects; governments has to regulate pollution; companies have to mitigate effects.	Deterioration of the environment and public health; corruption of materials and products; significant costs to clean up past problems.	Degradation of the natural world; depletion of resources; handling of waste; remediation of past problems. Shortened product life cycles due to burdens.

with Moore's law, which suggested that each new generation would be two times more powerful than the previous. Each new ×86 microprocessor provided significant benefits over the older version at the same time as the prices, in real terms, were declining.

With the explosion of environmental problems during the last half of the twentieth century and the actions of stakeholder groups like the Environmental Defense Fund, the World Wildlife Fund, the Sierra Group, and others – along with a myriad of new laws and regulations – another category of negative implications evolved and became an essential part of the equation. The notion of "burdens" became a significant consideration when calculating the value of a product, process, or transaction. This recognition is one of the most crucial determinations in the process of creating true value. Burdens detract benefits from customers, have negative impacts on stakeholders, or make society pay for living with or cleaning up the problems. Burdens are multifaceted and have incalculable effects on the enterprise and its constituents.

Burdens are often not apparent at the inception of the product, process, or business. For example, the effects of the first few kilograms of wastewater dumped into a river are impossible to detect and the consequences are miniscule. However, after many years of pouring a few kilograms per hour of wastewater into the same river, the pollution has a dramatic impact on the environment. The effects of automobile traffic and congestion can be viewed as burdens that make travel more difficult and ambient air quality less acceptable. While burdens may be difficult to determine during the early stage of an endeavor, it is imperative that a continuous evaluation be made to discover and mitigate such impacts. Table 2.12 provides several examples of burdens and their impacts.

A comprehensive list of burdens is impossible given that every product, process, and business creates burdens or has negative impacts on the environment. The aim of this discussion is not to explore the concept completely, but to suggest that reducing or eliminating burdens enhances value.[21]

One of the most important categories is knowledge. Knowledge is a positive resource which expands over time. It makes the products more useful and easier to use. It may also be the limiting factor in the life cycle. As the growth of knowledge about the specific product levels out, the ability to fuel the growth of its potential tends to slow down.

The value proposition of the twenty-first century focuses on maximizing the benefits, reducing the investment, and minimizing the defects and burdens. It provides a strategic perspective and a general measure for decision making.

Value maximization: the goal!

The ultimate solution for products and processes, and the enterprise, is to maximize value. Value maximization is a perfect fit with enterprise thinking. The objective is to achieve positive outcomes for customers, stakeholders, supply networks, and related industries. The goal is to create win–win situations so that everyone maximizes value. While it is impossible to prescribe the actual flow of value to every constituent, a balanced approach means that each receives its expected benefits and that the negative implications are minimal. Each constituent has its own needs. Customers want maximum benefits and the best solution! Stakeholders usually want to avoid the burdens. Suppliers, producers, and customers seek to minimize defects. Related industries want positive relationships and outcomes derived from the value-creation process.

The ultimate goal is to move toward the ideal situation: zero defects and burdens, and a low investment. The ideal situation is easy to understand from an external perspective. Customers obtain superior products at very low costs; stakeholders do not have to be concerned about negative consequences. However, producers might view this approach as a zero-sum game. All of the gains benefit the external dimensions at the expense of profitability.

The answer for producers is to achieve their objectives using value-creation techniques rather than simple marketing approaches, aggressive promotion campaigns, clever pricing strategies, or similar constructs. The price does not have to be zero. The personal computer is a great example. Prices have been declining for 20 years during which time producers have provided more-powerful products. Moreover, it is not just cost or price that is critical. Eliminating defects is the most obvious answer for achieving the ideal situation that provides an improved solution. Everyone's position is enhanced. For example, large companies spend millions of dollars each year on warrantee claims. Imagine what could be accomplished with the money if producers had no defective products! Imagine what customers would think! Eliminating all burdens is an area where enormous savings are possible. Over the last decade, chemical companies spent a higher percentage of their revenues on remediation projects pertaining to environmental impacts from past operations and products than they did on R&D. Again, imagine the potential impact on profitability if such burdens (environmental problems and the like) were eliminated.

Importantly, the question of profitability appears to be the most difficult to address for a win–win scenario. Firstly, if all defects and burdens were eliminated, the costs of the associated corrective actions would not be included in calculating the cost and price of the product. The price to the customer would be reduced without any negative impact on profitability. Imagine the implications! Secondly, as the products and processes are improved using advanced technologies, the costs per unit are typically reduced and volumes increased as savings are passed on to customers and the profit margins are actually improved. Indeed, the profit objective is based on achieving the strategic outcomes and not on maximizing the profit per transaction or per product.

Henry Ford proved this concept with the Model T. The genius of Ford was his recognition that profitability was achieved in the aggregate and not on a per-unit basis. Ford priced the Model T at a level that made it affordable to the mass market. He clearly understood the principles involved in value maximization during the early years of the Model T. However, he failed to realize the importance of innovation over the long term.

The evolution of the microprocessor provides a more recent example of the impact of value maximization from a producer's perspective. With all of Intel's successes during the 1980s with its ×86 devices, Intel did not achieve great financial success until it introduced the Pentium chips of the 1990s.[22] The latter products were not only more powerful they were significantly better value for everyone. Intel's market capitalization improved, its cash flow increased, and its overall reputation expanded dramatically because the products were more cost-effective, profits in total were higher, and customers were more satisfied. During the 1990s, Intel focused on satisfying all objectives, not just profitability. It dramatically reduced the unit cost of its products and at the same time achieved its overall profit and cash-flow objectives.

The goal is to provide exceptional value. The question is not how to make the trade-offs; it is about how to synthesize value-maximization thinking with business strategies and operations so that all objectives are achieved in parallel. It is the concurrent implementation of the internal and external requirements that leads to successful outcomes. Value maximization is a powerful construct that provides a strategic perspective on decision making.

Summary

The EMM is a most powerful framework for evaluating new-product opportunities and managing the NPD process. It provides a means for integrating the external dimensions

Table 2.13 *The relationships between the essential constructs*

Construct	Focus	Drivers	Key internal participants
Product delivery system	Operations	Market factors; economy; customers; suppliers; and competition.	Engineers, operators, production, marketing, and finance professionals.
New-product development	Innovation and integration	Value creation; global business environment; customers and stakeholders; partners; value networks; related industries; and the infrastructure.	NPD team; steering committee; R&D professionals; designers and technical engineers; production; marketing personnel; environmental, health and safety professionals.
Enterprise-management system	Strategic leadership	Business integration; strategic management	Board of directors; executives; senior management; business strategists; analysts.

with the internal dimensions and resources. It is the strategic alignment of all of the dimensions that enhances the probability of achieving success. New-product development is embedded in the context of the strategic-management system and the EMM. It focuses on the whole, not just the parts.

Product innovation transforms the existing product delivery system into a robust, reinvigorated management system for the future. The essence of NPD is to translate vision, mission, objectives, and strategies into successful product/market positions and outcomes that satisfy all constituents. According to Kaplan and Norton, an organization must use a balanced scorecard when making decisions. They suggest that business organizations must balance their objectives by including financial, customer satisfaction, organizational learning, and internal factors.[23] Clearly this applies to the NPD situation from a strategic perspective.

The NPD strategies have changed from simple management approaches based on customers, markets, and competitors to more-elegant constructs, which examine all of the consequences, implications, and impacts of management decisions and provide balanced solutions for all stakeholders and customers. Strategic integration requires objectives, strategies, and decisions based on market, social, economic, ethical, legal, political, technical, and environmental, health and safety considerations.

Linking business strategies and product development is the critical step in improving products and processes for meeting the expectations of the twenty-first century. Business leaders create the means to differentiate their products by offering balanced solutions to stakeholders and customers alike. The overarching business perspective is the creation of value. It is the value proposition which guides the development process and provides the focus for the participants and their constituents.

NPD strategies direct the entire organization toward the needs and expectations of the enterprise. Table 2.13 depicts the relationships.

During the past decade, leading organizations have dramatically changed their relationships with external entities. Customer satisfaction remains critical, but stakeholder attention and responsiveness have become equally important. Changes in societal attitudes, legislation, regulations, political pressures, and the overwhelming flow of information have become significant factors for being successful.

The EMM and its primary dimensions provide a comprehensive framework for developing new products:

- The EMM is a valuable methodology that includes the primary dimensions for assessing, discovering, formulating, implementing, and evaluating NPD opportunities.
- Objectives and priorities are identified through analysis using a systematic means to determine the most important parameters and their relationship to the business environment and the interests of the enterprise.
- NPD strategies are based on the situation and the implications of the business environment, and the opportunities, challenges, constraints, and concerns.
- Situation analysis is framed in an objective view of the EMM, taking the entire business environment into account.
- A systematic framework for assessing and understanding the consequences and impacts of the business environment provides knowledge on how to maximize value.

New-product development aims to identify the proper elements, to select and integrate the appropriate processes, to use effective methods and techniques, and to achieve results on a timely basis. The ability to develop new products faster and better than one's competitors is fundamental for gaining and maintaining a sustainable competitive advantage. In an era of diminishing product life cycles, the capability to conceive, create, design, develop, and launch new products is critical. Success depends on the commitment of management and the enthusiasm of the organization.

New-product development is the integration of five "P's". The "P's" are the **Plan**, the **Process**, the **Program**, the **People**, and the **Product**. The people are the essential elements that lead change through **imagination**, **inspiration**, and **insights**. These elements will be discussed in greater detail in subsequent chapters. Imagination comes from intellectual capital; inspiration comes from engaged, energized, and committed leadership; insights come from research, analysis, and involvement.

Figure 2.11 depicts the linkages between the essential aspects of product innovation and new-product development. The figure provides an overview of what IPD means to practitioners, professionals, and management. It also provides valuable insights for students of new-product development who want to comprehend the fundamental relationships related to product innovation.

IPD begins and ends with the new-product opportunity making transition the from concept to reality. Success is the destination. New **product**[24] success is achieved through a definitive **plan** that flows according to a well-established **process** and is executed by

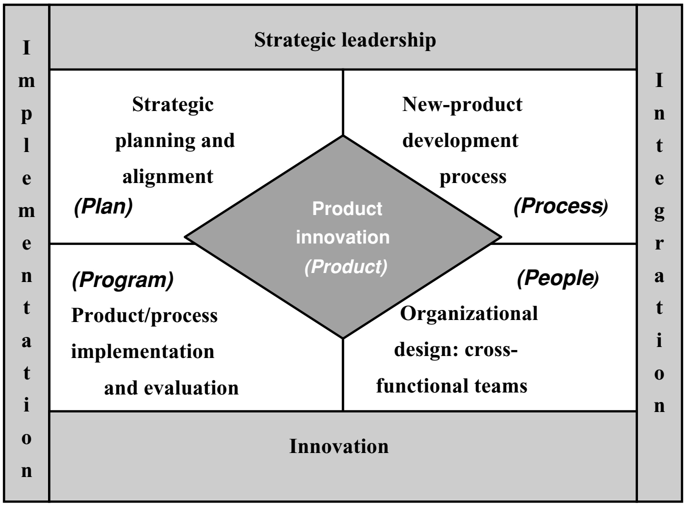


Figure 2.11 The essence of integrated product development

engaged, energized, and enthusiastic **people** having competent leadership who can integrate and implement the **program**. The emphasis on integration and innovation is pivotal because the formulation and implementation of a well-coordinated program depends on the alignment of resources and people to ensure that activities are completed on a timely basis and according to the game plan.[25]

Notes

1. M. H. Meyer and J. M. Utterback, The product family and the dynamics of core capability. *Sloan Management Review*, **34**:3, Spring (1993), 31–34. The article defines and illustrates the concept of core capabilities. The concept of core competencies and core capabilities will be further developed in this chapter.
2. C. K. Prahalad and G. Hamel. The core competence of the corporation. *Harvard Business Review*, May–June (1990), 79–91.
3. M. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance* (New York: Free Press, 1985, pp. 33–61). Porter's value system includes suppliers, the firm's value chain, the distribution channel, and the buyers. His generic value chain depicted inbound logistics, operations, outbound logistics, marketing and sales, and service as the primary internal activities. The primary dimensions of the EMM are essential the same constructs as Porter's model.
4. G. Hamel, *Leading the Revolution* (Boston, MA: Harvard Business School Press, 2000, p. 94). Hamel's model pertains more to the business situation than to the NPD process. However, his construct offers many insights into the essential elements required for analyzing and developing new products. Hamel focuses on customer interface, which is essentially the same perspective used in the EMM model. His value networks include suppliers, partners,

and coalitions. Value networks could be related industries, stakeholders, and the external infrastructure.

5. *Ibid*. p. 78.
6. Based on discussions at Mercedes on June 7, 2001.
7. R. H. Hayes, S. Wheelwright, and K. Clark, *Dynamic Manufacturing* (New York: Free Press, 1988, p. 279). They stated that management's ability to influence a development-project's outcome is high early in the development and declines as decisions are made. It becomes very difficult and costly to change after commitments have been made.
8. This is related to Steven Wheelwright and Kim Clark's book title: *Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality*.
9. Johnson & Johnson's CREDO is its stakeholder strategy. The CREDO is as follows:

We believe our first responsibility is to the doctors and nurses, and patients, to mothers and all others who use our products and services. In meeting their needs everything we do must be of high quality. We must constantly strive to reduce our costs in order to maintain reasonable prices. Customers, orders must be serviced promptly and accurately. Our suppliers and distributors must have an opportunity to make a fair profit.

We are responsible to our employees: the men and women who work with us throughout the world. Everyone must be considered as an individual. We must respect their dignity and recognize their merit. They must have a sense of security in their jobs. Compensation must be fair and adequate, and working conditions clean, orderly, and safe. Employees must feel free to make suggestions and complaints. There must be equal opportunity for employment, development, and advancement for those qualified. We must provide competent management and their actions must be just and ethical.

We are responsible to the communities in which we live and work and to the world community as well.

We must be good citizens – support good works and charities and bear our fair share of taxes. We must encourage civic improvements and better health and education.

We must maintain in good order the property we are privileged to use, protecting the environment and natural resources.

Our final responsibility is to our shareholders. Business must make a sound profit. We must experiment with new ideas. Research must be carried on, innovative programs developed, and mistakes paid for. New equipment must be purchased, new facilities provided, and new products launched. Reserves must be created to provide for adverse times.

When we operate according to these principles, the stockholders should realize a fair return.

10. Hamel, *Leading the Revolution*, p. 19. Hamel's comments on creating new wealth are most appropriate in this context. New-product development focuses are creating new opportunities for all of the participants, especially customers. It typically requires real improvements to the business situation, not just manipulating the elements.
11. R. Kaplan and D. Norton, *The Balanced Scorecard* (Boston, MA: Harvard Business School Press, 1996, p. 9). The balanced scorecard is a perfect fit for new-product development. Most organizations focus on multiple objectives during the NPD process. Financial goals are important, but there are many other reasons why new products have to be developed. Moreover, the realization of financial goals is often the result of satisfying customers and stakeholders.

12. A. Kenneth, *The Concept of Corporate Strategy* (Homewood, IL: Irwin, 1980, pp. 13–18).
13. H. I. Ansoff, *Implanting Strategic Management* (Englewood Cliffs, NJ: Prentice Hall, 1984, p. xv).
14. M. Porter, *Competitive Strategy: Techniques for Analyzing Industries and Competitiors* (New York: Free Press, 1980, pp. 34–46).
15. Prahalad and Hamel, The core competencies, 79–91.
16. K. Naughton, A fresh chauffeur for Ford's luxury cars. *Business Week*, October 11 (1999), p. 142.
17. R. Kranz, Ford to derive more models from 1 platform. *Automotive News*, **76**:5968, January 28 (2002) 18.
18. M. Porter, *Competitive Advantage* (New York: Free Press, 1985, p. 6).
19. The construct is true but there many examples of corporations that failed to catch up after there was compelling information pertaining to the need for change. NCR is a good example. It was slow to make the transition from mechanical devices to electronic devices. Because of its slow pace of change, NCR lost its leadership position in many of the markets that it served.
20. V. K. Narayansan, *Managing Technology and Innovation for Competitive Advantage* (Englewood Cliffs, NJ: Prentice Hall, 2001, p. 43).
21. This topic is very broad. Please read my book on sustainable development: *Sustainable Development: Inventing the Future through Enterprise Management and Technological and Product Innovation* (to be published 2005).
22. Harvard Business School, *Intel Corporation in 1999*, Stanford Business School Case SM-65, 1999.
23. Kaplan and Norton, *The Balanced Scorecard*.
24. The term "product" implies products and services.
25. "Plan" and "game plan" mean essentially the same. The plan is often defined as the document(s) that detail the flow of activities and actions from inception to commercialization and beyond. The game plan is a broad strategy outlining the actions required to achieve the objectives. In the context of this book, it is impossible to prescribe that the plan has to be formally documented or not. More companies are following the game-plan approach using templates to guide practitioners toward the end result.

3 The new-product development process and organizational aspects

Introduction

This chapter describes and assesses the new-product development (NPD) process, including organizational and leadership perspectives. Successful products are generally efficient in resource utilization (easy to produce), have effective product delivery mechanisms (easy to deliver), and are beneficial to customers (easy to use).

The "standardized" NPD process includes idea generation, concept development and selection, program definition, design and development, validation, pre-commercialization, and launch. Rapid product development requires close coordination, cooperation, and linkage between all of the participants, whether virtual or actual.

Innovation is difficult to mandate but it can be fostered. It is derived from dedicated people using creativity to discover new ways of thinking and solving problems. Cross-functional team integration is the organizational structure that allows collaborative behavior in a creative environment. It is essential for ensuring that the contributions of engineering, marketing, manufacturing, finance, and the other functions are in strategic alignment. The emphasis is on teamwork, information sharing, communication, and participation at all levels in the decision process. Creating a spirit of high performance is pivotal for success.

Management encourages, motivates, and inspires the organization to discover innovative solutions that lead to pre-emptive positions and outcomes with significant competitive advantages.

Chapter 3 includes the following topics and learning objectives:

- Understanding the management system (process management) for new-product development.
- Defining the "standardized" NPD process with its "phases and reviews" construct.
- Determining how to measure the potential risks and rewards of NPD programs using selected metrics.
- Describing the six phases of the NPD process.
- Understanding the organizational aspects of product innovation and how cross-functional teams are tailor-made for process management.

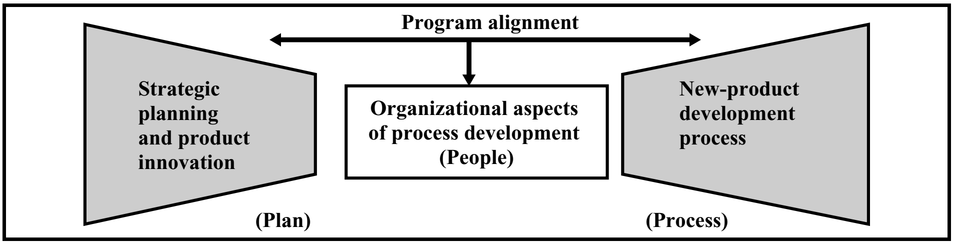


Figure 3.1 Alignment of the plan, the people, the process, and the program

Alignment of the NPD plan, the process, the people, and the program

Strategic alignment of the plan, the process, the people, and the program requires concurrent planning and execution. The NPD process requires a coherent, well-understood architecture used for implementing the process elements. The architecture must be based on an articulated strategy, well-defined principles and guidelines, objectives, and metrics. These guide a set of linked decision making steps that result in a higher probability of achieving a successful new product. The steps are embedded in the rational phases that represent the subsections of the NPD program. At the end of each phase there is a review to ensure that the program is on track, and to affirm that the commitment is still warranted.

"Phases and reviews" are the essential architecture of a systematic NPD process. A well-defined process requires integration of the full cross-functional team including upstream and downstream participants to ensure intensity and speed. Intensity means relating downstream elements to the upstream decision makers so that concurrent development is possible. This minimizes the interactions required to attain an effective solution by packing more activities and outcomes into space and time. Speed is achieved by using parallel processing to reduce the time required to complete the activities. Figure 3.1 shows the linkages between the upstream activities associated with strategic management and the process aspects of NPD.

As part of the strategic-management system, the NPD process incorporates the essential elements for designing and developing the product, and executing the program. The program is the support structure for ensuring that every activity is accomplished in a timely manner. The establishment of guidelines is the starting point for mapping out the process. The guidelines for process development provide a means for establishing the proper balance between the strategic and operational aspects. They also provide criteria for decision making, an essential part of the NPD process. Table 3.1 lists the most important guiding principles and their applications.

Table 3.1 *Guiding principles for new-product development*

Principles	Applications	Examples
Philosophy	The guiding philosophy for NPD focuses on the organization's values, culture, character, and aims. The philosophy provides direction and guidance. It focuses on building quality and value into the products and processes. It is the overarching guiding principle.	Motorola's philosophy focuses on six-sigma quality and exceptional customer value. Wal-Mart's philosophy relates to selling at low prices and providing exceptional value.
Value-creation proposition	The most important requirement for a successful NPD program is the creation of value for all participants. The NPD program has to ensure that each participant is rewarded commensurate with the contributions of internal participants and the expectations of external participants.	When initially introduced, the Lexus provided customers with more value for money. Lexus provided more features and benefits at its price point than its competitors.
Market and customer input	Decisions are based on inputs from potential customers concerning their needs and wants. Activities should be directly or indirectly linked to customers. Knowing the requirements of customers and preparing specifications in terms of their inputs are imperative for achieving success. Maintaining constant contact with the potential markets and customers for testing and validating decisions is critical for improving the probability of success.	Boeing had several of its most crucial customers participate in the development of the Boeing 777. People from customer organizations offer insights about the design that were not apparent even to the best design experts. Customers have latent needs that are not readily apparent.
Stakeholder input	Stakeholder satisfaction is just as critical as customer satisfaction. Stakeholders can be strong proponents or opponents of the new-product. An understanding of stakeholder requirements helps set the stage for defining requirements and developing product specifications that meet societal needs as well as customer needs.	Proctor & Gamble uses "Anticipatory Issues Management" as a mechanism for determining stakeholder issues during the NPD process and incorporates the input into the design.[1]
Parallel activities	The essence of NPD and cross-functional integration is to execute as many activities on a parallel basis as possible. It means working on the technical, market, economic, financial, and production aspects concurrently from inception to completion.	Ford was one of the first companies in the United States to use IPD and cross-functional teams. Parallel processing is essential for saving time and money.[2]
Flexibility	A process maps out the expected requirements. However, events and circumstances may preclude the implementation of certain activities or may require adjustment of the program. Flexibility has to be built into the process to accommodate such changes.	The phases and reviews are intended to provide the mechanisms to make adjustments. Nike is an example of a company with a very flexible structure.
Critical mass	NPD requires sufficient resources in each of the essential disciplines and areas to ensure that the activities can be carried out to completion. Thoroughness and speed are both important. There must be adequate resources at every level and phase for proper implementation.	The Apollo Program was one of the largest development programs in history. The program required a critical mass of support functions in addition to the primary participants.

An overview of the NPD process

The NPD process must be aligned with the management system and fit into the organizational structure. The NPD alignment typically includes the following standard elements: (1) policy and management commitment; (2) planning; (3) implementation; (4) measurement and evaluation; and (5) review and continuous improvement.[3] Senior management establishes the policies, procedures, and practices that provide the direction, guidelines, and standards for the organization and the NPD process. Management guides the organization through its principles, values, objectives, and strategies; setting the stage for planning and implementation. **Policies** determine the way that activities are to be carried out and provide directions for decision making; policies also establish the targets and the criteria for evaluation. **Procedures** and **practices** prescribe the routines for the normal flow of activities and provide guidelines for handling the basic elements of the process. While the use of formal procedures varies considerably depending on the management philosophy and the need for flexibility, most organizations have well-defined practices that facilitate interaction between people and the flow of work. Stringent procedures are often used as a means for mitigating high risks. The development of inherently risky products like pharmaceutical products, jet engines, or automobiles usually requires more formality and control than the development of less-risky products such as tissues and pencils.

The planning process identifies and delineates the upstream and downstream activities indicating what has to be done, when, by whom, and how. It includes defining the scope of the NPD program, assessing the opportunities, establishing the targets, and determining the criteria and metrics. It also includes establishing provisions for modifying the basic procedures and practices to accommodate changes in the business environment.

Implementation involves the execution of the NPD process and program. The details of the implementation of NPD are spelt out in the subsequent chapters of this book.

Measurement reviews and program evaluations are necessary parts of the NPD process for keeping on track and maintaining control. They assure management commitment and provide a formal decision-making process. As information is gathered and decisions are made they must be measured with respect to the criteria and metrics of the program to determine their consequences and validity. For example, concepts are tested using customer input for assessing the potential of the new-product opportunity; Chrysler used a computer-generated view of the changes to the 1998 Dodge Intrepid to get customer feedback. Measurements and evaluations proceed concurrently with the implementation of the NPD process. Ideally every decision, every transaction, and every outcome is validated in the real world to improve the prospects of success.

Management reviews are the critical steps in the NPD process. In many organizations, management employs a periodic-review function rather than a continuous one. In certain cases, management reviews occur at critical decision points or when a significant commitment of resources is required. The purpose of the review steps is to determine progress; to make profound decisions; and to determine the need for changes to policies, criteria, targets, objectives, processes, or outcomes.

Management leadership and commitment (Level 0)

Senior management provides the leadership and dedication that drive the NPD process. Senior management is instrumental in determining the course of actions and allocating people and resources.

The strategic context defines management's responsibilities and commitment. It translates the strategic objectives into an operational mode so that people know what is expected and how to implement the NPD process consistent with the overall direction of the organization. The strategic context related to new-product development is identified as "Level 0" or "Phase 0" because in most organizations it is usually well established and positioned prior to the start of NPD activities. It provides the mechanisms for formulating strategies, controlling processes and activities, and achieving outcomes through the careful execution and review of programs. Strategic management plays an active role during the execution of new-product development by reviewing and approving the results achieved.

Figure 3.2 shows the relationship between the strategic level and the process-management domain. The strategic level provides the resources and plans, and the process level focuses on development and results. Management has the ultimate responsibility to provide strategic leadership through the articulation of the vision, values, principles, philosophies, metrics, decision making criteria, and control mechanisms. Moreover, management allocates the resources; assigns the people; determines the plans, methods, and practices; and provides the information system for the analysis of the data.

Level 0 is pivotal in setting the stage for the NPD process and the implementation of an NPD program. It is also central for ensuring that there is an adequate review of each phase and sufficient monitoring of the NPD process.

Leadership encompasses the intangible aspects of directing the efforts of the organization toward achieving meaningful objectives and exceptional results while providing the means and incentives to encourage individuals, teams and the organization to exceed expectations.

Implementing the NPD program (Levels 1 and 2)

Process management is the heart and soul of product innovation. Since the majority of the new-product opportunities and most NPD programs are related to existing

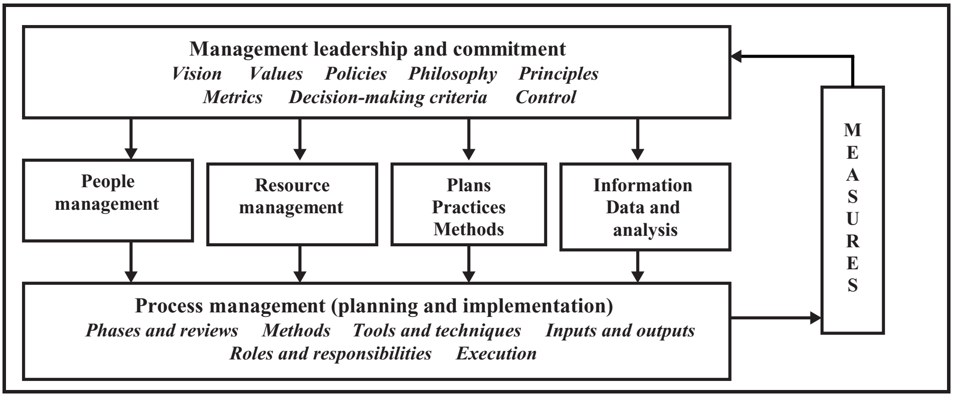


Figure 3.2 Management leadership and commitment model for new-product development – Level 0

products (improvements, repositioning, or derivatives) and are market-driven, process-management methods are vital for managing the flow of required activities. In other words, there is a defined route to be traveled in a systematic manner. Process management ensures that all of the essential requirements are considered and properly implemented using pathways based on similar requirements from program to program. It relies on continuous improvement of the products and the NPD process itself.

For example, Ford Motor Company realized in the early 1980s that it had to make dramatic changes to the way it developed new products. In developing the Ford Taurus, the company changed its product development methodology to a team-based approach using concurrent design philosophies.[4] The Taurus was a great success and Ford's product design and development process was improved; it was also used successfully for other models as well as being emulated by other companies. It was the introduction of new products like the Taurus and the Explorer which transformed Ford into a powerhouse company during the 1990s. Most importantly, Ford created an organization having a core competence in developing new products with high quality and superior performance.

Successful process management requires a close fit between the internal elements of the organization and the external drivers. This is particularly true for the integration of the needs and wants of potential customers with the design characteristics developed by the technical people for determining product specifications.

Process management is the concurrent application of the four essential inputs (people, resources, plans and methods, and information and data analysis) and their conversion into valuable outputs that meet the requirements of the NPD program and the key drivers. It is the basic transformation of all of the resources, capabilities, and information and data – from inception to completion – into value-adding outcomes. This includes the discovery and elimination of problems and barriers to success.

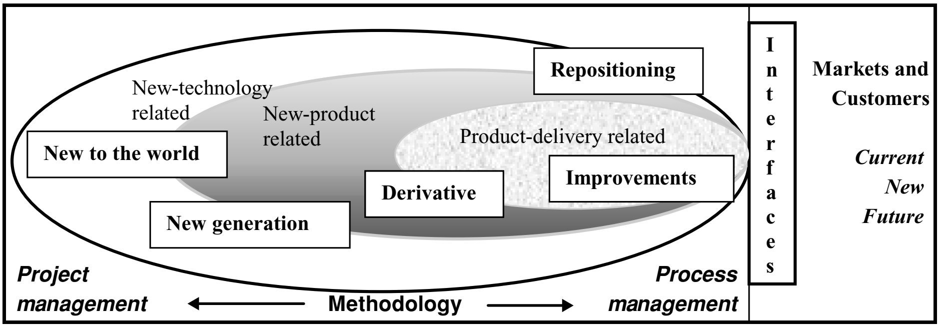


Figure 3.3 The realms of process management and project management

The NPD process includes the development of methods for building the product, and designing and building the hardware associated with the physical requirements of producing the product and its parts and components. Process management focuses on the flow of activities which enssures the right elements are included and implemented correctly. Success is accomplished by building quality and value into processes. Process management, especially from an internal perspective, concentrates on ensuring that all processes satisfy potential customers, meet stakeholders' expectations, and empower employees to succeed. A principal objective during implementation is the reduction of downstream problems by involving downstream participants in upstream activities.

Figure 3.3 provides a sense of the domains of process and project management.[5]

Process management is the essential management methodology used throughout this book. Project-management techniques are often more appropriate for new-to-the-world NPD programs where the path to success is not well established and an ad-hoc approach is required simply because the steps in the process are not understood or defined. This is more likely when the NPD situation includes new-to-the-world technology that is undergoing changes as the organization tries to find applications for the technology through new products. It also is the prevalent methodology for new ventures and entrepreneurial companies. The Project Management Institute's *A Guide to the Project Management Body of Knowledge* is an excellent source on project-management techniques for new-product development.[6]

The "standardized" NPD process

NPD process levels

Integrated product development (IPD) is a continuous process requiring the concurrent contributions of the entire organization. In reality there are only a few processes that are truly continuous. For example, integrated pulp-and-paper mills operate continuously 24 hours a day, 7 days a week, producing a steady stream of paper products.

Automobile assembly plants are machine-paced operations that have a constant flow of products being produced. Even in such cases, there are points where the processes are checked to make sure that they are still producing high-quality product. Most checks are accomplished within the process itself, minimizing downtime. The overall objective is to achieve high quality and performance, and maintain full production at the same time. The same philosophy is used for developing new products. The objective is to create the desired new product and get it to the market as quickly as possible, thereby minimizing downtime.

An NPD process with “phases and reviews” solves the complex problem of integrating activities and resources. Phases and reviews convey the thought that the process is continuous with well-defined patterns of activities. Such activities are systematic and synchronized and have non-disruptive review steps within the phase or at its end to determine the subsequent course of action.

Robert Cooper, noted author on new-product development, uses “stages and gates” to convey the subsections and review steps of the NPD process. The reasoning behind “stages and gates” and “phases and reviews” are similar, yet there are profound differences. Stages infer distinct steps that start and end. Indeed, gates suggest a stopping point for reflection and decision making. They connote the aspect that the process is discontinuous. Stages and gates also suggest that the decision makers are not the primary participants on the team. Management periodically intervenes to ascertain progress and approve the outcomes. This perspective may reflect what many practitioners actually follow during product innovation. Therefore, what is the appropriate application for stages and gates? Stages and gates are more appropriate for new-to-the-world products or technology development programs, especially if there are high risks involved.[7] For simpler NPD programs, the application of phases and reviews is more in line with the notion of a continuous process.

The purpose of phases is to subdivide the process into identifiable sections that can be clearly viewed in terms of the elements (requirements) and the attainment of the predetermined results. The reviews represent critical decision points on whether to proceed. For the standardized approach, the participants make a recommendation that management affirms or reverses. The review is also used to ensure that everyone has an appropriate level of confidence in the progress and that the ultimate NPD objectives are achievable.

The NPD process builds on the outcomes of previous phases and expands the results into a higher level of meaning and detail. As the process unfolds, the knowledge and information gleaned helps to reduce uncertainties. For example, during each phase, customer expectations are analyzed and tested to improve upon the knowledge gained from the previous phase. Phases are intended to be flexible enough to accommodate changing requirements or situations. In many cases, the activities of a downstream phase may start before all of the tasks of an upstream phase are completed. For example, an automobile company may start customer testing of the product before all of the design

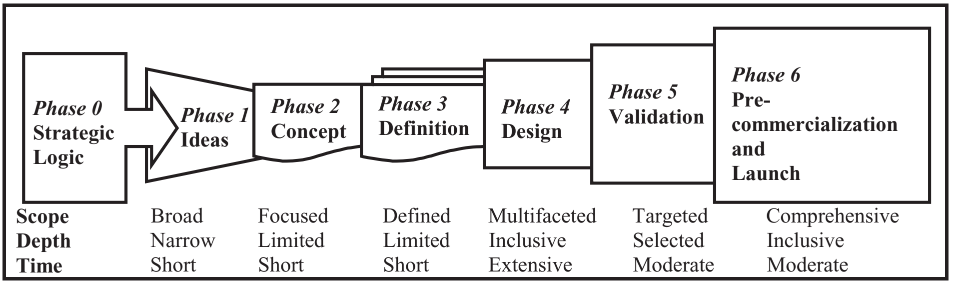


Figure 3.4 Visual depiction of the linkages from phase to phase

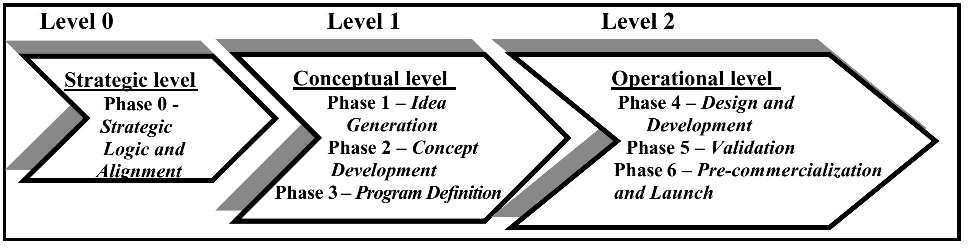


Figure 3.5 New-product process levels

aspects have been completed. If the final design issues are related more to production requirements than to product performance, moving to the next phase to save time may be appropriate. Moreover, information realized for the downstream activities may help to consolidate key decisions, especially design questions.

Figure 3.4 shows the linkages between the phases and provides a sense of the scope of the activities, the depth of the analyses, and the relative time scale. It suggests that the input from the upstream phase becomes the foundation for the downstream phase. It also conveys the sense of a continuum. The output of an upstream phase is seamlessly embodied within the body of the next phase and the process continues without interruption.

The NPD process can be divided into three levels for a better understanding of the linkages between the phases. The strategic logic phase is called “Level 0,” reflecting the input from the precursor activities of the strategic-management process. The initial level, Level 1, is the conceptual level, which identifies and defines the NPD program. Level 2 is the operational level, which includes the full scope of the design and development of every facet of the NPD program.

Figure 3.5 indicates the levels and the phases contained in the NPD process. The strategic level includes only Phase 0. It consists of all of the precursors required for formulating and implementing strategies. The analyses and determinations contained within the strategic level are typically done whether or not an NPD program is initiated. The expenditures for the strategic logic phase are usually not attributed to the NPD process, since it precedes the NPD process and it would be done anyway. It provides the information, data, and strategic direction for the conceptual level.

The conceptual level includes the idea generation for new-product opportunities; the analysis of the potential of each candidate; the generation, development and selection of concepts; and the definition and planning of the NPD program. The conceptual level is an analytical study of the potential candidates (opportunities) for new products; an evaluation of their suitability, feasibility and desirability; and the development and selection of concept(s) for further development. The conceptual level is typically a low-cost, low-risk, and modest involvement. Level 1 does consume time and effort, but the work can be easily redirected or in many cases restarted if significant problems or barriers arise that make the viability of the program uncertain or overly risky. The basic approach is to find viable new-product opportunities and define their potential, or to identify the unsuitable prospects quickly and eliminate them early in the NPD process.

The operational level includes the design and development of the product, the verification of the decisions, and the development and implementation of the means to bring it to the market. This level includes the engineering work, the design and production processes, the development and execution of the marketing program, the building or leveraging of the production capabilities, and the financial analysis to support decision making and the NPD program. The operational level consumes the most time and effort and includes a comprehensive analysis of every facet of the new product. It typically represents the majority of the investment required to launch a new product. It also represents a significant portion of the risk associated with the development of a new product. Generally, much of the investment for specific areas included under the operational level has little value if the NPD program is terminated or if it is not successful. For example, the marketing program usually requires high up-front expenditures for product-specific items such as advertising copy and layout; this expenditure, once committed, cannot be redeemed if the product fails.

For each phase, there are requirements that have to be completed prior to proceeding to the next phase. Depending on the actual program, there are several points throughout the NPD process when management makes decisions to continue or not. Those decisions are made based on the risks associated with the program, the expected rewards over time, the prospects for success, the required investments, and the ability to execute the program with a favorable result. There may be other criteria as well.

The six phases of the NPD process

The front-end phases of the NPD process

The front-end of the NPD process is the conceptual level used to determine what opportunities are suitable for development. It provides a definition of the requirements for the product and program. The front-end process typically includes generating ideas, scanning the new-product opportunities, developing concepts and selecting candidates, and defining the program.

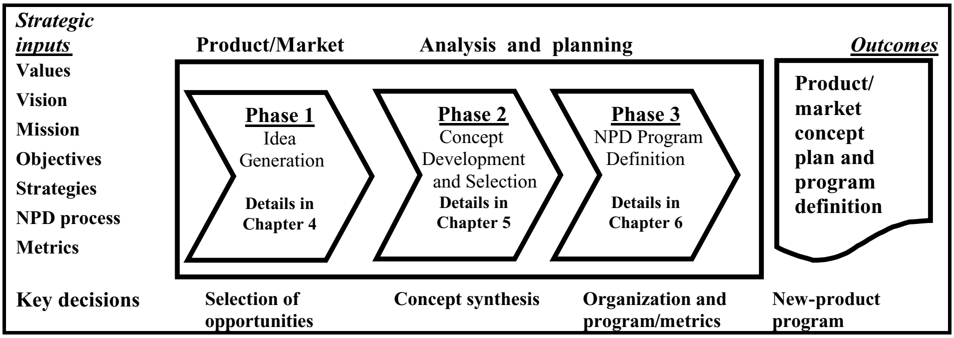
According to Karl Ulrich and Steven Eppinger, authors of *Product Design and Development*, the front-end process is the concept-development phase. They characterize the concept-development phase as identifying customer needs, establishing target specifications, analyzing competitive products, concept generation, concept selection, refinement of specifications, economic analysis, and project planning.[8] A. Khurana and S. Rosenthal define the front-end more broadly as the phases that include the foundation elements of strategy and structure, the pre-phase of market identification and technology analysis, phase 0 of concept definition, and phase 1 of product definition and project planning.[9]

While it may not be critical to separate the front-end phases into the strategic level and the conceptual level, as defined in the "standardized" model used in this book, the distinction between the strategic- and conceptual-development aspects is important for management and practitioners. The strategic level determines the scope of involvement for the entire enterprise- or strategic-management system; therefore, it is of a higher level of importance. The conceptual level or the front-end phases involve preparing the fundamental analysis of the opportunities, defining the new-product candidates, and determining the scope of the NPD programs; thus, the elements of those phases are specific to the NPD process for analyzing opportunities and selecting candidates.

In a study of 11 companies, Khurana and Rosenthal concluded that most of the companies had an unnecessarily ill-defined (fuzzy) front-end. They suggested that product-portfolio planning should be used to map new-product initiatives across the business to balance the selection of candidates in terms of risk to reward, time horizon, and the maturity level of the markets.[10] Regardless of the NPD process used, it is essential that it contains all of the necessary elements and maps out the process flow.[11]

A well-planned and fully executed front-end is critical for success. Generally, the front-end phases of Idea Generation, Concept Development and Selection, and NPD Program Definition are analysis oriented, requiring time and effort, but relatively low commitment of the organization's resources.

Figure 3.6 depicts the key elements of the front-end and their relationship to the NPD process. The purpose of the framework is to identify the essential elements and arrange them into an explicit framework that practitioners can follow from inception to completion. The generic flow can be modified to suit the specific needs of any program or organization. For instance, in certain high-risk NPD programs, definition may be the initial phase of the program so that the details of the requirements and the organizational aspects can be established at the beginning. Moreover, there are NPD frameworks that combine idea generation and concept development into a single phase. There are many variations.



Phases	**Idea generation**	**Concept development**	**NPD program definition**	
External dimension				
Market	Market size assessment	Market segmentation	Program definition	Market analysis
Stakeholders	Laws and regulations Key issues	Drivers identification	Stakeholder analysis	Stakeholder analysis
Supply networks	Supply network assessment	Logistics concept Sourcing analysis	Make or buy assessment	Supply networks analysis
Competition	Competitor assessment	Benchmarking competitors	Competition analysis	Competition analysis
Infrastructure	Assessment of requirements/limits	Identification of linkages	Supporting structures	Infrastructure analysis
Related industries	Related market assessment	Potential partner relationships	Supporting alliances	Potential partner relationships
Internal dimension				
Product/market	Product/technology assessment	Product/market attributes	Product architecture	Product plan
Marketing	Market research (wants/needs)	Customer needs and requirements	Target-product specifications	Marketing plan
Production	Resource assessment	Production resources Leveraging suppliers	Production planning Planning	Production/ logistics plan
Financial	Objectives restated Value analysis	Unit-cost estimate Investment	Financial targets	Financial plan
Organization	Core-team selection Leadership	Organizational design	Program management	Management plan
Evaluation methods and metrics				
Market	Market assessment	Market analysis	Concept testing	Market screens
Technical	Feasibility	Performance	Success factors	Technical screens
Economic	Viability	Unit cost	Economic analysis	Economic screens
Risk	Overall risk analysis	Investment risk	Risk to reward	Risk screens
Time	Feasibility	Time to market	Program duration	Strategic screens

Figure 3.6 The front-end phases of the NPD process (the conceptual level of new-product development – Level 1)

Design and Development, Validation, Pre-commercialization and Launch phases

The Design and Development Phase includes the initial design of the product, the testing and prototyping of the preliminary design, and the selection and finalization of the product design. It includes methods for including customer and stakeholder contributions.

The design starts with a careful analysis of what the customers requires in terms of features, functions, and benefits of the product. The design of a product is produced by the concurrent activities of all of the participants, including customers and stakeholders, who determine the specification of the product.

E. Raymond Corey – the Malcolm P. McNair Professor of Marketing, Emeritus, at Harvard Business School – stated that market selection and product planning are essential elements of successful marketing strategy. His concepts concerning the relationships between markets and products are extremely valuable in setting the stage for new-product design. The following are Corey's key concepts:[12]

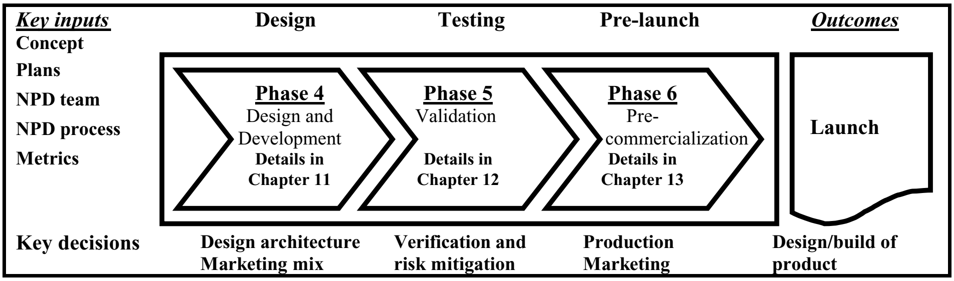
- A market segment may be defined as a set of potential customers that are alike in the way they perceive the product, value it, and use it, and in their patterns of buyer behavior.
- Market selection and product-planning choices must often be made together.
- The art of pricing is to have the price of the product equate to the value of the product to the customer.

Corey's insights shed light on the complexity of product design. The challenge is to design and develop a product based on the needs and wants of the market segment that it is targeted to serve. A well-planned and well-executed product design and development is critical for success. Generally, the Design and Development Phase requires investing in engineering the technical aspects of the design and then prototyping it. Designing and testing of the product often require a substantial amount of money and time. Design and development includes the marketing, productions, and financial implications.

The Validation Phase is intended to verify the design decisions. It ensures that the product functions according to its specifications and delivers on the expectations. Verification of the product and program is the desired outcome. It is a somewhat open-ended process. If testing confirms that the design meets specifications, the program proceeds on track. If difficulties arise, it may take time and money to resolve the problems.

The Pre-commercialization Phase covers the detail development and scale-up of the production processes and marketing campaign. Once the product design has been finalized and the product and marketing approaches are demonstrated, the process moves into the final phase prior to launch. The production resources and operations are established using existing or new resources. The general approach is to leverage resources whenever possible.

Figure 3.7 depicts the key elements of the operational level (Phases 4 to 6). It provides an overview of the elements and their relationship to the NPD process. The purpose of the figure is to put the requirements into a flow perspective using the basic dimensions in the text. It facilitates the process aspects of NPD. The generic flow can be modified to suit the specific needs of any NPD program.



Phases	Design and development	Validation	Pre-commercialization	Launch

External dimension				
Market	Customer-needs analysis	Market tests, alpha/beta	Market-segment testing	Life-cycle management
Stakeholders	Life-cycle assessment	Stakeholder evaluation	Stakeholder implementation	Stakeholder response
Supply networks	Supply-networks development	Supply-networks evaluation	Supply-networks implementation	Supply-networks involvement
Competition	Competition determination	Competition evaluation	Competition-plan implementation	Competitive response
Infrastructure	Infrastructure development	Support-structure evaluation	Support-structure implementation	Support-structure response
Related industries	Partnership/ally development	Partnership/ally evaluation	Partnership implementation	Related-industries response

Internal dimension				
Product	Product architecture	Prototype/pilot tests	Product-program preparation	Product management
Marketing	Marketing-program design	Marketing-mix testing	Marketing-program preparation	Marketing-program launch
Production	Production development	Manufacturing-pilot testing	Production-program preparation	Production/logistics program
Financial	Financial-program development	Financial-analysis sensitivity	Financial-program preparation	Financial program
Organization	Concurrent engineering/design	Organizational evaluation	Linkage with product delivery	Transition to product delivery

Evaluation methods and metrics				
Market	Beta testing	Market testing	Test market	Market performance
Technical	Product architecture	Prototyping	Production capability	Product performance
Economic	Development cost	Value analysis	Unit-cost control	Value proposition
Risk	Product risks	Market risks	Business risks	Long-term risks
Time	Time to market	Uncertainties	Thoroughness vs. time	Product life cycle

Figure 3.7 Design and Development Phase, Validation Phase, and Pre-commercialization Phase (the operational phases – Level 2)

Comments about the phases of the NPD process

The number of phases of an NPD process varies considerably from company to company. It generally depends on the complexity of the program. New-to-the-world products or those using new-to-the-world technology require more-sophisticated processes. If the risks are high, a more-deliberate approach must be taken to ensure that all of the key elements have been covered. If the NPD program varies considerably from the previous programs, then the organization should decide whether to use a process-management or project-management approach. The basic premise of process management is that there is an experience base to fall back upon.[13] The examples at the end of the chapter provide alternatives to the general theme.

The standardized NPD process relies on existing capabilities and knowledge and leverages them whenever possible. Since most NPD programs are related to existing products, the typical NPD process incorporates lessons learned from previous experiences allowing the participants to reduce the risk and uncertainty of the process and the program.

The precepts of the management system are critical for controlling outcomes. The process requires technical, market, economic, and financial measures and controls to ensure that results are obtained consistent with the requirements established at the beginning of the process. Exactly how those measures or metrics are determined depends on the specifics of the program. For the most part, they are prescribed during the Program Definition Phase. In some cases, they are mandated at the strategic level.

Management review

The purpose of a steering committee

Senior management has the ultimate responsible for establishing and implementing NPD processes and programs in most corporations. In large organizations, senior management often assigns the responsibility for reviewing NPD programs to a "steering committee" or a similar construct.[14] The steering committee usually conducts the management reviews within the scope of the NPD process; ensures compliance with the company's policies, procedures, and objectives; and determines what outcomes are to be achieved. The steering committee is also responsible for planning and implementing the NPD programs and approving the decisions of the program leaders and participants. It selects and provides support to the NPD leaders and the NPD teams by defining the responsibilities and authority of each participant, and the relationships between participants and within the NPD process.

The operational purpose of a steering committee is to review the progress of the company's programs, reduce risks and liabilities, decrease the costs associated with managing the NPD process, promote continuous improvements of the process, and position the company to take advantage of its new-product opportunities. It also periodically reviews the performance of the NPD process to determine its suitability, adequacy, and effectiveness. It addresses the need for changes to policies, objectives, and content. The steering committee is often the organizational entity that makes the approval/disapproval decisions at the end of each phase of individual NPD programs. In many organizations, the steering committee affirms the decision of the NPD team

Table 3.2 *Primary roles and responsibilities of the steering committee*

Management	Primary responsibilities
Senior management	Corporate vision; mission; values; goals and objectives; philosophies; policies; procedures and corporate practices; strategic direction; strategies; product positions; targets
NPD steering committee	Guiding principles; NPD framework, and process plans and programs; new-product objectives and targets, measures and metrics; screening criteria; risk management; managing constraints and limitations; management review; communications; corrective and preventive action; continuous improvement

and leadership, rather than actually making the decision. The theory is that the team and its leadership should have the best understanding of the NPD situation and its views should be followed in the majority of cases. It also empowers the practitioners to act as entrepreneurs running their own company or operations. The following are the typical responsibilities of the steering committee:

- Provide overall management of all NPD programs, processes, activities, and practices.
- Evaluate the performance of all of the programs and NPD activities.
- Develop and implement the necessary reviews of the programs, processes, and people.
- Ensure that necessary communication, training, and education are implemented.
- Make revisions and changes for continuous improvements.
- Communicate the results to senior management.

The steering committee ensures management commitment and is also the catalyst between the organizational departments and the NPD team(s). It provides guidance, information, motivation, and inspiration. It is a link to external customers and stakeholders and ensures that there are communication channels with the various external entities. It drives the ownership, responsibility, and execution of the NPD process throughout the organization. It clarifies the priorities of the corporate-wide NPD programs. Table 3.2 lists the primary roles and responsibilities of the steering committee.

The steering committee is concerned with the prevention, detection, and correction of NPD problems that could affect the overall performance and reputation of the company, and the success of the NPD programs. Its emphasis is on improving performance through the establishment of plans and programs, and the review of results to verify the accomplishment of the intended outcomes. Revisions to policies, objectives or targets, and procedures may be required due to changes in the expectations of customers and stakeholders, changing business conditions and trends, technological advancements, and the outcomes of audits.

The steering committee decides what actions, if any, the organization needs to make to ensure that all commitments are met. It examines the root causes of problems and evaluates the recommended corrective-action plans. The concept of continuous

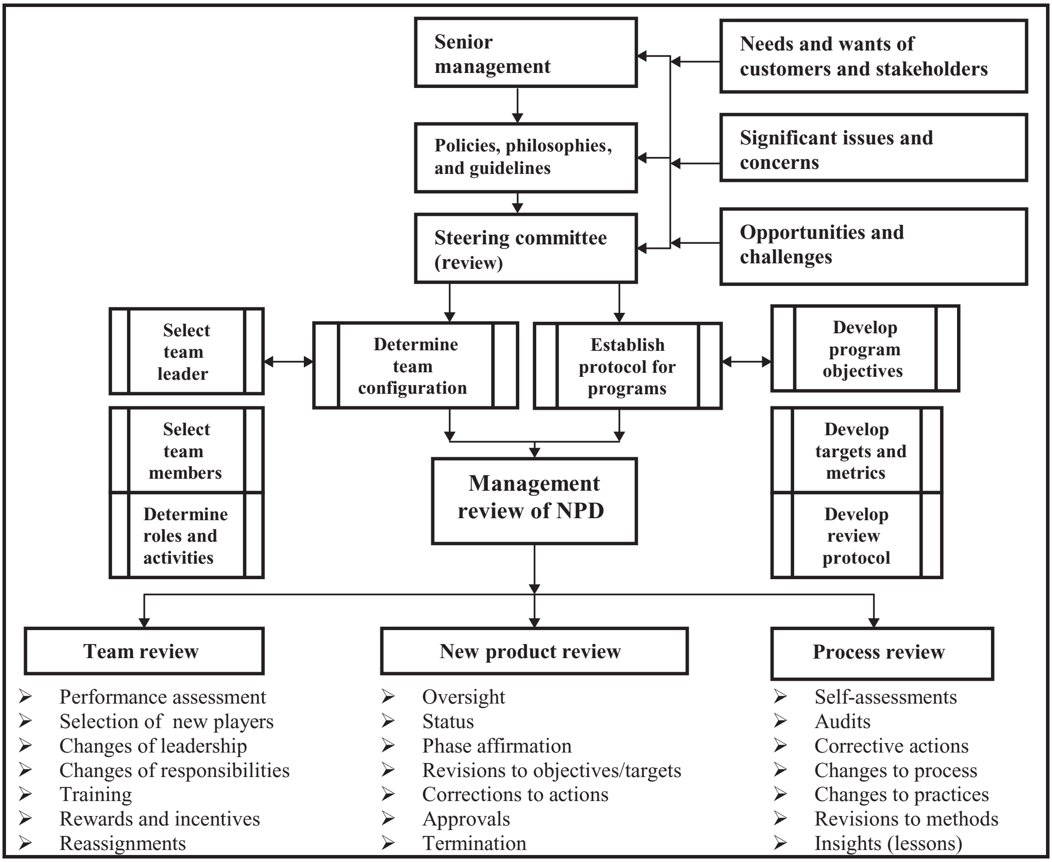


Figure 3.8 A view of the responsibilities of a steering committee

improvement is a significant part of the process of reviewing results. Improvements are achieved by continually evaluating performance against policies, objectives, and targets.

Figure 3.8 is a flow chart of the responsibilities of the steering committee. The steering committee provides reports or other communication mechanisms to ensure that executive management has a fundamental knowledge of the progress of NPD programs. Occasionally senior management plays a direct role in the development of an NPD program. This is especially the case if the program represents a significant challenge or involves a high level of risks. For example, Airbus has spent approximately €10 billion on the Airbus 380. The investment not only has a significant effect on cash flow, but the product is a critical part of the company's strategic position.

The reviews: management's and participants' view of the progress

The "end-of-phase" reviews are one of the most powerful aspects of the IPD and the NPD process. Such reviews provide management and the participants with a full view

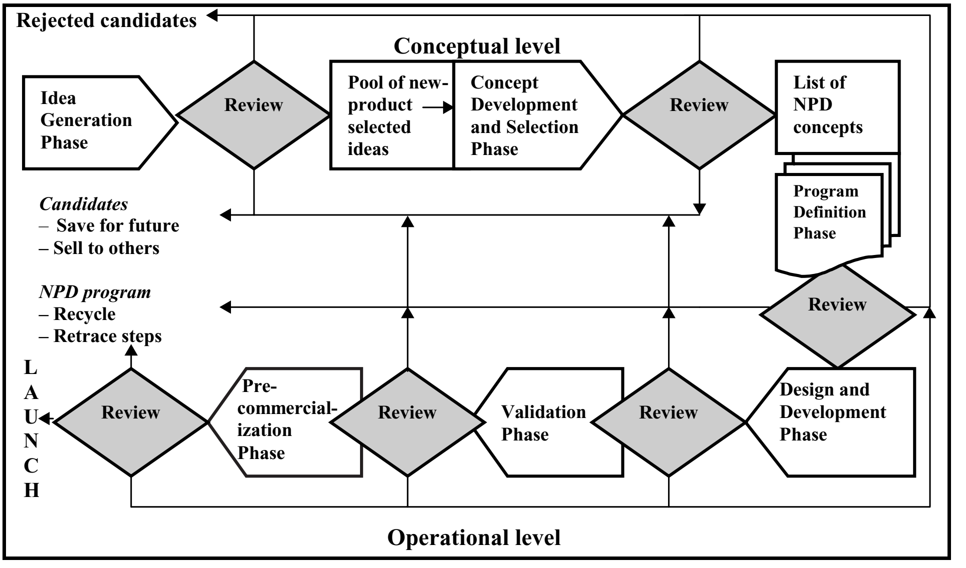


Figure 3.9 Standardized review process

of the progress made during the phase and the value of proceeding to the next phase. Occasionally such reviews are carried out within the process elements of a phase, especially if there are vital decisions to be made or if significant implications are involved. For example, a review may be conducted just prior to committing the funds to build a new manufacturing facility. However, the reviews are normally performed only after the preceding phase has been completed.

The steering committee, or senior management of a small company, participates in the end-of-phase review. The review process is quick and seamless; decisions are affirmed and it ensures that everything is suitable for continuing to the next phase. Theoretically, the review takes no time. It is often a simple meeting of the key participants. The outcomes of the reviews depend on the achievements made during the phase. Figure 3.9 shows the standardized version.

The new-product opportunities that are not selected during the Idea Generation Phase or the Concept Development and Selection Phase are often simply discarded. Occasionally they are stored for future consideration, especially if they were not selected due to the conditions of the business environment. Less often, the rejected candidates can be sold to others or might be developed under a partnership arrangement. The Program Definition Phase establishes the game plan for the concepts that are to be translated into a full NPD program. The review at the end of the Program Definition Phase is often perfunctory since the selection process takes place during the Concept Development and Selection Phase.

The operational level (Level 2) includes reviews at the end of each phase. Normally the purpose is to determine if everything is on course. An NPD program can be terminated during, or at the end of, each of those phases. Typically if a problem or difficulty is discovered some of the previous elements or phases can be retraced in order to correct the problem. If the concerns are overwhelming and the likelihood of success is remote, then the NPD program is withdrawn from further development.

Selected examples of the NPD process

The Stanley Works' product development process

On January 30, 1997, John Trani, the then recently appointed president and Chief Executive Officer (CEO) of The Stanley Works, made his initial remarks to the corporate headquarters staff.[15] Stanley was a 155-year-old hard goods company with a turnover of $2.4 billion. During his talk Trani made the following comments:

> They pay leaders for three things: to pick the right people, allocate the resources and build the organization's competency to perform. My intention is to do all of the above, and whatever else it takes to turn Stanley into the best new-product machine in the hard goods industry. One of my primary business tenets is "you grow or you fail." In order for us to grow, there will surely be a need for substantial change in our philosophy and execution. Some of the change will no doubt be painful. However, at the end of the day, we are going to turn Stanley into a world class leader in every business we participate in. We are going to become the Coca-Cola of the hard goods industry. Simply stated, we're going to have fun. We're going to make money. Above all, we're going to win![16]

Within one month of the meeting, Stanley created an NPD task force to restructure product-development. The task force benchmarked the product-development process (PDP) at several high-performing manufacturing companies (3M, H-P, and Rubbermaid). The objective was to adopt the "best of the best" and develop a world-class PDP. The selected PDP was based on a phase–tollgate process[17] that included specified metrics, milestones, approvals, tracking, and detailed documentation. The most important aspects were the applications of a time-to-market metric, a common computer-aided-design (CAD) platform, and cross-functional teams.

The Stanley concept was based on a cross-functional team approach with participants from engineering, marketing, and manufacturing on every team and representatives from finance, sales, customer support, and human resources on most teams.

Stanley uses the construct of phases with the notion of tollgates for the approval process. The company uses the tollgates to review the specific NPD program and to ensure that it fits into the broader corporate objectives. Stanley wants to ensure that it is not launching too many new-products at one time and diluting the probability of success. A systematic review of each program allows management to make sure that everything fits and that the company is allocating resources properly. Stanley uses product innovation as a means to differentiate it from the competition and it is one of the competencies of the organization.

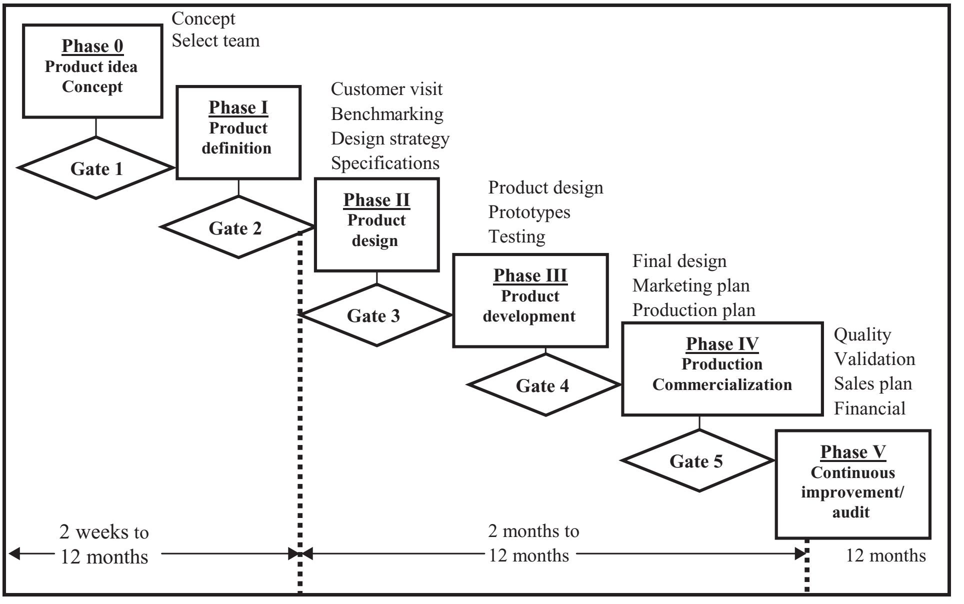


Figure 3.10 The Stanley Works product development process[18]

Figure 3.10 is an abridged version of the Stanley PDP. Stanley's PDP is an excellent example of the "standardized" model used in the text.

Design for six-sigma (DFSS) process models[19]

Overview of DFSS

Motorola, IBM, Texas Instruments, Xerox, Allied Signal who merged with Honeywell, and General Electric (GE), and several other Fortune 500 companies have adapted an NPD methodology that focuses on six-sigma.[20] GE was one of the original companies on the Fortune 500 list and today it is among the top ten. GE has a long history of innovation and change. Under the tenure of Jack Welch, it has become famous for seeking excellence and striving to be the best. It exemplifies a company that constantly reinvents itself.

During the late 1980s, GE revised its product-development processes to improve the development cycles. It established "a market-driven product development," using multi-functional, co-located teams. GE enjoyed some successes from the new processes, but individual organizations had difficulties getting the NPD teams to focus on the product development rather than other priorities.

Welch was not satisfied with the results and challenged GE to become a six-sigma corporation. In 1996, GE redesigned its product-development processes. It adapted the six-sigma philosophy for its innovation processes as well its production operations.[21] The goal was to deliver measurable quality improvements that were critical to the customer (critical to quality) and within cost requirements. GE's initiatives to become a "six-sigma" company evolved into its Design for Six-Sigma (DFSS) NPD methodologies.[22] GE reportedly saved over $2 billion in 1999, because of its six-sigma initiatives.[23]

DFSS represents the integration of total quality management (TQM)[24] and NPD processes that focus on value maximization by providing customers with the exact products they want and by eliminating the product and process defects that reduce some of the benefits. DFSS is a process-oriented methodology that targets the high-level view of the elements associated with improving a product or developing a new one. It provides a systematic means of achieving higher quality and world-class performance with a high degree of customer and stakeholder satisfaction.

DFSS consists of two NPD versions depending on whether the objective is to design new-products or to improve existing ones. The DFSS process for new-products is referred to as "DMADV"; it is a five-step process that includes the elements "define, measure, analyze, design, and verify." The other model is a simpler approach for improving existing products and processes. The elements of the incremental improvement process include "define, measure, analyze, improve, and control" (DMAIC). It is used for minor changes to existing products.

DFSS models are part of the transformation into the twenty-first century. These NPD processes are elegant and straightforward. DFSS focuses on the essence of the NPD situation. Its steps include the underlying framework of new-product development: the front-end of "define, measure, and analyze" and the back-end of "design and validate." DFSS models typify the evolution to a comprehensive model that covers the essential elements in true process format. It has an analytical level and a developmental level with an overarching philosophical perspective of six-sigma quality. The most crucial perspective of DFSS is the focus on what is critical to quality (CTQ). Prevention, detection, and corrective action drive the quality mantra. These views are embedded in the philosophies/methods discussed throughout the book.

Incremental "product-development" process – the five-phase DMADV six-sigma methodology (define, measure, analyze, design, and verify)

DMADV is the DFSS construct intended for product development. The DMADV process includes five interrelated phases: "define, measure, analyze, design, and verify."

DMADV uses "design and verify" phases that depend on creativity and new approaches for satisfying needs and objectives. Figure 3.11 gives an overview of the essential elements of the DMADV process.

The **Define Phase** is similar to the conceptual level of any NPD process. It identifies the scope of the program including the organizational considerations. The most critical step is determining the boundaries of the management system for measurement and analysis. What are the elements of the system? What are the goals and priorities?

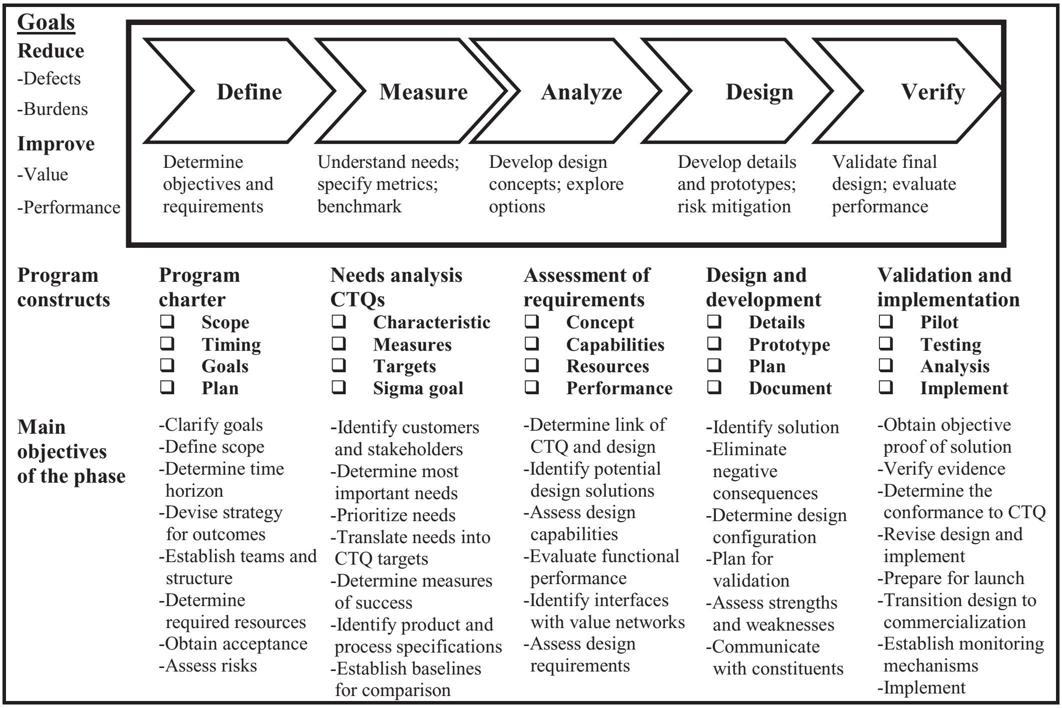


Figure 3.11 Five-phase DMADV six-sigma methodology

The Define Phase establishes the time horizon for the program. It defines the program life cycle and translates objectives into plans for execution. Usually, it involves establishing an organizational framework for implementing the actions. The organizational structure is team based with a definitive charter for linking participants with the external business environment. The charter defines the roles and responsibilities, necessary resources, and the time-line for actions.

The **Measure Phase** establishes targets and metrics that are critical to the customers and stakeholders (CTQ factors). From a preliminary assessment of the business environment, the team reviews the opportunities for improvements in the products, prioritizes the needs and expectations, and prepares preliminary product specifications for the analysis phase.

The Measure Phase focuses on the external forces to ensure that the program addresses the needs and wants of constituents. It benchmarks other corporations to ensure that competition or new technologies do not trump the proposed goals and targets.

In this phase, qualitative and quantitative data and information are examined to determine how to meet the expectations of customers, stakeholders, the community, employees, and the regulatory agencies. The examination includes assessing what metrics can be used to interpret the effects of management constructs. These include environmental stewardship, risk management, competitive-advantage, cash-flow management, and the effectiveness of decision making.

Much of the data and information to support the Measure Phase may already exist within the organization. Information and data of known and verifiable quality can be used to provide a reasonable basis for performance evaluation. Appropriate quality-assurance functions must be in place to ensure the validity of the data collection methodologies, modeling techniques, etc. This is particularly important if the information is used in external reports.

The **Analyze Phase** results in the selection of the most appropriate opportunities for product improvements. The Analyze Phase enables management to assess product performance measures in terms of CTQ factors, the principles of the organization, and the constructs of continuous improvement. The assessment views performance relative to: (1) the objectives, targets, and metrics; (2) industry peers; (3) benchmarks and best-in-class corporations; and (4) other products, operations, and sites. Assessment includes performance measures to discover opportunities for improvements. This includes checking for areas of non-conformance to government mandates or customer expectations, finding unresolved difficulties, and determining elements with high negative impacts.

The Analyze Phase is essential for articulating the definitive plan for implementing the program and gaining acceptance and commitment across the organization. It requires extensive detailed analyses about the products and processes, and all of the related implications. The phase involves a capability assessment to ensure that the organization has the capacity to execute the program. If there is a capability gap, the means to eliminate the gap have to be identified and deployed. If the gap is mitigated, the selected programs proceed to the next phase. If not, they are revised or terminated.

In the **Design Phase**, the preliminary design concept is translated into product specifications and detailed engineering instructions and drawings that define the physical aspects of the product. The engineering involves breaking down the work structure of the entire product into subsets (often referred to as work breakdown structure) and then building-up the pieces into parts and components, modules, and the final product. The detailed engineering includes calculations for determining material requirements, strength of the materials, arrangement of the components and parts, and the life-cycle considerations for eliminating defects and burdens. Such analyses also include techniques for mitigating risks and liabilities. The design parameters are based on performance requirements, industry standards, and government mandates.

The design phase also includes the development of a verification plan to ensure that potential failures are identified and mitigated. The verification plan is a crucial element of the design sequence. A review of the design ensures that it incorporates as much of the needs and requirements of the external dimensions as possible. The assessment examines the design in the light of customer needs and wants.

Customer satisfaction is one of the most important metrics of any design program. The primary effects of the solution matrix provide the essential elements of what

Steps	**Define**	**Measure**	**Analyze**	**Improve**	**Control**
Critical elements	Scope Timing Goals Plans	Customer needs Critical to quality Targets Measures	Functions Concepts Performance Gap analysis	Design elements Tests Risk assessment Change	Implement Validate Update Closure

Figure 3.12 Define, measure, analyze, improve, and control (DMAIC)

customers are seeking. Stakeholder assessment is much more open-ended. Generally, the secondary effects of the solution matrix focus on stakeholder expectations. Government stakeholders are important because public policy concerns, and all applicable laws and regulations must be addressed to ensure compliance. A thorough examination of the federal, state, and international laws and regulations is a good starting point. Legal compliance is not optional and, in many cases, determines what can and cannot be done. Completion of the development program in a timely manner may depend on compliance issues.

The **Verify Phase** includes building prototypes and pilot plants to test the validity of the design and the suitability of the new product in the business environment. The aim is to ensure that the products perform properly in the intended applications, that the potential for defects and burdens have been significantly reduced, and risks have been mitigated. Essentially, the Verify Phase validates the quality levels and performance characteristics before the product is launched on a large scale. If difficulties are discovered they can be rectified easily at a low cost. Design validation techniques cost money but are usually cost-effective. Resolving difficulties and mitigating defects and burdens before producing and selling the products lowers risks and costs, improves the value proposition, and enhances the financial picture.

Incremental "product-improvement" process – the five-phase DMAIC six-sigma methodology process (define, measure, analyze, improve, and control)

The DMAIC process is used for simple improvement programs that result in incremental improvements or changes to existing products. DMAIC is used for derivatives and enhancements, not new-to-the-world products or radical innovations. The general focus is on improving benefits or reducing defects and burdens. Figure 3.12 depicts the DMAIC process. The elements are similar to DMADV except for the focus on simple improvements.

A single function or the combined efforts of two functional areas often executes DMAIC programs.

Monitoring the NPD process

While monitoring new-product development over the development cycle of an NPD program, it is imperative that the new product, the process, and the people are enriched and obtain significant benefits from the experience. The monitoring process examines the progress and compares it with the expectations of internal participants and the external constituents. Various methods are used to ascertain the outcomes from the situation.

Firstly, simple checks can be used to determine if an activity or a number of activities have been completed. Check-sheets or templates as described in Chapter 6 are useful techniques for both guiding participants, and for making sure that the work has been completed. Testing is another mechanism used to determine that the work has been done and to certify the correctness of the outcomes from an external perspective. Testing is generally more costly and time consuming, but it provides a higher level of confidence. For example, having the customer actually use the product in a normal setting provides excellent validity, since such testing is based on the typical operating conditions of the customer. Such tests provide management and the participants with data that allow quantitative analysis of the results and a more-precise determination of the prospects for success.

Measures and metrics provide a sense of achievement on an ongoing basis. For example, the targeted cost of the product can be used as a metric. As the projected cost of the product is re-evaluated over time, determination of the product cost gives a sense of whether the cost structure is converging toward a definitive point or diverging toward greater uncertainty. The former gives participants a small "win" during the NPD process. The latter indicates that additional work is necessary to keep on the pathway to success. It also provides information and data to prepare financial calculations about the prospective cash-flow expectations. There may be an upper limit for an acceptable unit cost for the product; if projections suggest that the unit cost will exceed acceptable values, then the NPD program may have to be re-evaluated or terminated. The objective of using metrics or making such evaluations is to discover potential problems as early in the process as possible and to take corrective action. These evaluations also provide ongoing feedback that offers evidence about the viability of the NPD program. As key program metrics converge toward the positive, then the outcomes of the reviews at the end of the phases will typically be positive as well.

It is important to keep in mind the fundamental requirements of the NPD process. Some of these may serve as measures of the potential success of the program and an indication of whether it is on track. Table 3.3 lists some of the basic metrics for new-product development. The list is not comprehensive and it is intended to discuss only some of the more-basic metrics used during the development process. Indeed, one of the most important activities in the NPD process is to select the appropriate measures and metrics for evaluating the program. Given that the selection is dependent on the type of program and product, it is difficult to have a generalized approach. The metrics highlighted in bold letters are the critical measures that are used most frequently.

Fundamental metrics are used to evaluate the progress and potential for success of the NPD program. While there are many measures that the organization might use, the

Table 3.3 *Fundamental metrics of NPD*

	Product/market related	NPD program related
Market related	**Target market size (revenue/units)**	**Time to market (months)**
	Product profile/specifications	Core capabilities
Technical	**Performance and quality**	Uncertainty
	Health and safety risk	Yield (% output from input)
Economic	**Unit-cost target (in dollars)**	Sensitivity to changes
	Performance-to-price ratio (value)	Productivity
Financial	Gross-margin potential (%)	Development cost
	Required rate of return (%)	**Risks (image/reputation/other)**

choice depends on the type of new product and its potential life cycle. The following provides a more definitive view of the application of each metric in a new product setting:

- ***Target market size***. The size of the market is a key factor for the total projected cash flow, and the cost of the product relative to volume. If the potential market is smaller than expected, projected revenues are reduced, as are related profits. In many cases, significant levels of fixed costs require a certain volume of sales to absorb them. Moreover, often costs are related to volume. As discussed in Chapter 8, regarding the application of the learning or experience curve, unit costs typically decline as cumulative volume increases. Unless the market is large enough to reach an acceptable cost position, the product may have to be priced higher than customers are willing to pay. In either case, the reduced cash flow may threaten the viability of the new product. Given the critical impacts that market size has on potential sales and the associated financial implications, it is an excellent metric to follow for determining the prospects for success.
- ***Specifications***. There may be specifications that have to be met to fulfill customer or stakeholder expectations. The best example was the US Military's design requirement for basing designs on "mil specs." Contractors doing work with the federal government have to follow these government specifications. Government laws and regulations may mandate the use of certain materials or prohibit the inclusion of others. For example, the US Environmental Protection Agency published regulations phasing out chlorofluorocarbons (CFCs). Carrier Corporation met those requirements by producing a CFC-free (Puron) air conditioner. The ability to meet specifications from a customer or stakeholder perspective may be a key determinate for success.
- ***Time to market***. Time to market is a critical factor. This is particularly true for short-life-cycle products having a predetermined end date; any significant increase in time to market means reduced cash flow that cannot be recovered. For example, computer products and electronic devices are often based on a technology platform with a

fixed replacement date. The suppliers of the underlying technology, such as Intel's Pentium microprocessor, have a set life cycle for their technologies, improving them at regularly scheduled intervals. Time to market is an essential measure if the overall market life cycle is fixed by external conditions. The lost revenue during the delay cannot be recaptured.

Time to market is also critical when it is imperative to meet or beat competitive pressures. In some new-product categories the first to market has the opportunity to capture a share of the market that may be difficult to recapture at a later date. With pharmaceutical products, physicians are often reluctant to try the second new product if the first is working well. The first to market often enjoys a cost advantage until the others catch up in terms of volume. It is especially powerful when there is a strong inverse relationship between cost and volume.

- ***Capabilities***. As discussed in previous chapters, core capabilities are essential. A key advantage is knowledge of the market place and understanding customer needs. Unlike technological innovation, which focuses on the research and development skills and the technical capabilities of the organization, product innovation centers on market needs, marketing skills, and analyzing the financial implications. The new product has to be integrated into the product delivery system as quickly as possible. The central requirements of the internal aspects are the product-delivery capabilities of engineering, marketing, production, supply network management, and finance.
- ***Performance and quality***. In the same vein, performance and quality are often stipulated or set by the nature of the product or the conditions it must adhere to. When BMW created the new Z3 sports car (it has been replaced by the Z4) it wanted to meet certain performance characteristics so that the car would be classified as a sports model. Thus, it had to have a 0 to 60 m.p.h. (96 km/hour) capability in less than six seconds. Quality is often a customer-imposed requirement that is stipulated in terms of acceptable conditions.
- ***Health-and-safety risk***. For many products, there are environmental, health and safety consequences that may have to be mitigated. Compliance with environmental, health and safety regulations is the baseline for all companies. However, management should not rely on compliance as a given. The complexity of today's environmental regulations makes achieving compliance (or meeting stakeholder expectations) difficult. The growing awareness of product-related environmental issues – with special emphasis on pollution prevention, waste minimization, and sustainable development – has focused on the need for generally accepted methods of studying the environmental impacts of products throughout their entire life, popularly referred to as "cradle-to-grave" analysis. The so-called "product life-cycle assessment" or simply "life-cycle assessment" (LCA) – alternatively known as resource and environmental profile analysis or "eco-profiling" – is widely recognized as an environmental-management tool

as products, not just manufacturing processes, assume a more central role in the environmental debate. This topic is discussed in more detail in Chapter 7.

Companies that are committed to minimizing the environmental impact of their products and services must start with the basics and assure themselves that their environmental-management program is being handled properly. The long-term payback expected from investing the resources of time and capital needed to develop environmentally conscious products and processes can quickly be recovered by avoiding environmental problems and liabilities. However, a positive cost–benefit analysis is difficult to prove because the savings are based on avoided costs.

The metrics usually use existing products as a baseline, and stipulate an improvement level in terms of hazardous waste generated (or not generated), the total emissions created, the safety concerns, etc. These methods are intended to save money, reduce liabilities, meet stakeholders' needs, and increase market potential.

- ***Uncertainty***. Uncertainty is very difficult to quantify. The metric can be used to describe the number and level of unknowns that the organization is willing to tolerate. Generally, as information and knowledge become available through the development of the program, the level of uncertainty declines and the confidence that the program will obtain a successful conclusion increases. Thus, there are regions where the technical, market, and business risks are acceptable and regions where the risks are unacceptable. This construct is defined in more detail in subsequent chapters. In simple terms, there is typically uncertainty and a risk-to-reward relationship.
- ***Yield***. Yield describes how many useful products (materials) are produced in relation to the quantity of inputs used to produce the products. A higher yield indicates a better process. This relates not only to the technical aspects but also to the economic aspects. Like efficiency and other measures of output, yield is a measure of the viability of the product. For example, the production of recycled rubber from scrap tires became technically and economically viable when the production equipment was technologically sophisticated enough to achieve rubber recovery rates from the scrap tires of over 90%. Not only did the poor yield reduce the quantity of high-quality recycled rubber but it also increased the costs of disposing of the remaining materials because of contamination from the steel and fabric.
- ***Unit-cost target***. One of the most important metrics is the unit-cost target, especially for long-life-cycle products. Almost every product has a cost within which it must fit. If the cost is too high, there may be insufficient gross margin available to earn a profit; if the cost is too low, it might indicate that there is a missing attribute or factor. The unit-cost target should be calculated as soon as possible in the NPD process to provide insights into what has to be done, and what can be done. Product development is not an open-ended process. It has constraints that are real and important. Unit-cost target is one of the most critical factors and it often has to fit into very tight limits, especially upper limits.

- ***Performance-to-price ratio***. The concept of performance-to-price ratio or value plays a vital role during the NPD process. Customers seek benefits and expect performance that is related to their needs. They expect performance and quality to be built-in. Performance-to-price-ratio is a simple way of quantifying the value a customer receives for the given price level. This metric is very familiar to purchasers of personal computers.
- ***Sensitivity***. Sensitivity is a derived metric which relates to the others. It relates to the interrelationships between the key economic factors and the decisions made during the NPD process. In certain cases, development costs can be increased to accelerate the time to market. This is particularly important when there is a built-in time constraint to the market opportunity. Likewise a higher unit cost might be accepted in order to achieve better performance.
- ***Productivity***. Productivity is a measure of the management system and the production resources. The management system should rely on an integrated approach, with an emphasis on planning and analysis for discovering and solving problems during the upstream phases of the program.
- ***Gross-margin potential***. This is a simple metric. It is related to unit cost and selling price. High gross margins provide the means to develop marketing and distribution programs for supporting the introduction and growth of the product in the market place.
- ***Required rate of return***. Most organizations have a stipulated rate of return on capital. It is usually the weighted-average cost of capital plus some added amount for the inherent risk associated with the NPD program. The weighted-average cost of capital is:

  $$(\text{Cost of debt} \times \%\,\text{debt capitalization}) + (\text{Cost of equity} \times \%\,\text{equity capitalization})$$

  The required rate of return is normally the discounting factor for calculating net present value for determining acceptable financial reward. For further details see the supplement at the end of Chapter 6.
- ***Development cost***. Development cost is the total investment required for launching and sustaining the product in the market. It includes the costs for engineering, producing, and marketing the product. It also includes the costs of financing the program and the anticipated losses that might be incurred prior to breakeven. It might include the investment in inventory and the cost of carrying the inventory. Development costs are viewed as the investment required for launching the new product. It can simply be the outgoing cash flow for launching the product.
- ***Risk***. Risk is a broad metric. It often relates to the financial risk of the NPD program; i.e. risk is often seen as the total investment into the NPD program. However, the actual risk may be higher than the total investment. A poor product could damage the image and reputation of the company. Product-liability claims may be greater than

the value of the company as in the Dow Corning case involving silicone implants. Risk assessment is discussed in greater detail in subsequent chapters.

Effective metrics allow management to track and evaluate NPD performance, and keep the NPD program on schedule. The metrics should be dynamic and flexible in order to respond to changing business conditions. Metrics might be determined by benchmarking the performance of competitors, peers, and companies in related businesses, or the results of previous programs. A monitoring process with an appropriate number of metrics offers a balanced multi-dimensional approach for evaluating NPD performance so that progress toward achieving a given objective in one area is not made at the expense of performance in another area. The monitoring process includes the selection of the performance measures; a procedure for the collection, analysis, and reporting of performance-related data and information; and the interpretation of data by management and the participants. Again, the objective is to find potential problems and solve them.

Much of the data and information to support the measurement process – such as risk assessments, financial data, and inventory data – may already exist as a result of the routine operations of the organization. Information and data of known and verifiable quality can be used to provide a reasonable basis for evaluating the performance of the NPD program. Appropriate quality-assurance and/or quality-control functions must be in place to ensure the validity of the data-collection methodologies, modeling techniques, etc. This is particularly important if the information is used in the external reporting process.

Organizational aspects

A simplified internal NPD relationship mapping

The people assigned to the NPD process are usually embedded within the organizational structure. The success of new-product development depends on the input of all of the key functional areas of an organization. While it is impossible to map out all of the relationships that occur over the development of a new product, a simplified internal NPD relationship diagram is shown in Figure 3.13.[25] It indicates the key relationships and lists a few of the more-important connections.

This relationship diagram illustrates the connections between functional areas, the product-development program, and the organization (team). The NPD program should have direct relationships with all essential functional areas. Most importantly, it should have direct connections with potential and/or existing customers to obtain information and data about the new-product opportunities. The relationships and contributions of each of the areas will be spelled out in greater detail in later chapters. The NPD process defines the relationships and specifies the roles and responsibilities.

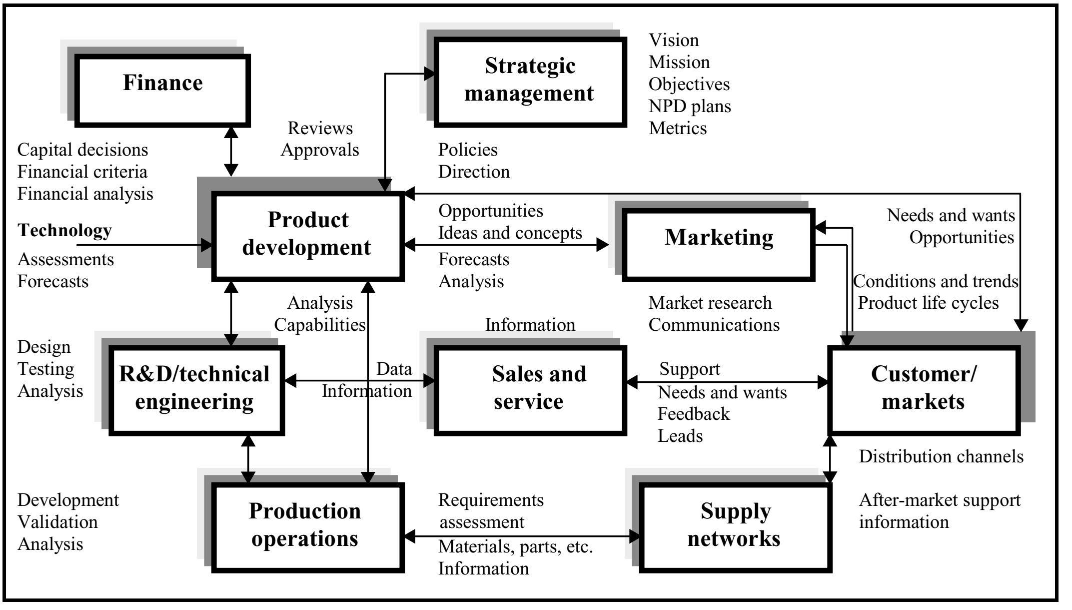


Figure 3.13 Simplified NPD relationship diagram

Cross-functional Integration

New-product development requires a collaborative approach for managing the NPD process and everyone involved. Developing a new product involves commitment on the part of management and all of the participants. Contributors to the NPD process must have patience and perseverance to succeed. Everyone must share a common vision of the NPD process and its objectives. They have to believe that success is achievable. However, they also have to be mindful of what the metrics reveal, and not allow their egos to impair their decision making when all indicators suggest that the business environment or other critical factors preclude them from obtaining that desired success. It is important that the failure of a new product is not seen as a personal failure.

The NPD organization uses a horizontal organizational structure focusing on the process as well as the activities. The cross-functional team is the typical structure since it facilitates participation on a concurrent basis. Cross-functional team integration is an organizational approach established to achieve collaborative behavior in highly interactive product innovation environments. It enhances the skills and capabilities of the participants by forming interdisciplinary teams for the planning and implementation of the program. The emphasis of the team is on achieving the overall results, excellence, and creativity. Team members establish the basis for performing the work, set the priorities, specify the design and development activities, assess the alternatives, and evaluate the results.

Cross-functional teams link downstream activities with upstream decision making. Knowledge of the downstream capabilities and limitations allows the team members to select solutions that are appropriate for the needs and requirements of the entire program, not just a specific functional area. The collaboration between upstream and downstream participants allows the team to minimize the number of interfaces necessary for accomplishing specific tasks. Unlike the sequential approach in which participants are employed only when necessary, the cross-functional teams of the integrated NPD process perform their responsibilities on a concurrent basis. This minimizes communication needs because participants are interacting with each other and cross-fertilizing the team with inspiration and insights.

Collaboration is extremely important for achieving effective teamwork and world-class performance. Participants cannot perform unless they have the skills, knowledge, and information for making good decisions. Collaboration ensures that knowledge is conveyed efficiently and effectively as the process elements advance from phase to phase. It also suggests that conflicts within the processes are resolved as early as possible. It is less likely to build in difficulties, since the downstream participants have input into the upstream decisions.

The cross-functional team is not a magic bullet, just an effective mechanism that facilitates linking all of the activities required to develop a new product. Working collaboratively shortens the NPD process because it reduces the number of transactions necessary to complete the work. It minimizes paperwork and learning requirements because of the parallel flow of the work. Whenever people frequently meet face to face, difficulties are managed and problems are solved. Bringing issues into the light opens up dialogue and promotes good decision making.

Analyzing the requirements for a design decision with all of the appropriate participants on a concurrent basis enhances the process by providing a rapid mechanism to diagnose and resolve unexpected situations or changes to the plan. Using the cross-functional team is a balanced approach for arriving at decisions, since the various perspectives (participants representing engineering, marketing, production, and financial) are all party to and understand the implications of the decisions.

The basic constructs of the teams

Establishing the NPD team is one of the most important elements of the NPD process. It is generally initiated very early in the NPD process to capture the available knowledge and ensure that a very broad perspective is used during the front-end phases when there is a lot of uncertainty.[26]

The NPD team usually includes participants from: engineering, design, technical, marketing, sales, support, production, process development, quality, and finance departments. Participants contribute their expertise and knowledge to a balanced approach to making decisions.

There are many models used to structure the team. Probably the most widely recognized is the approach articulated by Wheelwright and Clark in their book, *Revolutionizing Product Development*.[27] They suggested four types of team: functional, lightweight, heavyweight, and autonomous. The Project Management Institute Standards Committee recognizes similar types of teams: functional, "projectized," and matrix.[28] Matrix teams may be weak, balanced, or strong; similar to those described by Wheelwright and Clark.

A **functional team** is one in which the work is carried out within each functional area and the functional manager directs the scope of the work. Functional management is responsible for the inputs and outputs. This approach generally brings a high level of expertise to the NPD process, since the functional area has complete control over the resources. The main problems are the coordination between the functional management and the control of the NPD program. Often there is a lack of overall direction and control, which contributes to longer development cycles and a lack of balance.

The **lightweight team** has a program or project manager/leader who coordinates the work of the functional organizations through liaison representatives. The program or project leader has limited influence over the work or the people. The functional manager maintains a strong role with respect to the work and the individual contributors. This type of team is seen as an improvement from an integration perspective because there is an individual responsible for the whole of the NPD process and the individual contributors have a sense of the NPD program. It is still a weak form of team-based methodology and is indeed a lightweight approach.

A **heavyweight team** has a manager or leader who is responsible for the program or project and generally has a team of people dedicated to the NPD program. The people are often assigned to the manager and are generally co-located if possible. A heavyweight leader exerts strong and direct influence, integrating the people and resources available to the NPD process. The weakness of a heavyweight team is that its members have less contact with their functional organization. It may create conflicts within the overall organization that are difficult for the participant to resolve. However, it does fit the conceptual perspective of IPD and may be an acceptable compromise in certain organizations. It is definitely a matrix form of management. If care is not taken, some of the learning that is achieved during the NPD process may be lost when the program ends and the people go back to their functional organizations.

Autonomous teams have people directly assigned to the teams and they are fully committed to implement the requirements of the NPD process. An autonomous team leader is solely responsible for the participants and they report to the NPD manager or leader. The strength of the autonomous team structure is that it is independent of internal conflicts that may exist in other structures. People are dedicated to the NPD process and program. The weakness of the structure is its relatively small resource base. Unless there is collaboration with the larger organization, the autonomous team may have insufficient resources or knowledge to get the work done efficiently and

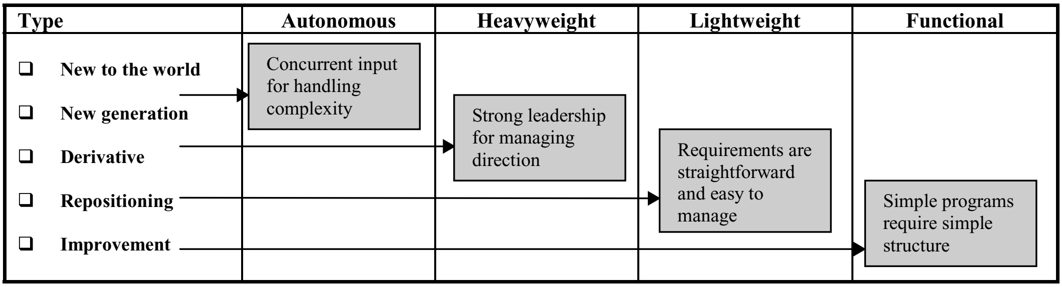


Figure 3.14 Relationship between team type and new-product type (generalized)

effectively. It is also more dependent on the leadership skills of the people managing the team.

The NPD process does not specifically identify the type of team an organization must have. It describes teams in terms of the participants, the activities, and the process. Teams are comprised of people with different skills and capabilities. The actual team mechanism depends on the nature of the NPD program. Figure 3.14 gives guidance on selecting a team type.

This diagram indicates the general relationship between team type and new-product type. Many companies separate their NPD programs into two or more categories. The simple improvements are straightforward, based on well-known and well-traveled pathways. Such programs may not require an elaborate structure or a complicated process. A functional team structure might be adequate, especially if one of the functional areas handles a majority of the requirements. For example, the repositioning of a product into a new market segment may be essentially a marketing-driven process; therefore, marketing takes the lead and the other functional areas support where necessary. On the other hand, new-to-the world products are typically complex, requiring inputs and contributions on a concurrent basis from all of the functional areas. It may not be possible to reduce the risk of such NPD programs unless there is a dedicated (autonomous) team with strong leadership. The autonomous team structure may offer significant advantages to management for such programs, given the need for balance and broad perspectives. Lockheed's famous "Skunk Works" is an example of developing new-to-the-world technology and products using autonomous teams. The F-117A stealth tactical fighter, the U-2 spy plane, and the SR-71 Blackbird were all developed using dedicated teams.[29]

The selection of the team structure is highly dependent on the actual circumstances of the given situation. The type of team construct used for an NPD program is a key determinant that is generally decided upon very early in the process. Regardless of the type used, IPD development involves inputs and analyses from all of the functional areas to ensure that informed decisions are made. In addition parallel processing is pivotal to cross-functional integration regardless of the type of team.

Organizational planning and team selection

Overview

Organizational design and team selection are important steps. They are front-end steps that are accomplished just before the Idea Generation Phase or during the Program Definition Phase, depending on the situation. Team members have to work together throughout the program, share their knowledge, and contribute to the success of the process. Organizing the team requires insights and knowledge about the people involved and how they fit into an effective relationship.

Choosing a team structure

The initial step is often the assignment of a champion/manager/leader. The champion may be a senior executive who has initiated the NPD program or participated in creating the strategic logic for the new product. The champion is often the principal advocate for the creation of the opportunity. Bill Gates was the advocate for "Windows." Robert Noyce, Gordon Moore, and Andy Grove were the executive champions behind Intel's development of microprocessors. The champion is the individual or small group who oversees every aspect of the NPD process or program and acts in the capacity of an "Owner."

Leading change at Intel through effective leadership

The microprocessor technology of the twentieth century owes its origin and development to the Intel Corporation and its contributions to the technology and product development. Intel is the dominant designer and producer of microprocessors used in personal computers and related electronic devices. The microprocessor was pivotal to the rapid changes in technologies used by a wide range of industries from the automobile industry to food processing industries; it improved the social, economic, and environmental viability of everything it touched. The high economic growth rates of the 1990s and the improvements in quality of life in developed countries are related to the contributions of the microprocessor.

Robert Noyce and Gordon Moore founded Intel in 1968. Noyce had been an executive at Fairchild Semiconductor, one of the developers of the integrated circuit. Moore was an engineer with a doctorate in chemical engineering from Cal Tech. He was one of Noyce's colleagues at Fairchild, responsible for R&D. Noyce and Moore were co-founders of Fairchild. The Intel founders were not the typical entrepreneurs, since they were already successful, well-known industry players with vision, determination, and a keen sense of what they wanted to accomplish.

One of their first moves was to select Andy Grove as director of operations, responsible for product development and manufacturing. Grove was an assistant to Moore at Fairchild, responsible for process development. He had a Ph.D. in chemical engineering from the University of California at Berkeley. Grove's personal philosophy helped Intel define the company during the early years and set the stage for the establishment of its management system. Grove did everything possible to stay ahead of the competition and confront problems early on. He instilled a philosophy of using rational analysis to solve management issues and tackle long-term difficulties early.

Intel is the industry leader from every perspective. It leads the world in the design, development, production, and marketing of its microprocessors. Intel has managed innovation by being on the leading edge of change. Its business strategies reinforce the public perception that Intel is an innovative company keenly aware of the social, economic, technological, and environmental implications of its products and processes. To minimize competition from other chip manufacturers, Intel increased its new-product introductions, thus shortening the product life cycle of microprocessors, branded its products with the Pentium name, and promoted the “Intel Inside” logo. Intel’s technological and product innovations, and the integrative capability of personal computers, have had an incredible impact on producers, users, and society.

In a business environment of shrinking life cycles and rapid change, the speedy development of new products is an important means for Intel to maintain its competitive advantage. Strong leadership from the top provides the pathway to success.

Source
www.intel.com/reseach/silicon/morreslaw.htm.

The first step is to establish guidelines for the selection of team members based on the blueprint for the NPD process and directions provided by management. The leader, management, and the steering committee collaborate to select an appropriate leader for the NPD program. Toyota uses the term “Chief Engineer” to identify the champion in charge of an NPD team.[30]

The second step involves the organizational design, which is often based on one of the team structures previously discussed or an adaptation thereof. The team structure defines how the team is organized and what the key roles are. It also determines the scope of responsibility of the leader, which varies from an “overseer” for the functional type to the “boss” for the autonomous type.

The third step involves team formation, which includes an assessment of the capabilities of the people that are available and an evaluation of the skills and knowledge of the candidates for the team, and the actual selection of the team. The assessment includes a process of mapping the resource base to the needs of the NPD program. Based on the evaluation and contributions from senior and functional management, the team is selected to initiate and execute the program. The final step is a determination about team development. In addition to formal initiation and awareness building about the NPD program and the NPD process, team members may require specific training on the tools and techniques used during the process. They may also need training on

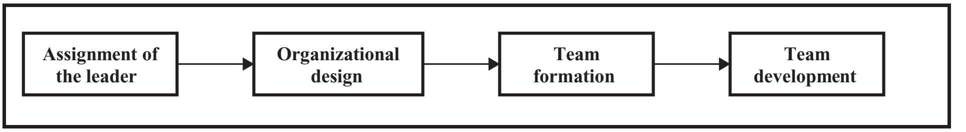


Figure 3.15 Choosing the team structure for the NPD process

the organizational aspects and the interpersonal skills they need to perform their roles and responsibilities.

Figure 3.15 depicts the essential elements of team selection. There are pluses and minuses to each of the approaches. The art is to select an approach that meets the needs of the competing goals and objectives.

Assignment of the leader

The team leader, regardless of the title given (project manager, program manager, NPD champion, etc.), is the pivotal person in most NPD situations. The leader is responsible for integrating the team into a cohesive force. Based on strategic direction from senior management, the NPD leader provides the management and administrative structure for creating effective team dynamics and a result-oriented NPD program environment. First and foremost, the leader provides leadership! The people involved in the NPD program obtain results because they are dedicated and have a sense of purpose.

New-product development is about **leading change**. It is about leadership. The most important function of the team leader is to inspire people to achieve outstanding results and excellence in every endeavor. Inspirational leadership engenders a spirit within the team to be the best, and creates motivation and enthusiasm within the work environment. Inspirational leadership energizes the team to seek opportunities and discover new ways of doing things. It means getting people to think "out of the box."

The leader is the director of the NPD process and program, orchestrating the activities and coaching the players. The actual roles and responsibilities of the leader depend on the situation (type of new product), the organizational construct (type of team), and the management system.

The program leader does not have to be the same person all the way through the NPD program. For example, IBM changes the leadership role depending on the primary focus. During the early phases the leadership role may be handled by the marketing professional; however, during the design phase the technical area assumes the role.[31]

Organizational design

Determination of the organizational design is often carried out during the Strategic Logic and Alignment Phase. It is based on the overall approach used by the organization. However, if there is not a prescribed methodology, the choice of organizational design

Table 3.4 *Advantages and disadvantages of team types*

	Advantages	Disadvantages
Functional	Simple, efficient with functional support, facilitates training and knowledge; reinforced by expertise from functional area.	Focus is on the functional requirements instead of the program; may not be effective because team members have other responsibilities.
Lightweight	Easy to manage; can be viewed as a compromise between the functional and the autonomous; efficient use of resources applied when needed.	Conflicts in management direction; team members may have commitment conflicts; participants may have two bosses to manage.
Heavyweight	Compromise for larger programs by providing strong program leadership while still maintaining links with functional department for support.	Training becomes more difficult to support because the focus shifts toward the program. Incentives for functional participation may be weak. Requires collaboration.
Autonomous	Excellent for managing creativity and complexity; provides focused and dedicated people on the team; direction is provided by NPD program leader; participants are fully engaged in the program; enhances creativity by reducing distractions.	Requires independent operation without much functional support; difficulties in obtaining fully qualified participants in each area; especially troubling if there are many similar NPD programs; may not result in efficient use of participants.

is made immediately after the start of the NPD program. The construct is typically a form using cross-functional teams.

Table 3.4 lists some of the advantages and disadvantages of each type of team. The assessment is a simple snapshot of a complex question. Vijay. K. Verma discusses the applications in more detail in *Managing the Project Team*.[32] In the complex business environment of the twenty-first century, there are many other types of team structures that may be selected. With the growing number of partnerships and strategic alliances, and the number of business units that are spread around the world, virtual product teams are coming to the fore. This construct is discussed in further detail in Chapter 14.

Team formation

The starting point for forming a team is to understand the capabilities of the people who are available to participate on the team. The process includes an assessment of the requisite capabilities, knowledge, and skills. Such an assessment is dependent on the overall requirements of the program and the situation. If these requirements are available prior to the Idea Generation Phase, then the capability assessment can be addressed, and team members are selected at the beginning of the NPD program. In cases where the set of ideas or concepts must be developed before the team is defined, then such assessments generally occur during the Program Definition Phase.

Team formation should be made on the basis of the requirements of the NPD process. The team is responsible for the management of the NPD process as well as the development of the product. The team focuses on the management issues defined in Table 3.5.

While the items listed in the table appear to be extensive, the leader and the team assist each other in obtaining results. ***The leader's most important responsibilities are the product, the people, the program, the plan, and the process***. The team focuses on outcomes and getting results. The up-front activities of setting the guidelines for the NPD program are crucial for simplifying the process. It is similar to having a well-written script when producing and directing a movie. It is easier to direct people who know what is expected than having to tell them what to do every step of the way. Indeed, NPD speed is obtained when the leader does not have to tell the participants what to do.

Team building is a critical part of the process. The leader has to develop and maintain enthusiasm, commitment, and trust. The leader must maintain frequent contact with the participants and support their activities. The critical responsibilities of the leader and the team include identifying and mitigating risks. Resolving difficulties is central to leadership. Conflict resolution is an inherent part of any NPD program. New-product development deals with change and whenever there is change, conflict is a possibility.

Team development

Verma suggests that there are five stages that new teams go through: "forming, storming, norming, performing, and adjourning."[33] Forming is the initial step occurring when the team is selected and members become acquainted with each other; the members become familiar with their roles and with the capabilities and limitations of their colleagues.

The storming stage occurs when team members and the leadership attempt to resolve open issues and difficulties between the participants, including personality conflicts. Verma suggests that "this stage is inevitable and should be embraced as productive, if handled appropriately."[34] In reality this is part of the process of moving toward a richer understanding of the requirements and specifications of the program, ultimately the "norming" stage.

Norming occurs when the team members know and accept their roles and responsibilities. "Performing" is the productive stage with the members working together as a team having trust and mutual respect.

"Adjournment" occurs after the program has been terminated or turned over to the product delivery system. While in some cases the team simply goes on to the next program, this stage represents the end of the process.

Table 3.5 *Traits of leading and the qualities of NPD teams*

	Leadership	Direction	Guidelines	Team building	Conflict resolution
Defining	Establish mission and objectives of NPD program	Articulate game plan (program); articulate NPD process	Establish criteria and boundaries; define metrics	Select organizational design; establish training requirement	Articulate guidelines for dealing with problems
Planning	Articulate management approaches	Establish focus for activities; develop plans	Set priorities; identify scope of effort	Develop manpower requirements; develop incentives	Identify barriers to success
Organizing	Inspire participants	Obtain commitments	Establish accountability	Select participants and supervision	Establish mechanisms for resolution
Directing	Achieve results through simple mechanisms	Articulate authority and responsibilities	Identify critical factors for success	Integrate members into team; provide team development	Facilitate problem solving
Communicating	Facilitate discussion with internal players	Establish communication with external dimensions	Determine the required reporting mechanisms	Establish protocol for meetings, discussions, presentations, etc.	Establish change notices; communicate lessons learned
Controlling	Establish protocol for decision making	Monitor activities on an ongoing basis	Establish review points and conditions	Build consensus; establish reporting mechanisms	Maintain tight control over variations
Evaluating	Articulate review and approval process	Validate results; seek out hidden defects	Identify critical risk factors	Promote self-assessments and corrective action	Perform audits and program reviews
Resolving	Keep management informed	Build in continuous improvement	Establish mechanisms for feedback	Keep participants informed and active in decision making	Collect and distribute information

Verma's approach is one of many similar constructs for developing a cohesive team. The flow of the steps or stages may unfold in a formal or informal way.

Some fast-paced companies suggest that there isn't time to go through such stages during a development program. Teams simply have to start producing from day one. The right answer may be somewhere in between.

"Virtual" project teams

New communications technology, primarily the Internet, is linking individuals and organizations around the world, making routine face-to-face meetings among project team members far less necessary than in the past. "Virtual" project teams can work within and between geographically separated organizations, without ever physically getting together. For example, EMC Corporation electronically links members of NPD projects and hardware engineering from their facilities in Massachusetts, North Carolina, and California to work together during the design, engineering, and prototyping phases of a project.

Virtual project teams can be highly effective for product development, but there are several natural side effects due to the physical separation of team members. Two of the common negative consequences of virtual teams are the lowered level of trust among members, and the frequent lack of effective communication patterns. Team members having the opportunity to interact directly, particularly in non-business settings, are more likely to develop a sense of team camaraderie.

Program managers can help to ensure the success of a virtual NPD team by improving communication flows among team members. Some suggestions on how to use communication to build a better virtual team include the following:

(1) To improve the chances of developing trust between team members, develop relationships by including at least some face-to-face contact time (e.g. at kick-off meetings and a few follow-ups).
(2) To maximize support, commitment, and exchange of ideas, provide full program-status information to all team members on a regular basis.
(3) The program manager needs to keep all members "in the loop" and not let geographic separation cause communication breakdown.
(4) To avoid wasting time recycling information, project managers should create a set of team rules regarding routine information sharing (i.e. how often and what types of information).
(5) Since you cannot observe non-verbal behavior or body language with email or other electronic communication forms, gauging message "intent" is sometimes difficult. Therefore, establish clear expectations and a firm set of rules regarding interpersonal behavior.

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Summary

IPD is an evolving methodology for creating new products using cross-functional teams and having an accelerated NPD process to systematically evaluate opportunities and develop new products. IPD focuses on speed, quality, flexibility, and cost-effective product attributes. The trend in product innovation is toward more integration and acceleration, linking the people and the process using best practices and innovative technologies.

The framework for the NPD process is highly dependent upon the situation. The DFSS approach is indicative of current thinking. It has a process for simple changes to existing products and a more elaborate NPD process for new-to-the-world types of products. Its “define, measure, analyze, design, and validate” model is an example of the focus on the essential elements of the NPD program. Table 3.6 compares the essential elements of the DMADV with the “standardized phase and review” NPD process.

The aim of the comparative analysis is to examine the NPD process in terms of what it is supposed to do and not just what it is. The argument made throughout the chapter is that the NPD process can take many forms. The essential differences are the scope of the NPD program and the new product type (degree of newness). Most of the constructs have common elements and cover the basics in a similar fashion. They all have the conceptual level and an operational level. The standardized NPD process described herein is intended to follow the typical flow and thought processes involved in developing a new product. It is a process that is easy to define and follow from a participant’s perspective. The strength is its logical flow and its ability to minimize the time, money, and effort invested in a candidate until there is sufficient evidence that the candidate warrants the full investment. The weakness is that many activities have to be revisited as the case builds from an idea into a concept, and then to a design and its validation. While such potentially redundant activities take time, they also ensure that the situation is continuously being updated and that if anything was missed in the initial phases there are additional chances of discovering it downstream.

The purpose of this discussion is to articulate that the standardized NPD process described and assessed in this chapter is more than a theoretical approach. There are many similar approaches being used by leading corporations. NPD is about defining opportunities, determining how to measure their value and the risk to reward, analyzing the business environment and the opportunities from an internal and external perspective, designing innovative products, validating their value, and commercializing new products to achieve success and a sustainable future.

In today’s business environment, eliminating redundant activities is essential for achieving speed and timeliness. In the final analysis, senior management and the participants have to select the right process for the situation and manage it correctly.

Table 3.6 *A simple comparative analysis of the DMADV model with the standardized NPD process*

Level	DMADV model	Generic phases	Critical factors
Conceptual	**Define**	**Idea generation** **Program Definition**	Discover appropriate opportunities; understand customer needs; map out NPD program requirements; develop a game plan.
	Measure	**Concept Development and Selection** **Program Definition**	Determine the criteria used for selecting candidates and for success; ensure that metrics are used for decision making; prioritize goals and opportunities.
	Analyze	**Idea Generation** **Concept Development and Selection** **Design and Development**	Brainstorm and benchmark; prepare comprehensive assessment of internal and external forces impinging on the situation; assess risks and uncertainties; establish a logic for decisions.
Operational	**Design**	**Design and Development**	Create the product attributes; define the value proposition; satisfy the requirements of the external dimensions; incorporate quality, performance, cost, time-to-market objectives.
	Validate	**Validation**	Test product; ensure that objectives are met; mitigate risks; reduce uncertainty; ensure compliance.
		Pre-commercialization	Prepare for launch; ensure thoroughness; complete process.

Speed is important, but thoroughness and eliminating defects are critical. The NPD process is a documented process which provides a disciplined implementation of the program elements from inception to completion. A good process is one that is based on customer and stakeholder inputs and has an integrated, team-based approach with activities flowing in parallel as far as is possible.

There is no single NPD process that covers the wide variations in new-product types and business environments. Leadership is the magnet that brings the elements together and provides the glue that holds everything in place as the process proceeds from beginning to end. Remember that product innovation is a continuum. Completion may mean closing out one NPD program and starting the next. Leading change means that innovation is a never-ending process.

Notes

1. D. Anderson, Key concepts in anticipatory issues management. *Corporate Environmental Strategy*, **5**:1, Autumn (1997), 7–17.
2. *F. Betz, Strategic Technology Management* (New York: McGraw-Hill, 1993, pp. 70–75). Ford developed the Taurus during the early 1980s using concurrent engineering techniques. Concurrent engineering and the notion of "Team Taurus," which integrated the participants on the team, were the early applications of IPD.
3. This framework is essentially the flow suggested by ISO 9000 and ISO 14000.
4. Betz, *Strategic Technology Management*. This was one of the first examples of IPD.
5. R. Cooper, *Winning at new-products: Accelerating the Process from Idea to Launch*, 3rd edn (Cambridge, MA: Perseus Publishing, 2000, p. 130). Cooper as well as other authors uses similar new-product types. There are other types, as discussed earlier in the book, but these are the essential few.
6. The focus of this book is on process management. An excellent source on project-management techniques for new-product development is the Project Management Institute's manual entitled, *A Guide to the Project Management Body of Knowledge* (Philadelphia, PA: Project Management Institute, 1996).
7. R. Cooper, *Product Leadership: Creating and Launching Superior New Products* (Cambridge, MA: Perseus Books, 1998).
8. K. T. Ulrich and S. D. Eppinger, *Product Design and Development* (New York: McGraw-Hill, 1995, p. 18).
9. A. Khurana and S. Rosenthal, Integrating the fuzzy front-end of new-product development. *Sloan Management Review*, **38**:2, Winter (1997), 103.
10. *Ibid*.
11. A major difficulty during the fuzzy front-end is the lack of clear insights as to the importance of the NPD program and the need to proceed quickly. The investment is low and the clarity is thin.
12. E. R. Corey, *Industrial Marketing, Cases and Concepts*, 3rd edn (Englewood Cliffs, NJ: Prentice Hall, 1991, pp. 4–6).
13. The scope of this book focuses on a standardized (generic) NPD process that relies on technology readily available from internal or external sources. Where the development of the selected technologies is crucial to the success of the NPD process, project-management techniques should be considered unless there is a well-established pathway.
14. Companies have different names for the same construct. The Stanley Works calls the group responsible for such reviews, the "Program Review Board."
15. Trani had successfully transformed GE Medical Systems Division into a global business enterprise with more than $4 billion in revenue. He left GE and became the CEO of The Stanley Works.
16. C. Harrison, The Stanley Works – launching new-product development process. Unpublished (1997), 1.
17. A tollgate is a review step at the end of a phase when the results are evaluated and a decision is made about proceeding or terminating. It is similar to R. Cooper's construct.

18. C. Harrison, The Stanley Works. The PDP shown in the figure is taken from the source document, which contains much more detail. I would like to thank The Stanley Works for its support.
19. K. Simon, DMAIC versus DMADV. www.isixsigma.com/library/content/c001211a.asp. P. Waddick, Six sigma DMAIC quick reference. www. isixsigma.com/library/content.
20. M. Barney, Motorola's second generation. *Six Sigma Forum Magazine*, **1**:3, May (2002). Article is located on www.asq.org/pub/sixsigma/past/vol1_issue3. Six-sigma is a statistical construct that results in approximately three defects per million opportunities. Six-sigma level means that products and processes satisfy the customer 99.999, 66% of the time. A four-sigma company has approximately 6,210 defects per million opportunities. TQM and six-sigma constructs are covered in more detail in Chapter 7.
21. M. Goldstein, Six sigma program success factors. *Six Sigma Forum Magazine*, **1**:1, November (2001).
22. S. Fellenstein, Dishing up success: Six Sigma helps create GE's latest dishwasher. *Quality in Manufacturing*, October (1999).
23. B. Hayes, Six sigma critical success factors. www.isixsigma.com/library/content/c0415a.asp.
24. TQM is discussed in detail in Chapter 7.
25. The graphic is intended to outline the typical or most important relationships. For most corporations the structure is complex and is difficult to map out in a single diagram. Even the graphic shown is complicated.
26. Project Management Institute, *A Guide to the Project Management Body of Knowledge*, p. 94. The Project Management Institute Standards Committee stated that "organizational planning is done as part of the earliest phases."
27. S. Wheelwright and K. Clark, *Revolutionizing Product Development, Quantum Leaps in Speed, Efficiency and Quality* (New York: Free Press, 1992, p. 191.
28. Project Management Institute, *A Guide to the Project Management Body of Knowledge*, pp. 17–22.
29. B. Rich and L. Janos, *Skunk Works: A Personal Memoir of My Years at Lockheed*, (New York: Little, Brown and Company, 1994, p. 8).
30. D. Sobek, J. Liker, and A. Ward, Another look at how Toyota integrates product development. *Harvard Business Review*, **76**:4, July–August (1998), 36–49.
31. IBM Microelectronics Division, *Integrated Product Development Process* (1996).
32. V. K. Verma, *Managing the Project Team* (Philadelphia, PA: Project Management Institute, 1997).
33. *Ibid*., pp. 70–76.
34. *Ibid*. p. 103.

Part II

Establishing the foundation: the conceptual level

At the dawn of the twenty-first century, leading businesses are focusing on innovation as the means for achieving their strategic objectives and obtaining competitive advantages. Strategic management's priorities are shifting from focusing on the product delivery system and selling products to leading change through creativity and discovering new opportunities in the business environment. Conventional new-product development (NPD) approaches are evolving into powerful, comprehensive management processes and techniques that integrate opportunity, innovation, and the development process into highly capable and responsive constructs. For example, General Electric's (GE's) Chief Executive Officer (CEO) Jeffrey Immelt wants GE to focus more on innovation, and to become the leader in introducing new products and services.[1]

The conceptual level involves the exploration of new-product ideas, the maturation of new-product concepts, the selection of appropriate opportunities for further development, and the determination of the overall game plan for the NPD program. The conceptual level as defined in Chapter 2 includes the activities and decisions necessary for laying the foundation for the successful design and development, and commercialization of a new product. The road has many pitfalls, problems, and challenges as organizations have to respond to the ever-changing landscape of demanding customers and concerned stakeholders. The NPD process has to be systematic, yet flexible enough to accommodate shifting requirements over time.

The conceptual level aims at managing Idea Generation, Concept Development and Selection, and Program Definition phases in an integrated fashion that is both comprehensive and expeditious. The front-end phases of Idea Generation, Concept Development and Selection, and Program Definition are essentially intellectual efforts for determining the "why, what, and how" of the NPD program. They are typically analysis-related exercises that are quick and inexpensive.

While the NPD process depicted in this book represents a "standardized" framework, laying the phases out in a manner that facilitates their understanding and application, "world-class" organizations are moving toward even more integration and flexibility. NPD processes in the real world are evolving toward fully integrated NPD processes with as many activities being implemented simultaneously as possible and using strategic relationships whenever possible.

Integrated NPD processes provide a dynamic solution for enabling coordination between all of the participants. As innovators increase their reliance on partners, alliances, suppliers, and far-flung organizational elements, the need for timely and effective development methodologies has expanded dramatically. It means linking people, data, information, technologies, and decision making. New-product development provides a more-exciting, fast-paced reality, offering enormous opportunities for the creative organizations that want to change the world.

Part II describes the conceptual level for generating new-product ideas and turning them into well-honed new-product concepts that become fully articulated candidates. Such candidates are evaluated with respect to predetermined criteria that include business, market, financial, stakeholder, and competitive perspectives.

Part II includes the following chapters:

- **Chapter 4 Identifying new-product opportunities: Idea Generation (Phase 1)**
- **Chapter 5 Concept Development and Selection (Phase 2)**
- **Chapter 6 NPD Program Definition (Phase 3)**

Part II represents the front-end of the NPD process. It is typically an in-depth assessment of the opportunities available to the company that results in the selection of the most fruitful for further development. The front-end also includes mapping out the NPD program in sufficient detail so that practitioners know what is expected and are guided by the process as they implement the program.

Note

1. C. Deutsch, GE research returns to roots. *New York Times*, December 26 (2002), 1–4. http://www.nytimes.com.

4 Identifying new-product opportunities: Idea Generation (Phase 1)

Introduction

Exploring new-product opportunities involves the generation, development, and evaluation of ideas for new products. The fundamental steps include understanding the needs for new products, discovering existing and potential sources of ideas, describing internal and external requirements, and assessing the opportunities. The steps include reflecting on goals and priorities, examining guidelines, resolving problems and conflicts, evaluating ideas, and selecting candidates for further development.

Idea generation represents the genesis of the new-product development (NPD) process. While new-product development is a continuum in many organizations with ideas constantly flowing from individuals, teams, and business units, the Idea Generation Phase is the formal starting point of the NPD process where the ideas are identified, assessed, evaluated, ranked, and screened. New-product ideas are obtained from every facet of the business environment and the organization.

The exploration of new-product opportunities requires an extensive study of external business conditions and trends including understanding market needs and wants, and stakeholder expectations. It also requires a thorough assessment of the internal strengths and weaknesses with respect to the existing product portfolio and capabilities. Occasionally, luck plays a role as well; ideas simply become apparent or occasionally mistakes in the laboratory turn into opportunities. 3M's Post-it Notes are an example of a product line that evolved from the failure to develop a super adhesive. The semi-sticky substance that resulted from the experiments became the perfect material for making detachable notes.

Many NPD opportunities originate from customers and markets that have difficulties with existing products or have needs that are not being addressed. Customers want solutions to their problems; they seek better value from the products and services they buy. Therefore, it is essential that customers and market-related forces play pivotal roles in identifying the opportunities for new products. Solving the defects of an existing product presents an opportunity to create a new one.

Changes in the business environment are also significant sources of new-product opportunities. For example, a new law or regulation may restrict the use of a given material incorporated in existing products, creating the need for a substitute. Opportunities can come from many sources, including customers, competitors, suppliers, distribution channels, related industries, and the infrastructure. International markets are also rich sources of ideas. For example, Proctor & Gamble (P&G) improved its US-based disposable diapers based on insights and lessons learned in the Japanese market.

Technology is a source of new products, especially if technological innovation provides an enhanced means of meeting customer needs. Innovations developed outside the organization or its industry may provide exciting opportunities for dramatic improvements in the prevailing market situation. For example, microprocessor technologies have infiltrated almost every sector of the economy from automobiles to appliances. The processing power of those devices provides manufacturers in many industries with the opportunity to reduce the size of their products, improve overall performance, and/or lower costs. Bendix Corporation invented electronic fuel injection that provided radical innovation in the automobile industry when it was combined with microprocessors to perfect fuel-control capabilities.[1]

Techniques used to find and develop ideas for new products run the spectrum from market-driven approaches to technological solutions and beyond. Market assessment establishes an understanding of the needs for new products. Technology assessment links the organization's capabilities and research endeavors with market needs and external development to create an understanding of potential sources of opportunities. An assessment of the business environment may uncover latent or hidden requirements, or potential opportunities that are not apparent to the casual observer. Amazon.com's extensive use of the Internet during the 1990s demonstrates the phenomenon. It took advantage of being an early mover, using a new business model to provide customers with innovative services that facilitated the search and purchase of the right book for pleasure or professional interests. It changed the time, location, and convenience factors associated with selling and buying books.

Idea generation is open-ended with less structure and definition than the other phases. Given that creativity and out-of-the-box thinking are essential parts of idea generation, the lack of a precise pathway is not a limiting factor. However, it is important to have a well-established flow of activities and techniques for executing the elements of the phase.

The initial steps of idea generation are often a carryover from the Strategic Logic and Alignment Phase. The basic requirement is to affirm the foundation for generating ideas. The more difficult step is to discern a pathway from the starting point through the creative steps of identifying and articulating the new-product opportunities, evaluating the candidates, and selecting high-potential ideas for further development during the Concept Development and Selection Phase.

The Idea Generation Phase provides structure for the discovery of ideas, which is critical for organizations that are seeking a comprehensive approach for accelerated product development. The methods and techniques discussed in this chapter provide the mechanisms for achieving the necessary balance for obtaining suitable ideas. If the process is not structured properly, idea generation takes too much time or it is not able to identify the right opportunities; if it is too structured, creativity may be restrained. In either case, product innovation suffers.

The Idea Generation Phase includes the fundamental methods for developing and analyzing new-product opportunities. The elements described in this chapter provide the foundation for subsequent chapters.

Chapter 4 includes the following topics and learning objectives:

- Understanding the needs and requirements of customers and stakeholders and how they are sources of new-product ideas.
- Exploring methods for identifying new-product opportunities.
- Developing a systematic process flow chart for idea generation.
- Determining the methods for ranking and rating the candidates for selection.
- Selecting candidates for the subsequent phase.

Setting the stage for the NPD process

The Strategic Logic and Alignment Phase provides the foundation for the NPD process. It defines the business and product areas of interest, and establishes the strategies, objectives, goals, and direction. The first step in the Idea Generation Phase is to link the NPD process to the strategic logic of the organization. This transitional step reaffirms the strategic drivers. It identifies the strategic requirements for new products and describes the new product categories that should be addressed. It also stipulates the strategic needs of the organization. Table 4.1 identifies the key elements. It is a derivative of Table 2.11; however, the focus is on product opportunities.

In setting the stage for identifying new-product opportunities and the Idea Generation Phase, the organization requires guidance from senior management on the product/market segments to examine and the types of new products to explore. The NPD strategies and policies define the range of categories that fit into the organization's capabilities and the general needs or strategic gaps that have to be fulfilled by new products. The market-leadership position is always a significant strategic question. Does the organization wish to lead or to follow with its new product(s)?

Goals and objectives define the categories that are most crucial and express the specific targets that are to be achieved. The overarching goal is to improve the value proposition of new products. Value, performance, and benefits objectives are often tied together. Management may state that the new product must reach the market in 24 months or that the quality of the new product must be less than ten defects per million opportunities for defects. It may also establish the level of risk that is tolerable in terms of total investment or impacts on the business. For example, the company may

Table 4.1 *The linkages between strategic logic and the NPD process*

Categories	Elements	Significant questions
Objectives and goals	Value and benefits Performance and quality Financial and risks Time to market Investments	What are the most important objectives and goals? Are there new-product types that must be addressed?
New-product strategies	Market focus (segments) Product positions New-product types Leadership position	What are the directions and expectations of the overall program for developing NPD? What are the guidelines?
Functional strategies/ objectives	Product/market Marketing Production Financial	What are the functional strategies and objectives? What is the NPD process?

stipulate that the NPD opportunity cannot risk more than 10% of the available cash flow.

The functional strategies for new products often involve the internal needs of the organization. The marketing area may want a new product to complement the existing product lines in order to defend against aggressive competitors who are capitalizing on the organization's weakness in not providing a complete package of products. Production may need a counter-seasonal product to balance its manufacturing capacity. Engineering may need to equalize its workload. Finance may want a new product that improves long-term cash flow. Each area may have its own agenda that must be defined and managed.

Many organizations reflect on their aspirations without thinking about limitations. Limitations are potential sources of difficulties. The organization may lack certain capabilities and resources or have a weakness in a specific area which will have a significant impact on the NPD process. A lack of financial depth is a typical limitation. For example, when Chrysler designed and developed the LH models, it did not have sufficient cash flow to implement the entire program. It depended on its suppliers to develop many of the components under strategic partnership arrangements. The suppliers invested their capital to complete the design work so that they could have the long-term benefits of supplying production components.

The initial activities include defining the barriers that may have an impact on the NPD process. Whereas this is part of the Program Definition Phase as well, it is critical to identify the barriers as soon as possible and find solutions to improve the prospects of success.

Financial goals in particular must be clearly stated. The financial goals are often the most critical metrics and are used as screening criteria to evaluate acceptable candidates.

The typical financial goals include profitability, gross-margin per cent, net present value, and internal rate of return as outlined in the Supplement to Chapter 6. Financial applications and implications are examined in detail in Chapter 10.

The Idea Generation Phase flow chart

The primary objective of the Idea Generation Phase is to provide an expeditious means of identifying, describing, analyzing, and evaluating the external dimensions and the strategic, market, technical, organizational, managerial, informational, legal, and systems requirements of the new-product ideas. It is a conceptual approach for transforming hazy ideas into meaningful new-product candidates. The challenge is to find and explore innovative new-product ideas that have the potential for satisfying customer and stakeholder expectations, and quickly convert them into candidates for further development or eliminate them from consideration.

While there is a logical sequence that should be followed for idea generation, there is no single best flow for generating new-product ideas. Most of the key elements can be managed concurrently and integrated at the culminating steps when the ideas are rated, and ranked, and the best candidates selected for further development. It is recommended that organizations generate pathways that meet their unique requirements and provide flexibility and creativity.

Management establishes a framework that meets the requirements of scope and content of the NPD program, and then lets the organization (NPD team) decide what should be included and what works best for them. The prime purpose of the framework during idea generation is to readily uncover opportunities without a lot of unnecessary duplication between functional organizations or using excessive internal and external resources. The typical management methodology is to define a general protocol, giving only the minimum level of detail necessary to ensure that the essential factors have been covered.

Figure 4.1 provides a general flow chart for idea generation (Phase 1) identifying the most important elements of the first phase of the NPD process. The flow chart consists of identification and delineation of the essential dimensions; including product, market, stakeholders, suppliers, competition, infrastructure, and related industries. It culminates in the selection of new-product candidates (opportunities) that move on to the Concept Development and Selection Phase.

The flow chart also details the aforementioned dimensions as they relate to the internal dimensions: strategic, organizational, technical, marketing, production, and financial (the internal dimensions are listed at the top of the flow chart). It links the internal and external dimensions in a two-dimensional matrix that provides the concurrent development of the content and decisions of an NPD program. The flow chart is a simple device for ensuring that all of the elements are covered in a logical way. Moreover, the

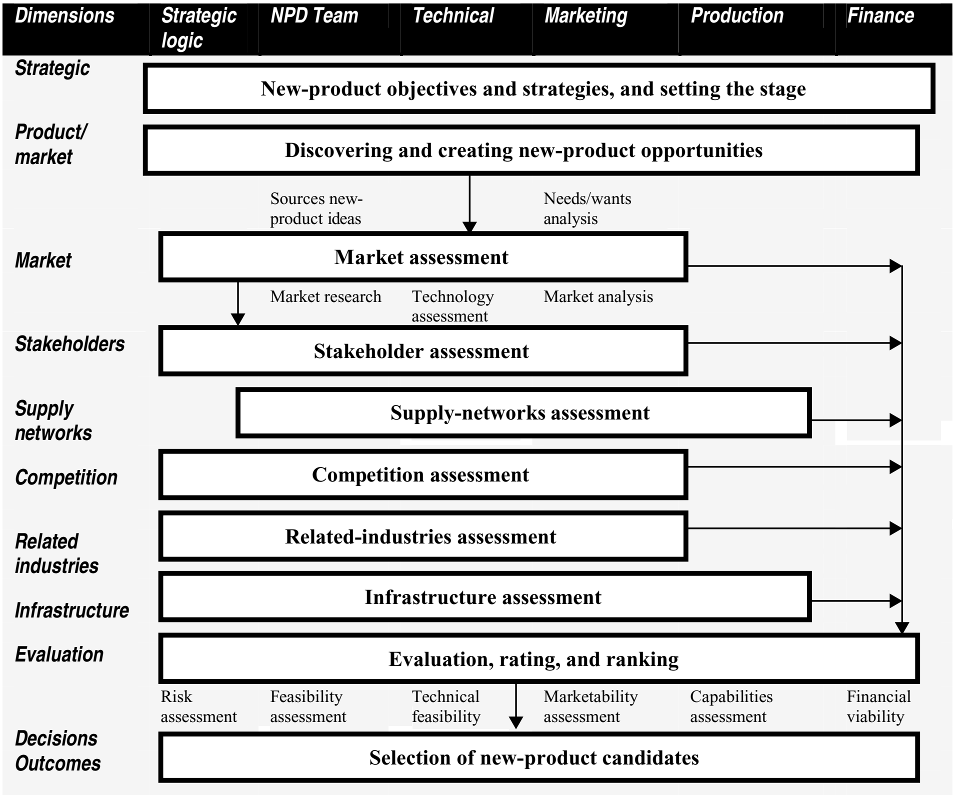


Figure 4.1 Idea Generation flow chart (Phase 1)

flow chart prescribes the preferred sequence, if the elements cannot be implemented on a concurrent basis.

Discovering and creating new-product opportunities

Understanding customer needs

Customers desire/expect products that provide much better solutions in satisfying their underlying expectations. The primary needs and wants are often expressed directly and are clearly defined and understood. For instance, the need for milk and bread is obvious and is based on the human condition and the need for subsistence. However, latent needs are more difficult to determine and often require the new solution before the need can be fully articulated. The development of new technologies opens the doors for stimulating customers to seek new solutions for old problems or to find new possibilities for satisfying their needs. Customers want products with features, functions, and benefits that provide complete satisfaction (the features, functions, and

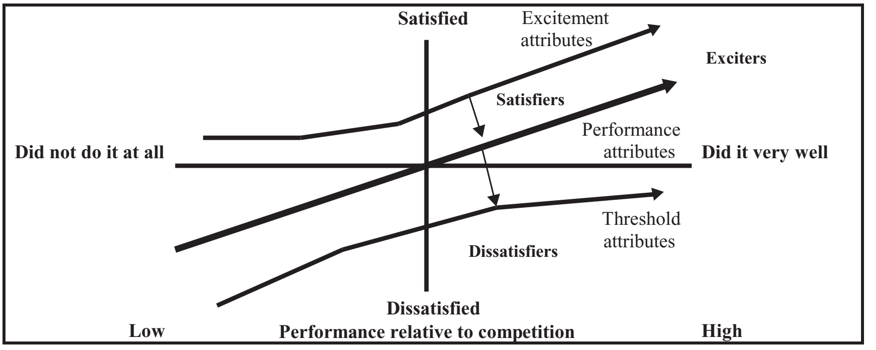


Figure 4.2 The Kano diagram: evolution of attributes

benefits are called “product attributes”). However, perfection is a dream that remains elusive although the general trend for new products is very positive and is moving in the direction of dramatically improved products with much better solutions. Customer needs and wants are continuously changing. The Kano diagram shown in Figure 4.2 is an excellent tool for understanding customer perceptions about product attributes as they evolve over time.[2]

The diagram suggests that the new-product attributes offer customers incredible enjoyment when introduced, but become commonplace over time as customer expectations proceed to the next level and competitors emulate the success of the offering. According to Kano’s description of the phenomenon, the “exciters” (unique attributes) become the standard or expected “satisfiers,” which may eventually drift into being “dissatisfiers.” The best example is the coffee-cup holder in automobiles. The original innovation brought a unique status and feature to models that had them. They provided exceptional satisfaction. Approximately 20 years later, few customers think about coffee-cup holders since they are available in most cars. The story is complex, but the message is simple: producers cannot rest on their laurels or on previous successes given the dynamics of the business environment and global competition. The benefits of a competitive advantage dissipate quickly as customers and markets change and competitors catch up. The automatic shut-off device in electric irons is another excellent example. When it was introduced, the safety device was an exciting new feature. Over time, government mandated that all irons have such devices and it became a threshold attribute.

Identifying new-product opportunities begins with a review of existing products and services.[3] This step is often part of the Strategic Logic and Alignment Phase during which the existing product portfolio is examined to assess short-term difficulties, long-term vulnerabilities, and near-term opportunities and needs. The assessment should highlight preliminary candidates that trigger the start of the Idea Generation Phase. In most cases, some of the existing products have to be refreshed, repositioned, or replaced. Other products in the portfolio are reviewed to determine if there are any specific problems or difficulties requiring corrective actions.

Products have both tangible and intangible benefits. The tangible benefits usually relate to the physical characteristics of the product, and its fit, features, and functions. The intangible benefits are the psychological aspects. For example, a new high-specification personal computer provides functionality and speed along with the intangible benefit related to the feeling of owning the latest technology or of being the first on the block with the newest model. BMW discovered in the early 1990s that it was more successful when it was selling new models because its German customers enjoyed the prestige of owning the first of its kind or a new version of an existing model. Understanding customer needs is essential for identifying opportunities for new products. These concepts are explored in more detail in the next chapter.

Sources of new-product ideas

Product/market sources

The most obvious sources of new-product opportunities are the existing product lines. Solving problems, repositioning products, serving new market segments, meeting new needs and wants, and providing additional benefits and performance are all sources of new-product opportunities. Using existing products as sources for ideas provides a means of leveraging the knowledge, capabilities, and resources related to those products and to the organization. An organization usually has a significant database and knowledge associated with its product portfolio and that information can be used to facilitate its analysis of new-product opportunities.

Identifying problems with existing products is a simple way of discovering opportunities for changes and improvements. Problems associated with existing products create negative impacts on the internal functions, such as difficulties in manufacturing or with marketing and customer applications. Such problems make the products less attractive, create liabilities, and possibly damage the reputation of the organization. Problem solving often has a big payback in improving customer satisfaction, protecting the product portfolio, and obtaining financial rewards. Another primary source of new-product ideas is available through examination of customers and markets to identify unsatisfied needs. Examining customer and stakeholder needs is a fundamental method that is used throughout the NPD process.

Repositioning an existing product within a market segment may improve its potential and long-term viability. Cost cutting is often a simple way to reposition the product as a result of a performance-to-price ratio that is better than its previous position. Such new-product opportunities are highly leveraged and can be easily justified in most cases because they are based on current capabilities and resources.

Finding new market segments for the product involves a more-detailed analysis of the external factors and the needs of the new segment. Such efforts are usually based on the solid foundation of product knowledge and internal capabilities, minimizing the

Table 4.2 *Sources of new-product opportunities*

	External perspective	Internal perspective
Product related	Introducing new-product line	Developing new technologies
	Expanding scope of the product	Improving production capacity
	Developing standard product	Securing new capabilities
	Creating new packaging	Finding substitute materials or parts
	Adding new features	Finding new sources of supply
Market related	Repositioning in existing segment	Solving existing problems
	Serving new market segments	Finding new distribution channel
	Adding new benefits	Establishing new relationships
	Meeting new needs and wants	Leveraging resources
	Lowering prices	Providing service support

product-related efforts, but require significant adjustments to the external perspectives and the marketing campaign. The new market segment may have an entirely different make-up from an enterprise perspective. There may be significant differences in the wants and needs of customers and stakeholders. There may be different competitors and related industries.

As customer needs change due to pressures in the global business environment, products have to be modified to accommodate the new requirements. Depending on the nature of the new requirements, the implications for the product and its marketing vary considerably, from simple changes in the product attributes to a complex array of new specifications requiring an elaborate NPD program to manage the changes and their impacts.

New-product opportunities arise from internal changes, from developing new technologies, or from adding new capabilities – such as acquiring new supply networks for distributing the product in the market place. Likewise, the external business environment drives change through ongoing demands for better products and value. The dynamics of the market place offer the richest sources of opportunities for new product.

Table 4.2 lists some of the sources of new-product opportunities from a product/market view and from internal and external perspectives. The matrix focuses on the product- and market-related aspects, as well as the general source of the ideas.

Each time an employee addresses a customer need or makes contact with customers, there are opportunities for obtaining ideas about new products. Likewise, contacts with suppliers, distributors, and others in the value system provide the means to discover betters ways of offering products and services.

External sources of new-product ideas

The enterprise-management model (EMM) described in Chapter 2 provides an excellent framework for examining the external sources for NPD opportunities. Continuous changes in the business environment create new opportunities. Such changes have to

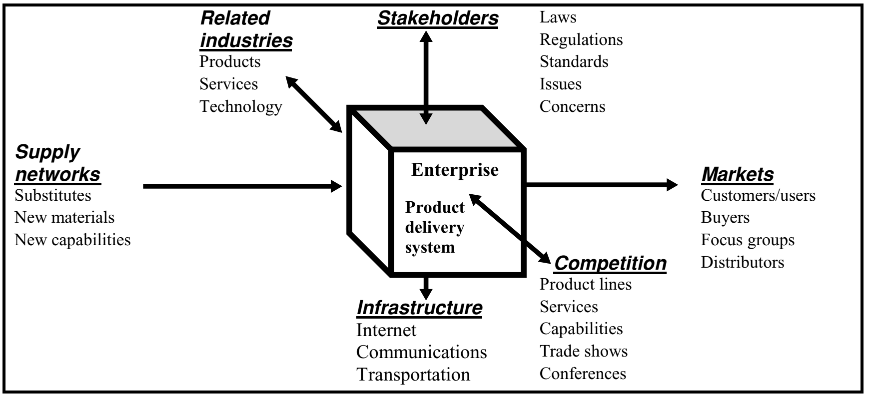


Figure 4.3 Sources of new product ideas using the enterprise-management model

be tracked and identified as sources of new-product ideas. As a simple example, new federal regulations published in the Federal Register in the United States and similar documents elsewhere mandate new requirements. NPD professionals or other specialists should keep up to date with the changes in regulations so that any implications or impacts can be translated into positive outcomes through new products and services. On the other hand, failure to track such changes may create vulnerability in the existing product portfolio.

Figure 4.3 shows selected sources of new-product ideas based on the critical external dimensions of the EMM.

Customers are a rich source of new-product ideas. Given that the majority of new-product opportunities are market driven, it makes sense to look to customers for new ways of serving them. Customers are not all the same. Customers may find problems associated with the current products, identify new uses for existing products, describe the functions and benefits they expect, and provide other ideas for additional improvements.[4]

Historically, sales and marketing were the primary conduit to markets and customers, providing the interface between the organization and the customer. However, limiting customer contacts to sales and marketing may block a significant amount of dialogue with the operating level of customer organizations. Sales and marketing have only a limited exposure to customers. They deal with buyers, managers, and executives. The real source of ideas often lies with the actual customer users who may be difficult to reach without coordinated efforts.

The company's service personnel may have day-to-day contact with the maintenance people in customer organizations who understand the positive and negative implications and impacts of the existing products. They can suggest improvements and ways to solve problems. The fact that the technical people interface with each other may garner opportunities for linking market information with the NPD programs.

Industrial customers are often developing new products themselves which require contributions from their critical suppliers. Early involvement with "leading-edge" inputs often provides the innovator with the ability to capture "first-to-the-market" advantages.

In addition to a broad examination of customer contributions, identifying leading-edge customers may lead to discoveries that are not apparent in the mainstream of product usage. Lead users may be dissatisfied with the limitations of existing products and may have found ways to improve existing product situations with ingenious innovations. Those innovations may be desirable solutions for other customers. Eric von Hippel of MIT developed the technique of "lead user" as a means to identify breakthrough ideas for new products.[5] Von Hippel and his associates conducted several studies to show that lead users generate outstanding new-product ideas that provide opportunities for achieving superior results.

Channel distributors can provide insights into new ways of delivering the product. There may be new methods or processes for reaching customers, like the Internet or other telecommunications solutions. Such means could provide opportunities for improvements or even radical changes to the existing product delivery structure. Dell Computer became the lead supplier of PCs in 1999 through its focus on direct marketing.

Competitors are also good sources of new-product ideas. An analysis of the product lines of competitors may provide insights into their NPD programs and product attributes, and the unique benefits that they provide. Such information may show where there are opportunities for capitalizing on their new-product initiatives, for countermanding such initiatives, or for discovering gaps in their product lines. Such revelations may suggest opportunities for exploiting the competition and improving product offerings. However, not all gaps represent viable positions. Gaps in product lines may be due to fundamental market factors indicating that there isn't an opportunity for a new product. A simple scan of the competitive-product offerings may suggest that there is room for a new product, but, in reality, the space represents a non-viable position. For example, there are very few two-seat coupés that are not intended to be sport-type cars. Daimler-Chrysler has developed the Smart Car, which is targeted as a small-sized coupé for congested cities where parking is a major concern. The Smart Car might be successful in Germany, given the density of the population and the relatively short distances between the cities.[6] The key question is whether a demand exists for such a car in America.

As with customer contacts, information and details about competitors are not just the domain of sales and marketing. Support services and technical personnel often become familiar with competitive products as they service products for customers. They can compare and contrast the various products of their customers. Such information can be a valuable source of ideas.

R&D and engineering staff can provide insights about the competitor's design by tearing the product down to its basic components and use the concept of "reverse engineering" to determine how it was designed and built.[7] The information gleaned during such a procedure includes the technical design, the product characteristics, functionality, sources of the components, the product cost structure, and the financial implications. Such information provides both strategic and operational inputs into the NPD process and the sourcing of new-product opportunities. It provides data on the range of cost structures for similar products, helping with the determination of a new product's feasibility. A quick assessment may suggest that certain products do not warrant expenditure of time, effort, and money.

Trade shows and conferences provide current information about competitors, their capabilities, and their products. In an attempt to provide potential customers with an awareness and understanding of their offerings, competitors often disclose an enormous amount of valuable information to the public through various formats including the web pages on the Internet, brochures distributed during trade-shows, and articles in the trade publications.

Developments by supply networks represent opportunities to improve products or create new products. New materials may provide solutions to existing problems or offer new features and benefits. The aluminum can was a more expensive material than the steel can, but being lighter it proved to be the best solution from a total-cost perspective. Plastic containers are superior to glass in many applications, especially when breakage is an issue. Suppliers' R&D programs may lead to improvements that provide new ways to incorporate their materials in the product lines of their customers. Such improvements or substitutes offer new opportunities for users of those materials. Strategic arrangements with suppliers may lead to innovations that might not be possible without collaboration. Joint development programs lead to innovations based on a cross-fertilization of ideas. For example, Lipton Tea worked with the Dexter Corporation, its supplier of tea-bag paper, to develop new options for tea bags. The early integration of suppliers into the NPD process provides insights about fundamental changes in materials or components.

Scanning related industries provides a rich source of innovation. Developments of new technology or new products often provide exciting prospects for developments in other industries. Electronics have made an impact on most industries, providing solutions that are smaller, faster, and more economical. The microprocessor is the quintessential product of the last quarter of the twentieth century. Demand has been so prodigious that most durable products have some form of microprocessor for simplifying and enhancing features, functions, and benefits.

The infrastructure likewise offers significant sources of new-product ideas. The global expansion of telecommunications, along with the reduction of the cost structures, offers means of developing new products that were not available just a few years ago. Telecommunications are pervasive. They provide the means of getting ideas from customers, collaborating with suppliers, solving problems for stakeholders, etc. It is the glue that facilitates transactions and interactions. The Internet is becoming a ubiquitous means of communication. Its growth provides new ways to reach customers and provides products and services on a low-cost basis. The Internet and the World Wide Web provide large corporations, and also entrepreneurs, with options for launching a new product that do not require a huge up-front investment.

Stakeholders are a vital source of new-product ideas. Obviously, changes in government laws mandate changes in products. The driving forces behind low-emission automobiles are the various government initiatives to improve air quality in the United States, Europe, and Japan. The automobile industry is responding with research programs and new-product offerings to achieve the proposed standards. The Honda Insight is an ultra-low-emission vehicle developed in response to the clean-air regulations in Japan and the United States. Similarly, there may be new-product opportunities when governments eliminate rules and regulations. The existing products may not be suitable after deregulation.

Stakeholder expectations are very broad and reach beyond the government sector. Industry pressure (public interest) groups often press producers to change, reduce, or eliminate certain products or practices. For example, certain cosmetics manufacturers were persuaded to eliminate animal testing as part of their NPD process. Typically, stakeholder groups are viewed as a negative force. This perspective possibly comes from the activities of the many environmental groups campaigning against toxic substances and hazardous waste or opposing specific products like sport utility vehicles. In contrast, stakeholders may strongly advocate a new product. They may endorse a perceived solution to a problem or an improvement to existing conditions. For example, customers may not care about a plastic beer bottle replacing the traditional glass bottle, but groups concerned about safety may. Given the incredible number of stakeholders, the benefits of exploring their perspectives can be large and can lead to many significant findings.

Proctor & Gamble (P&G): the threat to disposable diapers

The threat to P&G's line of disposable diapers was a serious business concern during the late 1980s and early 1990s. According to P&G's 1991 annual report, sales of disposable diapers represented 17% of P&G's revenues or approximately $4.6 billion. When first introduced in 1961, Pampers was viewed as the ultimate new product being superior in every way. As the solid-waste disposal problems grew during the 1980s with the closing of landfills, external pressures exposed the principal weakness of the disposable diaper: it was not biodegradable.

P&G's initial steps to improve the environmental quality of Pampers and Luvs were dramatic. The Ultra brand was introduced, using only 50% of the materials, and in 1989 the packages were compressed into tightly packed plastic bags, reducing packaging materials by 80%. However, the basic problem remained. Notwithstanding those improvements, consumers, environmentalists, and state legislatures were still concerned about the environmental effects of disposable diapers. Nebraska enacted a law banning non-biodegradable disposable diapers. The law was to take effect from 1993. Other states proposed similar initiatives but the laws were not enacted. While P&G claimed that Pampers and Luvs were 80% degradable, there was widespread belief that the 3.5 to 5 billion pounds (1.7 to 2.3 billion kg) of disposable diapers that end up in landfills would not degrade. In order to mitigate its negative position, P&G commissioned Arthur D. Little, Inc. to study the environmental, health, and economic impacts of disposable versus cloth diapers; the study found that there wasn't a clear advantage to either. Knowing that most of the materials in disposable diapers are organic and that only the plastic is non-degradable, P&G focused on composting as an alternative.

P&G conducted several tests concerning the "compostability" of the disposable diaper. Being expert at market testing, the company used field results to determine the feasibility of composting. With positive responses, P&G was confident that they had a viable solution. Studies confirmed that Pampers and Luvs diapers were compostable when the plastics were screened out during the composting process. As with most solutions, P&G had to close the loop on improving the position of its disposable diapers. P&G cooperated with consumers, retailers, environmental groups, community leaders, and government officials so that the company's stakeholders had a voice in the solution. Communications with stakeholders was a vital element in the overall solution. Consumers had to be encouraged and convinced that the compostable disposable diaper was an effective solution. While P&G is still working on the solution, its overall efforts have dramatically improved the quality of its products.

Sources from an internal perspective

New-product ideas may come from strategic management, R&D development, engineering, marketing, production, finance, service support, employee suggestions, etc. From an internal perspective, sources of new-product ideas can come from upstream processes, downstream processes, and the strategic process. Figure 4.4 indicates the key internal sources of new-product ideas from a process-management perspective.

The strategic process includes analysis of current capabilities and product positions as discussed in Chapter 2. The insights gleaned from the analysis opens the door to new-product opportunities. Strategic management creates the vision that defines the overarching needs for new-product opportunities and they often participate in creating new-product opportunities. Licensing technologies, buying companies with technologies and products, and other related strategic initiatives are ways in which executives help create opportunities.

Many internally driven new-product opportunities originate in the upstream processes and activities of the organization. Upstream processes are those that provide information, resources, and linkage to the front-end of the NPD process. For example, R&D initiatives for developing new technologies are eventually transformed into new-product initiatives. The new products may be replacements for obsolete or very mature products that no longer meet the organization's objectives or satisfy the needs of customers and stakeholders. The revisions to the Ford Taurus in 1996 were made in recognition that the original design of the 1980s, which had been modified in 1992,

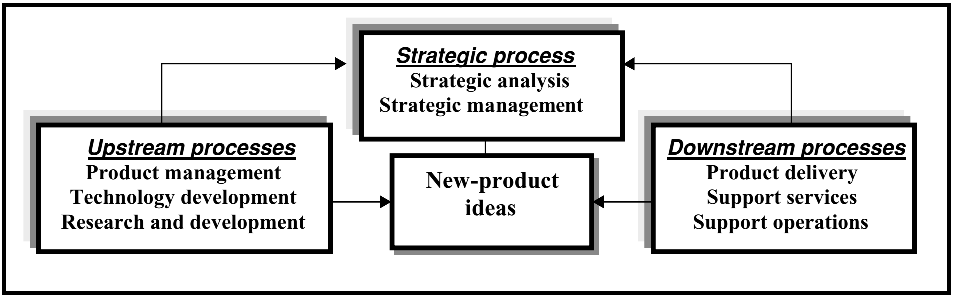


Figure 4.4 Internal sources of new-product ideas

was tired and lacked context with the customers of the 1990s. The Taurus had been the market-share leader in its category but was struggling to maintain its position.

Employees involved in downstream processes and activities are a rich source of ideas. Downstream processes are those that support existing products through the product delivery system and related activities. Based on their knowledge and experience, they often have suggestions that lead to improved products or new ones. Employees who deal with the product delivery system possess information about the products produced and delivered by the system. Such knowledge can be exploited to discover opportunities for improvements or innovations. Sales, marketing, production, support service, etc. personnel can provide insights about improving the effectiveness of the system and the products. This includes employees at all levels, not just the professional staff. Communication links between such employees and the NPD organization(s) are crucial. Often the people with the greatest insights about customer needs (service, support, and sales personnel) have limited access to the NPD efforts.

Brainstorming

Brainstorming is a popular way of exploiting the organization's knowledge of its business environment. The approach is simple and straightforward, using informal and formal methods. Employees from prescribed areas of the organization related to product development, or in certain cases all employees, are solicited to provide suggestions and ideas for new products. Brainstorming requires an open exchange of ideas without negative feedback or adverse consequences.

Informal methods tends to be open-ended constructs. Employees are encouraged to provide "out-of-the-box" ideas and express their thoughts freely without regard to feasibility or merit. Such methods are very useful for organizations seeking a wide range of alternatives especially ones that are not based on the existing situation. They are typically used when the organization is trying to be entrepreneurial by developing new-product lines or even new businesses. Open-ended methods take more time and effort, but may lead to some thrilling new alternatives. They tend to be bottom-up approaches with participants controlling the inputs. This encourages creative thinking and innovative solutions to business challenges.

Formal approaches are more systematic. The participants are directed in their efforts to discover new-product ideas and are often required to respond to questions that frame the responses in a given direction. This is particularly the case when the potential NPD programs are based on the existing core competencies and core capabilities of the organization, which are extremely powerful and provide the means for achieving superior results. The formal methods tend to be more efficient and productive, but their strengths are also their limitations. Formal methods tend to impinge on creativity by structuring the responses. Participants are forced to keep within the boundaries established by the management. Formal approaches are often top-down methods focusing on areas that senior management wants to concentrate on. For example, Pratt & Whitney (P&W), a major producer of jet engines for the airlines and the US Military, has a well-defined scope of business. Its product lines are very narrow and new-product opportunities are related to a small set of choices. When exploring new-product ideas, P&W has a defined space for the potential candidates. Moreover, due to the significant investment required to produce a new product, the company focuses idea generation in targeted areas. Brainstorming in such cases tends to be very narrow.

Market assessment

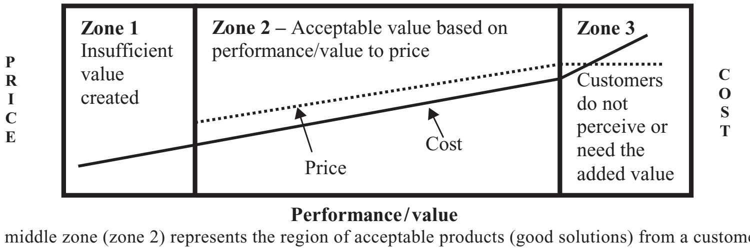
Value analysis

Value analysis explores the value that customers derive from existing products and potential new products, and examines the performance/benefits they receive in terms of the price they have to pay (the value proposition). Within the relationship of value to price, there may be an opportunity for additional products, or changes to existing products, to serve segments of the market not being satisfied. The key to value analysis is finding new avenues to generate more benefits or fewer defects. Is there a better way to design, build, and deliver the product? Is the value proposition adequate?

Figure 4.5 provides an excellent view of value proposition as it pertains to products and market space. The middle zone as depicted in the graphic represents acceptable value. In zone 2, customers receive an appropriate level of value for the price that they have to pay.

Zone 1 represents inferior products that customers are not willing to buy regardless of the price. Zone 3 represents products that have so many “bells and whistles” that add to cost and price but do not add to value. Customers are unwilling to pay more than a certain amount to fulfill their needs. The extras are unnecessary. Generally, customers are seeking more value and performance for their money.

A shift in the performance-to-price relationship to the right may open opportunities to serve customers with new products that offer new advantages; more for less. The more value customers obtain the more willing they are to buy the products that meet their needs. The history of the personal-computer industry has been one of improving



The middle zone (zone 2) represents the region of acceptable products (good solutions) from a customer perspective. The left-hand area (zone 1) is the zone where there is insufficient value or performance generated to provide the minimum level of customer satisfaction. The left-end of zone 3 represents the maximum performance or value that customers are seeking. Going beyond that limit (the left boundary to zone 3) increases the cost of the product, but customers are unwilling to pay more for the additional features, functions, or benefits. Moreover, in many cases, the extra performance or value, if any, is not worth the additional price.

Figure 4.5 Price and cost: profit versus value[8]

the performance-to-price relationship of the products so that more customers can afford to buy one.

Customers seek benefits, not product characteristics. Air conditioners provide a good example of this perspective. Customers purchase air conditioners because they wish to enjoy the comforts of the conditioned air. They want the solution but do not really want the device itself. Air conditioners are loud, bulky, and expensive to operate, but customers are willing to put up with the difficulties because they enjoy the benefits.

Necessity is the mother of invention: the Honda hybrid vehicles

Numerous states, as well as many other countries, have enacted clean-air laws in an attempt to reduce hazardous air pollutants such as carbon monoxide, hydrocarbons, carbon dioxide, sulfur dioxide, and nitrogen oxides. Such legislation forced automobile manufacturers to develop low-emission vehicles (LEVs). Even cleaner categories have followed, including ultra-low-emission vehicles (ULEVs) and super-ultra-low-emission vehicles (SULEVs).

In response to the need for cleaner-burning vehicles, Honda developed the Insight hybrid electric vehicle (HEV). The Insight uses a gasoline engine to recharge batteries, and regenerative braking to capture energy during the normal braking process which most vehicles simply throw away. The Insight has a traditional transmission that uses power from an internal combustion engine, but then draws supplemental power from its batteries to increase gas mileage to 61 m.p.g. (26 km/l) in the city and 68 m.p.g. (29 km/l) on the highway.

Other hybrids currently available include the Toyota Prius and the Honda Civic hybrid. Ford has developed a hybrid sedan as well, and plans to introduce a hybrid SUV in fall 2004.

Source

Lake, M., A tale of two engines: how hybrid cars tame emissions. *New York Times*, November 8 (2001), G7.

Market-research methods

Market research for finding new-product opportunities

Since the market is a primary focus for new-product ideas, market research provides an outstanding means of understanding the needs and wants of customers in specific market segments. Market segments are the specific targets within a market that represent the new-product opportunities. Customers have a wide variety of choices for solving their problems, but in most cases, there are shortcomings in the existing products which provide opportunities for improvements or new ways to achieve the desired results.

Market research is used to determine the manifested and latent customer requirements so that the new products might incorporate the features, functions, and benefits that provide outstanding customer satisfaction. Depending on the specific purposes and objectives, the market research might have a narrow focus or be more open-ended with a broad perspective, seeking as much knowledge as possible. If there are well-defined areas of interest specified during the strategic logic phase, searches tend to be highly structured in scope and range. For example, during the late 1980s, Boeing had a clear understanding of what kind of new-product opportunities it wanted to explore. The new product, the Boeing 777, had to fit into the strategic logic of corporate requirements as well as meet the needs of the existing market structure. The search for information pertaining to that situation was very narrow and was clearly defined by the nature of the requirements.

If the needs for new-products are more open-ended, cutting across various market segments, then the scope of the market research is not as easily defined and the efforts are more difficult to structure. However, even in the case of an open-ended search, guidelines should be provided to the researchers that define the level and scope of the activities. The guidelines may specify the markets to be examined or the areas to be explored. Regardless of the situation, limits have to be identified so that the market-research activities can be completed in a relatively short period of time. Time is often the limiting factor. The open-ended approach is also used when the organization is trying to break out of its existing mold by seeking to satisfy customers in more-dynamic ways or by changing the current business or product portfolio. For example, Monsanto wanted to reinvent itself by moving into biotechnology. It wanted new products that provided customers with unique solutions to their problems and contributed high margins to Monsanto's financial situation. Monsanto executed an orderly transformation of its product portfolio from commodity, synthesis-type chemical products to proprietary products serving speciality market segments.

Market research used for discovering NPD opportunities requires technical precision, thoroughness, and balance. The fundamental objectives are to learn as much as possible about the customers and the market segments and to discover salient aspects of the needs and wants including the physiological and psychological elements.

Sources of information	Existing data (secondary)	Customized data (primary)	Cost
Internal	Company databases: records, reports, analyses Marketing programs for current products New-product plans Strategic plans Research and development	Interviews with key people Surveys of employees Panels of professionals Consultants Partners	**Low** ↓ **High**
External	Government documents Annual reports, 10k reports Internet websites Trade associations Publications, trade journals Advertizing agencies Professional research firms University research	Mail surveys Telephone interviews Personal interviews Focus groups Expert panels Research studies Market analyses Contract studies	**Low** ↓ **High**
Cost	**Low** →	→	**High**

Figure 4.6 Sources of information for market research

Activities must be balanced so that all of the goals of the NPD process are achieved. Cost considerations are critical as well. For the typical NPD situation, research has to be done quickly and at a low cost, at least during the Idea Generation Phase. Figure 4.6 lists the main sources of market information, these are divided into internal and external sources of information and whether the data exists or has to be developed.

Costs tend to increase as the sophistication of the research methodology increases. Obtaining existing data from internal or external sources is generally the most cost-effective means for exploring new-product opportunities. For most industries and markets in developed countries, there are an enormous amount of data and information in the public domain. Government agencies like the US Department of Commerce publish documents on industry activities based on Standard Industrial Codes that provide market data and relevant information about the conditions and trends in given industrial segments. The US Department of Labor provides detailed information about labor and industry statistics. The US Environmental Protection Agency provides insights into, and outlines the implications of, regulatory requirements that may offer opportunities for products and services.

Trade associations provide a rich source of information about their members and the industry or group they serve. Many trade associations publish almanacs covering the developments during the previous year along with the fundamental statistical information pertaining to the activities of the association. The typical information includes market size, growth rate, principal competitors, buyer behavior and patterns, technologies, etc. For example, the Computer Industry Almanac, Inc. publishes an annual almanac of approximately 750 pages providing industry information about products, people, companies, technologies, and forecasts.

Annual reports on competitors, potential customers, and market participants are excellent sources of information about the key players in the selected market. For large companies, the amount of detailed product information tends to be limited because the general structure of the reports focuses on the corporate level. Such reports are intended to provide financial results and generalized information. In certain cases, “10k” reports and other reporting requirements provide more detail than the annual reports. Product brochures and web pages also offer significant insights into the products and processes of competitors, suppliers and related enterprises.

Trade journals and related publications tend to follow the trends in given industries and provide rich sources of information on activities, processes, and events. They often disclose full market data including market structure, statistics, and performance. Many professional research organizations develop market information on a contract basis or provide multi-client studies on selected market segments. In both cases, the costs are relatively high, but the data are generally tailored to specific requirements of the NPD activities. For example, in the computer industry, the Gartner Group of Stamford, Connecticut provides high-quality research and industry reports for clients willing to pay a fee for the information.

University research is a substantial source of information and analysis. Academic scholars and researchers conduct surveys, analyses, and studies of companies, industries, and economies to facilitate a broader understanding of the research phenomena and their implications. Case studies also provide significant insights into the realities of current business practices and programs and offer feedback on the experiences of innovators and practitioners.

After exhausting readily available mechanisms for tapping existing sources of information and data, more expensive, customized sources can be sought to fill in the blanks. In certain cases, a well-tailored approach for obtaining the appropriate information may indeed lead to the best solution for getting results in a timely and cost-effective way. It is dependent upon the situation and the balance between saving time and money.

Internal resources often provide the fastest and least-costly means for obtaining the information being sought. This is particularly the case for NPD programs that are highly leveraged on existing product lines or capabilities, where there is a wealth of internal knowledge. Using internal databases is less fruitful for new-to-the-world products, where the internal information and knowledge about the specifics of the product situation are often very limited.

Information about new-product ideas can be solicited from employees through interviews or obtained through suggestion programs using key personnel. Surveys can be used to query employees about their thoughts and ideas about new products. There are numerous methods for finding out what employees think, including employing panels of participants and internal focus groups, and studying executive responses to questionnaires.

The external mechanisms for gathering information include mail surveys, telephone interviews, personal interviews, focus groups, and expert panels. Each of these traditional methods has strengths and weaknesses. Again, it is often a matter of time, effort, and money. On the high end of the scale, research studies and customized market analyses are the most time consuming and cost the most money.

The bottom line is the identification and understanding of customer needs and wants, and other relevant market information that may lead to understanding and assessing new-product opportunities. The suggested process starts with the simplest, fastest, and least-costly market-research method and proceeds to the more-sophisticated approaches until the list of new-product ideas is qualitatively and quantitatively sufficient to ensure that there are adequate opportunities.

The scope of the research should be defined based on the new-product objectives, the target markets that have been identified, the constraints of time and money, and the program goals and metrics. Scientific principles should be used to ensure that the results are valid. Most importantly, the use of market research for idea generation focuses on generating ideas, assessing their potential, and then selecting viable candidates for further development during the Concept Development and Selection Phase.

Table 4.3 provides a summary of the generalized approach. There are many variations to the flow. The market-research process can also be used for conducting a market assessment or any other analyses related to external parties. The same methodology can be used for concept development. Because there are usually fewer new-product concepts than ideas, the market-research process follows a more rigorous approach during the Concept Development and Selection Phase.

Background research (passive methods)

Passive methods are used for obtaining information readily available to the public that may contain insights about new-product opportunities. A literature search provides information relating market conditions and trends, competitors' initiatives, technological innovations, and general business developments. A search of the literature is generally quick and inexpensive and does not attract any attention. With the preponderance of databases throughout the world, there are enormous amounts of data and information available on most topics. Indeed, many companies provide large quantities of information on their web sites, via public disclosures, and through official reporting mechanisms to government agencies.

Using passive methods tends to be a flexible approach since the research and the subject matter thereof can be expanded at any time. Moreover, the information gleaned from one session may lead to new research areas as the information is analyzed and insights gained set the stage for further research. The basic problem with passive research is that it is generally based on current or past information and data, not on future conditions, trends, or their impacts. It takes insight to reflect on the information to discern the relevancy and implications. Not all of the answers are readily available, nor is all of

Table 4.3 *Market-research process for new-product ideas*

Steps	Market-research process	Specific areas
1. Determine goals/scope	Determine what information is required.	Examine market segments, customer needs and wants, stakeholders, competition, supply networks, infrastructure, and related markets.
2. Obtain existing data	Obtain readily available information from existing sources.	Conduct an initial study to obtain existing information from internal records, the Internet, government sources, research organizations, etc.
3. Conduct a gap analysis	Identify additional requirements not available through existing means.	Conduct a gap analysis to identify the missing information, prioritize the needs, and determine how to obtain the data.
4. Determine options	Determine the market research options that are likely to provide immediate results and meet goals.	Develop a research design. Generally, standard statistical methods are used to ensure the results are valid. Develop a questionnaire or other data-collection mechanism.
5. Identify means	Determine the resources and time constraints.	Examine the resource requirements and the timeframe available to complete the research; identify the constraints and develop a schedule.
6. Evaluate methods	Evaluate the feasibility of the options in terms of time, costs, and benefits.	Assess the requirements and determine the most advantageous means to achieve the results in terms of time, money, and impact.
7. Select methods	Select the appropriate research design.	Select and develop the best research mechanisms for the situation.
8. Execute program	Execute the research program and obtain the information and data.	Conduct the research as formally as possible to eliminate bias and improve validity and reliability.
9. Analyze	Analyze the data and evaluate the implications.	Select the information that meets the design goals and study the implications.
10. Interpret	Present the results.	Interpret results and think about implications. Record and present results.

the information factual. The main limitations are the lack of interactive discussions and the inability to expand information beyond what is provided, although the Internet offers some forms of interactivity.

The Internet allows the researcher to obtain an incredible amount of data and information in a short period of time. Searching the Internet is easier than traditional literature searches and in most cases more fruitful. Moreover, the Internet has the advantage of being interactive. The researcher can pose questions that customers, stakeholders, and others may answer. Obviously, this capacity to interact with respondents is very beneficial when trying to develop new ideas about products and services. However, care must be exercised. Internet sources provide both accurate and inaccurate data and information. It is risky to rely on the accuracy of the information without testing its validity. Follow-up mechanisms, using other sources to test the reliability of the information and data, should be in place.

Attending trade shows and conferences is an outstanding way for obtaining relevant information. As part of the data-gathering exercise, the researcher must determine what are the appropriate shows and conferences for a given product category and determine the schedule for the most significant events. There is usually an annual cycle of trade shows for industries or product categories. Trade shows and conferences have proceedings that document the papers and articles presented during the events. The limitations of using such vehicles are the costs to attend the events, the timing of the events, and the knowledge required for understanding the proceedings. Dr. Horst Wildermann of the Technical University of Munich conducted a survey of 139 European companies that studied the origin of ideas for product improvements and innovations. His work indicated that 21% of the ideas came from trade fairs and conferences.[9]

Surveys, focus groups, and benchmarks (active methods)

The traditional method for gathering customer information is the "tried and true" use of a survey or questionnaire. Depending on the new-product category, the survey questions might focus on improvements to existing products or a general determination of what customers want or expect from products. During the Idea Generation Phase, the purpose of a survey is to solicit the view of customers in a manner that inspires free-thinking and an open exchange of ideas.

Given the nature of the process, the methods employed should be relatively simple. The objective is to obtain valid inputs at a reasonable cost. The more elaborate constructs are typically used during the Concept Development and Selection Phase. Again, it depends on the types of new products.

The standard means for getting the information is the questionnaire or survey instrument. The format of the questionnaire may include specific questions relating to a

Key: 5 = very satisfied; 4 = satisfied; 3 = neither satisfied nor dissatisfied; 2 = dissatisfied; 1 = very dissatisfied.	5	4	3	2	1
General satisfaction					
1. Based on your experience, how satisfied are you with the product?					
2. What did you perceive its value as?					
3. How satisfied were you with its quality?					
3. How satisfied were you with its features and functions?					
4. What was your assessment of the following?					
➢ Our professionalism and competence					
➢ Our understanding of your needs					
➢ Our ability to solve your problems					
Technical support					
5. How satisfied were you with the following?					
➢ Ease of communicating; handling of information					
➢ Competence of our people and technical services					
➢ Responsiveness and time to get solution					
6. How satisfied were you with the support you received?					
➢ Ability to get service					
➢ Ability to obtain a solution					

Key questions
What are the advantages and disadvantages of our current products?
What suggestions would you make to improve our products?
What are the most important benefits? What is the value?
What are the suggestions you have for new products?

Figure 4.7 An example of a customer-satisfaction survey

given topic or open-ended questions pertaining to the area under study. The number of questions should be manageable and easy to analyze. The construction of the instrument should provide results that can be interpreted using statistical analysis (quantitative methods). Qualitative results might be solicited during idea generation to obtain a broad overview of the opportunities without spending a lot of time and money drilling into the details. The purpose is to lay a foundation for further research if the idea materializes into a concept. Figure 4.7 provides an example of a simple customer-satisfaction survey.

The number of customers involved in the process depends on the size of the customer population, the degree of confidence required, the nature of the market dynamics, and the statistical accuracy of the instruments.[10] If there are a number of core customers who can be relied on for the veracity of their comments, a small group may provide outstanding comments and insights. The main concern is the possibility of skewing the selection of respondents. Any skewing based on intended or unintended biases tends to leave out valuable contributors, especially those at the extremes who may have unusual insights.

A focus group is a special arrangement for obtaining information from customers. It is an appropriate approach for obtaining ideas about new products, but great care must be exercised to ensure that the group has been selected randomly. If the group members tend to have similar backgrounds or points of view, the result may shed light on only a small part of the potential customer population. The value of using a focus group for idea generation is that the process can be interactive with a large group of respondents. Focus groups work well when using the open-ended format.

Other traditional mechanisms for getting information include personal interviews, telephone surveys, and direct mail; each has advantages and disadvantages. Personal interviews provide flexibility and generally higher response rates. The results tend to be valid since the person conducting the interview has control over the process. Generally, there is an opportunity to get additional information from the respondent, since there are two or more people involved and most people are courteous enough to complete the interview. The main disadvantage is the high cost associated with meeting people at their location. Extensive travel times could have a negative impact on the timeliness of information and on the timing with respect to the NPD process.

Telephone interviews are a popular way of overcoming the problems with personal interviews. They are fast and relatively inexpensive. A large number of interviews can be completed in a short time frame. The large number of potential respondents may help improve the validity of the results. The limitations include the short amount of time that respondents are willing to answer questions, the lack of precision in determining who the respondents are and the veracity of their answers, and the fact that telemarketing approaches are so widely used that many people are often unwilling to participate. Moreover, government rules make it difficult for telemarketers to operate by restricting calling times and allowing people to have their numbers removed from calling lists.

Mail surveys are simple and low cost. Questionnaires are mailed to recipients who complete them in the privacy of the home or office. There is no interviewer to influence or bias outcomes. However, there are many limitations to the approach. The biggest problem is the low rate of response. A good response rate might be 5 to 10% and, in many cases, the rates are between 1 and 2%. Moreover, the wrong person may answer the questions, thereby skewing the results.

Expert opinion is an alternative to customer surveys or internal brainstorming. A panel of industry experts is assembled or is queried to obtain views and opinions about opportunities for new products. The experts may be selected from many fields, such as marketing, finance, economics, etc.; thus, they may provide diverse inputs. However, such panels tend to focus on the normal perspectives of the industry. They are usually an excellent means for determining incremental changes to existing products. They may not always be as adept at discovering solutions that are more radical. The main advantages are speed and diversity. The main disadvantages are high costs and the lack of direct customer input. However, the method may be used in combination with other techniques.

Market analysis

Based on the market research, a preliminary market analysis is prepared to provide an overview of the market potential of the target market segment(s). The market analysis includes a definition of the market segment(s) being addressed, the critical market-segment requirements, and a profile of the target customers.

The market-segment definition provides the fundamental market information used to determine the attractiveness of the target(s). The definition provides a description of the market and the essential statistical aspects. It includes the total market-segment size in volume and revenues, and the portion of the segment that would be served by the new product. The general flow of the analysis follows the broad market-attractiveness assessment provided in Table 2.10, except that the focus is much narrower addressing only the specific target market segment(s). Some of the main concerns include market size and growth rate, legal and regulatory requirements, seasonality, price sensitivity, and specific customer wants and needs.

The market factors that are examined to determine the potential of the new-product idea depend on the type of market segment and its characteristics. The following is a list of the most important elements:

- What market segment(s) are the most suitable for positioning the new product(s)?
- What is the value proposition?
- Who are the "lead users" and/or the critical applications?
- What are the most important needs and wants demanded by the market segment(s)?
- Why would potential customers seek the new product as a solution to their needs?
- What are the size (revenues and units) and growth rate of the market segment(s)?
- What are the most important factors for achieving success?
- Where, when, and how are product(s) used in the segment(s)?
- What are the seasonal aspects?
- Who are the primary competitors?

The customer profile or customer analysis provides a detailed view of what the potential customers are seeking. It involves identifying the key customer groups that are potentially the early purchasers of the new product, understanding their expectations, and examining potential purchase patterns. The customer analysis lays the foundation for determining the potential benefits of the new-product idea and defining program mechanisms for establishing a new-product opportunity. The concept of lead users is helpful in carrying out customer analysis. The following are some of the key questions that the customer analysis addresses:

- Who are the potential customers for the new product(s)?
- What are the most important customer needs and wants?
- What are the benefits that fulfill the customers' objectives?
- What are the major influences on buyer behavior?

- What kind of information do customers require for making informed decisions?
- How would customers purchase the new product? Through what channels?
- What are the decision-making processes?
- What are the essential economic drivers?
- What are the essential requirements for achieving success?

The actual questions and methods used to complete a customer analysis depend on the type of new-product opportunity and the category of customers involved (consumer, industrial, or government). The objective during the Idea Generation Phase is to obtain sufficient detail about customer preferences so that an effective evaluation of ideas can be performed. The intention is to have the means to determine the feasibility of the idea so that the potential can be examined.

Market assessment is an ongoing process that finds relevancy during each of the phases. Subsequent market assessments are grounded during the conceptual phases by laying the foundation for understanding customer preferences and determining the market fundamentals. The bottom line is to determine what the NPD program should include and to identify the prospects for success. Is there an opportunity? The customer analysis is used for evaluating the basic requirements necessary for success.

Technology assessment

Technology plays a vital role in every NPD program. Most new products (especially for incremental innovations) are related to existing products and depend on the prevailing technologies used to design and produce those products. However, when technology is the driver, product innovation and technological innovation are directly linked in the process. In such cases, the new technology becomes an essential part of, or a precursor to, the NPD program. It provides the opportunity to obtain a new competitive advantage, especially if the company is the "first to market" with innovative technology.

For these technology-driven programs, there is a high technical risk as well as a program risk. The technology may fail to fulfill its promise and not achieve a critical breakthrough. Even with successful technology development, customers and markets may not be prepared to accept the new technology. It may be ahead of the right timing for such technology. Moreover, all of the other dimensions are usually required to be in place for a successful entry, and failure is often due to the lack of integration across the external dimensions. In many cases, organizations typically focus on the technology and technical aspects, neglecting to place sufficient resources in other vital areas. Imagine what sophisticated computer hardware is worth without powerful software! Think about what customers need to enjoy the benefits of automobiles using fuel cells for power rather than gasoline engines! The availability of hydrogen in the distribution channels would be a great asset for developing such cars.

Most NPD programs rely on proven technology from their own proprietary resources or from external partners and the public domain. The use of existing technology in a new way provides the means to generate a new product. The fusion of two or more technologies into a product in a way that had not been done before may lead to a new product.

Technology is an essential ingredient in the development of new products. Having the technology does not ensure success. Indeed, it is crucial that the NPD process is followed to ensure that all of the essential elements are properly examined to discover requirements and to avoid mistakes.

Assessment of the external dimensions

Stakeholder assessment

Stakeholders are entities that play a direct or indirect role in establishing the requirements and specifications of new products. They may function as interested parties due to the impact of products and related processes on the environment, society, or the economy. Stakeholders include: the local community; consumers in general; environmental groups; political parties; regulatory agencies; the international community; and individuals, groups, and organizations potentially affected by the new product(s). They also include consumer groups, environmental organizations, financial organizations, the media, or similar entities that pay attention to the effects of the product after commercialization. Certain stakeholders – such as government agencies, industry organizations, and professional groups – have a review role or are approval authorities during the later phases of the NPD process.

Stakeholder assessment attempts to identify and analyze the significant considerations and implications that the new products would have on potential stakeholders. It attempts to minimize mistakes or oversights by understanding all of the implications: environmental, economic, social, political, and technological. The inclusion of stakeholder assessment in the NPD process makes it more complex than conventional approaches due to the large number of potential parties that are affected. However, it offers a more-comprehensive view of reality because the single framework covers the most important aspects and process requirements.

The purpose of stakeholder assessment is to assure that nothing has been overlooked and that the best choices for inputs and outputs have been made relative to stakeholders. The importance of stakeholder assessment has increased significantly during the last decade as environmental, health and safety, and liability issues have escalated. It is an important part of achieving sustainable development.[11]

Stakeholder assessment depends on the actual situation and the external entities affected by the product. Typically, in the United States, federal and state laws and

Table 4.4 *Selected stakeholder categories*

Category	Product type	Entity	Roles
Special commissions of federal government	Pharmaceuticals	Food and Drug Administration	Protocol, testing, and approvals
Government agencies	Chemicals	US Environmental Protection Agency	Procedures, permits, and reporting
Industry standards	Electrical devices	Underwriter's laboratory	Testing and certification
Consumer organizations	Consumer products	Consumers report	Testing, reporting, and commenting
Non-government organizations	Manufacturers	Public research Information groups	Research and disclosures

regulations set forth requirements that the new product must meet before commercialization. Laws and regulations often stipulate mandatory requirements that the product must incorporate. Many new products have to go through a certification process to gain approval from the regulatory agency. Government and industry mandates, which have to be included in the product specifications and the testing requirements, are the most important areas of stakeholder analysis. For example, automobile manufacturers must follow very stringent safety regulations designed to protect the occupants of the vehicle, and the product itself has to be certified by the National Transportation Safety Board. Similarly, the Federal Aviation Authority (FAA) certifies the airworthiness of all new aircraft in the United States. Boeing and Airbus have to perform special "airworthiness" certification tests to obtain the approvals to fly their new aircraft designs. Table 4.4 provides a list of selected stakeholder categories and identifies their roles.

Stakeholders may reinforce the potential benefits of the new products by supporting the need for the products as an alternative to existing products and practices. Many environmental groups are supporting the development of hybrid automobiles as a means of reducing emissions and improving air quality. On the other hand, some of the same organizations are lobbying to create barriers to the growth of sport utility vehicles (SUVs) because of the their poor fuel efficiencies and concerns about safety standards.

The stakeholder assessment includes identifying the main stakeholders, analyzing their goals and strategies, determining the influence on the success of the new product, and assessing the implications on the overall game plan. The critical aspect is the understanding of the major issues facing the development program and what has to be done to manage the process. If the issues are overwhelming, the prospects for success may be significantly reduced.

Supply-networks assessment

Supply-networks management is the process of effectively managing the flow of materials and finished goods, information, and relationships from suppliers through distribution channels to customers using a systems perspective to achieve a high level of performance. Today's supply networks are more dynamic because of advanced technologies, the narrowing of the supplier base, ongoing innovations, and the impacts of regulatory requirements. Supply networks must be integrated on an enterprise basis, yet remain flexible to the changing conditions of the market place.

Supply-networks management plays a vital role during the NPD process. The organization generally has to decide how it plans to produce the product during the early phases of the NPD process. If a significant part of the product is to be obtained from suppliers, they must be part of the NPD process.

The primary procurement objective is to support business operations with the best products and services at the lowest cost and highest quality. A procurement-management framework provides a means of identifying, describing, analyzing, and managing the physical, managerial, informational, and systems requirements of the supply chain. The challenge is to initiate innovative approaches to achieve the financial and operational goals of the business and to implement the best practices available to secure an advantage over competitors.

Supply-networks assessment is a comprehensive analysis of the capabilities of supply networks and resources. The main questions relate to the opportunities and options that suppliers and distributors offer for enhancing the prospects for the new-product idea. It includes the following areas: strategic, financial, technical, information, and legal.

The decision to outsource the supply of key parts and components or the entire production process has long-term consequences on the operations and requires a complex assessment of the situation and the needs of the management system. The assessment includes examining the advantages and disadvantages of outsourcing the production of the parts or product to suppliers, the impacts on the NPD process, and an analysis of the alternatives.

The assessment covers the management aspects of the evaluation and selection methods. In managing procurement-related programs, new expectations and interfaces drive the activities. The fundamental steps include: setting goals; mapping the process flow; planning; evaluating existing and potential capabilities of each supplier; identifying internal and external needs; developing a master plan; establishing policies, procedures, and guidelines; setting priorities; resolving conflicts; and evaluating performance. Supplier management and development include the actions taken by the purchaser to manage its suppliers effectively and efficiently. The goal of such a program is continuous improvement.

Competition analysis

Based on an analysis of the industry structure and the selected market segment(s), a competition analysis is essential to determine the primary adversaries and their responses related to the new-product idea. The analysis is different from the perspective discussed in Chapter 2, since the focus is on specific competitors in the targeted market segment(s); the focus is very narrow. The intent of the analysis is to ascertain detailed information and data about selected competitors who are the most likely to present a threat to the success of the new product.

During the Idea Generation Phase, the approach is to obtain sufficient details about the primary competitors so that an effective evaluation can be made about the viability of the given new-product ideas. The analysis includes answering the following questions:

- Who are the most important competitors affecting the prospects for the idea(s)?
- What are their objectives, strategies, and expected responses?
- What are their major strengths and weaknesses, relating to the new-product idea(s)?
- How can the idea(s) be enhanced to exploit their weaknesses or minimize their strengths?
- What strategies or alternatives tend to minimize the impact of competitors?

The competition analysis should result in a statement or view of the expected competitive impacts that allows the decision makers to understand the challenges and make a determination about the feasibility of the new-product ideas. The assessment might include only a representative number of competitors to get a sense of the landscape without spending a lot of time and money obtaining a complete picture. The more-thorough analysis is typically done during the Concept Development and Selection Phase, after the number of potential new-product candidates has been reduced to a manageable number. Again, the basic approach is to have a good sense of the competitors and their capabilities so that a determination can be made about the prospects of the new-product ideas. If there are many ideas, the number of potential competitors that have to be analyzed may be very large. Thus, great care is required to ensure that the efforts expended are worthwhile.

Assessment of related industries

The importance of related industries and their effects has been traditionally underestimated. It is important to evaluate the supporting functions provided by other industries. In certain cases, the new product has little chance of being successful without the contributions of related industries. Trading securities would be very difficult today without integrated computer systems. The stock markets have expanded dramatically during the 1990s because computers facilitate data collection and management. The computer has significantly lowered the cost of handling transactions, making it possible to increase the number of transactions, and reduce the cost per transaction.

Infrastructure analysis

Traditionally, producers were only concerned about the flow of their products to customers using established distribution channels. They assumed that the external infrastructure would adequately provide the necessary support to facilitate logistics and communications. Today, there are many channels and means to get products to customers and to communicate cost-effectively across broad distances. The infrastructure plays a vital role in facilitating a product's fit into the market place and providing the linkages with its business environment. It provides the support system that allows the product to function properly and to achieve long-term success.

The infrastructure consists of networks of linked and semi-independent participants and resources including the airways, waterways, and roadways that facilitate the movement of products to and from markets. Established networks reduce the costs and confusion associated with the desired outcome.

Infrastructure analysis employs a needs assessment. It lacks the formality of the more traditional management techniques due to its relatively new status. In the past, most business models simply assumed that the infrastructure was available and would be available to support the needs of the new product.

The infrastructure is always an important dimension, although for many products the implications are obvious and are taken for granted. For example, airlines and airframe producers assume that the airports will accommodate the airplanes. While that assumption is usually a good one, airplanes like Airbus's new-product candidate, the A380 Super Plane, may be so large that the existing airport infrastructure may have to be radically modified to meet its needs.

Infrastructure analysis includes a critical assessment of the system requirements as they relate to the enterprise, a functional analysis, and a synthesis of the linkages into a comprehensive view of the relationships. The system requirements represent an articulation of the essential linkages with the infrastructure that provide the requisite support for the product. This first step is simply the identification of the mandatory infrastructure support elements that are necessary to ensure success of the new product. The second step is a functional analysis of the requirements. It describes and assesses the capabilities and constraints of the infrastructure. It provides an understanding of what the infrastructure can do. The third step is the synthesis of the functions into a comprehensive view of how the capabilities and constraints support or limit the viability of the potential new product.

A thorough analysis is time consuming and costly. The general approach is to keep the initial analysis during the Idea Generation Phase as simple as possible. The construct can be expanded during subsequent phases providing a more-thorough analysis of the new-product opportunity as greater commitment and investment into the new product is warranted. Figure 4.8 provides an example of this process for the automobile.

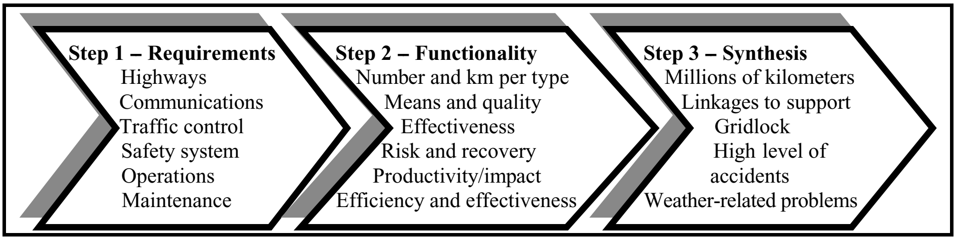


Figure 4.8 Simple construct of infrastructure analysis

While the construct is very simply, it does convey some of the essential issues, capabilities, and constraints associated with the highway system. The aim during the Idea Generation Phase is to provide a quick overview of the situation with respect to each idea. If the idea survives to the next phase, more detail is added.

Evaluation and ranking of new-product ideas

The purpose of the evaluation and ranking of new-product ideas is to assess their feasibility and to determine which ones merit further development during the Concept Development and Selection Phase. The process is simply to eliminate the ideas that don't fit the strategic logic of the organization; those that are not feasible from a technical, economic, market, or risk perspective; or those that require capabilities and resources that are beyond the means of the organization. There may be many reasons why a new-product idea is eliminated from further considerations, including having more ideas than can be dealt with given the resource and time constraints that normally exist.

The culmination of the Idea Generation Phase is the identification of a list of new-product ideas that warrant further investment of time and money; the list is often prioritized according to fit, desirability, and risk-to-reward relationship.

The evaluation step focuses the strategic alignment of each idea and its relationship with the goals and targets of the NPD programs. The process can be simplified by placing each of the ideas into one of four categories, based on two of the most important criteria, market demand (need) and strategic fit (logic). The criteria used may vary depending on the actual situation. Since strategic fit and market demand/potential are fundamental for most situations, candidates can be placed in the following categories:

(1) ***Clear strategic fit with strong market demand***.

(2) ***Clear strategic fit with uncertain market potential***.

(3) ***Unclear strategic fit with strong market demand***.

(4) ***Unclear strategic fit and uncertain market potential***.

In most cases, the first category represents the new-product ideas that have sufficient merit, based on the strategic needs, to obtain approval for the next phase. Such candidates may follow an expedited process, reducing the time and costs involved. Often these "must-do" candidates are driven by internal and external forces that are "self-evident." The middle two categories require subsequent analysis in selected areas to determine their suitability and feasibility. The fourth category suggests a high level of uncertainty; therefore, the ideas may require additional efforts to fully understand the fit and market potential or may require special handling to determine their fate.

The evaluation and rating of the ideas can take many forms. It is important to bear in mind that the capability of the organization to develop new products is a key determinant. The first and simplest approach is a qualitative assessment of the potential fit of the idea based on the resources and capabilities of the organization. This method has many variations from a simple assessment to a complex review of the variables involved in the process.

The purpose of the assessment is to provide positive or negative comments that affect the selection of the idea candidate. These include barriers to success and internal limitations to proper execution. The qualitative method provides a visual perspective of each new-product idea, highlighting the advantages and disadvantages. The main difficulty with the approach is that the interpretation is dependent on the skills and experience of the participants involved with the process. Biases may play a factor as advocates of certain ideas may skew the assessment. As with many similar assessment tools, it is usually biased toward leveraging existing resources and capabilities. Such built-in biases may not be too detrimental for incremental innovations, but it could be a significant difficulty for more-radical innovations. Therefore, the instrument is more effective for product innovations.

Table 4.5, "Capabilities profile and resources assessment," is a straightforward means of evaluating a new-product idea. The aim of Table 4.5 is to suggest some of the categories that would be evaluated; it is not intended to provide a comprehensive view of all of the essential areas nor does it necessarily fit all situations.

Examining the internal impacts as per the "Capabilities profile and resources assessment" provides a quick view of the fit of each candidate with respect to the current core capabilities. It is simply the initial perspective. The basic problem associated with just using that technique is that it skews the selection process to those candidates that leverage existing resources. Candidates representing significant movement from the prevailing product portfolio are not viewed very favorably. However, such candidates may have outstanding external potential, representing opportunities to diversify and gain entry into new markets or new business situations. Thus, including both internal and external dimensions in the analysis is necessary for obtaining a balanced approach.

Table 4.6, "New-product-idea rating," provides an example of a quantitative method that reduces some of the subjectivity of the qualitative methods. Again, the method

Table 4.5 *Capabilities profile and resources assessment – new-product candidates*

Category assessment	Yes	No	Advantages/disadvantages
Product/market			
• Fits with existing product lines	☐	☐	
• Fits existing product/market segments	☐	☐	
• Adds breadth and depth of product line	☐	☐	
Marketing and distribution			
• Capitalizes on marketing resources and skills	☐	☐	
• Uses market/marketing capabilities and knowledge	☐	☐	
• Fits NPD capabilities and skills	☐	☐	
• Fits knowledge and skills of sales force	☐	☐	
• Leverages channel coverage and capability	☐	☐	
• Uses current relationships	☐	☐	
Operations			
• Leverages production resources	☐	☐	
• Has a cost advantage/learning curve	☐	☐	
• Requires flexibility of plant and equipment	☐	☐	
• Requires proprietary know-how	☐	☐	
• Has positive impact on labor-force situation	☐	☐	
• Supports quality assurance and control	☐	☐	
• Uses cost of raw materials	☐	☐	
Overall cost position			
• Has favorable relative cost position	☐	☐	
• Achieves competitive cost position	☐	☐	
• Has a favorable cost structure	☐	☐	
Research/engineering			
• Leverages technical skills	☐	☐	
• Offers patent protection	☐	☐	
• Leverages R&D capabilities	☐	☐	
Financial capabilities			
• Offers excellent cash-flow potential	☐	☐	
• Leverages financial management skills	☐	☐	
• Is in line with financial capability	☐	☐	
Organizational			
• Provides sense of purpose and dedication	☐	☐	
• Has adaptability to change	☐	☐	
• Uses leadership qualities	☐	☐	
• Leverages cross-functional abilities and skills	☐	☐	
• Offers flexibility	☐	☐	
Corporate portfolio			
• Manageable risk	☐	☐	
• Ability to support new product	☐	☐	
• Access to government agencies	☐	☐	

Table 4.6 *New-product-idea rating*

	Importance (X)	Weighting (Y) 1	2	3	4	5	XY	Comments
Product considerations							***10.4***	
• Fits with product lines	**0.3**		√				**0.6**	
• Leverages resource base	**0.4**			√			**1.2**	
• Supports quality	**0.3**				√		**1.2**	
• Fits core capabilities	**0.8**		√				**1.6**	
• Has potential for patents	**0.1**		√				**0.2**	
• Fits management experience	**0.4**			√			**1.2**	
• Leverages technology	**0.9**				√		**3.6**	
• Fits knowledge and know-how	**0.8**	√					**0.8**	
Market considerations							***19.0***	
• Market segment size	**0.9**			√			**2.7**	
• Market segment growth	**0.6**				√		**2.4**	
• Longevity of life cycle	**0.7**			√			**2.1**	
• Performance to price	**0.9**			√			**2.7**	
• Low competitive response	**0.6**				√		**2.4**	
• Loyalty of customers	**0.9**			√			**2.7**	
• External requirements	**0.8**					√	**4.0**	
Marketing considerations							***10.9***	
• Promotion impact	**0.3**			√			**0.9**	
• Product differentiation	**0.6**			√			**1.8**	
• Distribution network	**0.8**				√		**3.2**	
• Brand-name recognition	**0.9**			√			**2.7**	
• Sales coverage	**0.5**		√				**1.0**	
• Marketing reach	**0.3**			√			**0.9**	
• Packaging aspects	**0.1**				√		**0.4**	
Production/procurement							***8.5***	
• Production cost	**0.7**			√			**2.1**	
• Production capabilities	**0.9**				√		**3.6**	
• Supply-chain impact	**0.3**				√		**1.2**	
• Delivery time	**0.4**				√		**1.6**	
Economic considerations							***13.5***	
• Investment requirements	**0.9**			√			**2.7**	
• Low-unit-cost potential	**0.9**				√		**3.6**	
• Low project risk	**0.9**			√			**2.7**	
• Low product risk	**0.9**		√				**1.8**	
• High profit potential	**0.9**			√			**2.7**	
Competition							***4.5***	
• Severity	**0.9**		√				**1.8**	
• Strengths	**0.9**			√			**2.7**	
Stakeholders							**7.2**	
• Potential impacts	**0.9**			√			**2.7**	
• Relationships	**0.9**				√		**4.5**	
Infrastructure							***5.1***	
• Capabilities	**0.8**			√			**2.4**	
• Supportive	**0.9**			√			**2.7**	
Related industries							***3.6***	
• Supportive	**0.9**				√		**3.6**	
Total							***82.7***	

(Criteria: 5 = favorable; 1 = unfavorable.)

and elements contained therein are intended to provide a suggestion of what could be considered. The actual factors would depend on the situation. The main advantage is that each idea is rated independently and the score for each is summed and compared with the others. Presumably, the higher ratings are the better ideas. However, some elements may be more important in a given situation.

Great care has to be taken with such mechanisms. They are useful for providing a simple ranking of the candidates, but they can easily distort the results. For example,the requirements depicted in Table 4.6 are biased toward internal factors, indicating that the organization favors more of a leveraged situation. While this approach is acceptable as long as it is recognized as such, the repeated use of the instrument with the same weighting factors tends to prioritize the candidates based on fit rather than market opportunity. The internal and external factors can be balanced so that there is an equal weighting between the two. Another option is to divide the instrument into two sections, one pertaining to internal factors and the other related to external factors. Such a construct provides a better view of the situation.

Practitioners should develop their own criteria for determining which ideas fit. The process is dependent on the criteria established by the organization to determine which ideas move on to the Concept Development and Selection Phase. The balancing act is to reduce the number of ideas to a manageable set so that the organization is not diluting its efforts by having too many ideas moving on to the next phase, and at the same time not prematurely eliminating viable new-product opportunities.

Selection of new-product ideas

The Idea Generation Phase should result in a balanced list of new-product opportunities which are reviewed to determine the candidates for selection as viable product concepts. Table 4.7 provides a summary of the most crucial factors in the selection.

The process of evaluating the ideas is highly dependent on the business environment and the NPD situation. It is also dependent on the organization's preference for detail analysis and specifications. In many cases, there is an attempt to restrict the presentation of information to one page or one sheet per candidate. This is particularly the case if there are a large number of candidates. The construct of the summary document should follow the internal and external dimensions of the enterprise model. Most organizations use a proposal format to summarize the salient factors about each candidate.

Summary

The Idea Generation Phase is intended to be systematic and straightforward. Many corporations combine the Idea Generation Phase with the Concept Development and

Table 4.7 *Simplified standard form for summarizing the new-product idea*

Title of idea	
1. Description	• What are the essential attributes of the proposed product? • How does it fit the strategic logic of the organization? • What is the value proposition?
2. Target market segment(s) and product/market strategies	• What is the target market segment(s)? • Identify the principal strategies for commercialization of the idea. • How does the idea fit into the market and what are its main benefits? • What is the product position and how can the market be reached?
3. Business environment and competition	• What are the most important factors of driving forces in the business environment? • Identify the most important business conditions and trends affecting the idea. • Who are the most important competitors? • How is the idea different from the offerings of competitors? • What are the expected competitor responses?
4. Critical factors for success	• Identify the most important factors for achieving success. • Identify the means for designing and marketing the new product.
5. Main barriers to success	• What are the most critical limitations? • Who or what stands in the way?
6. Main financial considerations	• Estimate the expected product costs, expected sales volume, and projected revenue. • Estimate the total required investment. • Estimate the net present value or internal rate of return.
7. Risk factors	• What are the most significant risks?
8. Time line	• Determine the expected development cycle. • Identify the expected launch date.

Selection Phase. In reality, there is little difference if the process is smooth and expeditious, and there are limited numbers of new-product candidates. If there are many potential new-product candidates or if there is not a sense that the proper candidates have been defined, the Idea Generation Phase is an important part of the NPD process. Alternatively, if there is a strong sense of what the candidates should be and there are a relatively low number of options, then the NPD process can start with concept development.

The overall objective, as stated numerous times, is to be both thorough and timely. The NPD situation mandates a full and accurate view of what has to be done and what is possible. It is both strategic and operational. The notion of balance is essential for achieving success.

Notes

1. R. A. Burgelman, M. Maidique, and S. Wheelwright, *Strategic Management of Technological Innovation*, 3rd edn (New York: McGraw-Hill Irwin, 2001, p. 550).
2. J.-P. Deschamps and P. R. Nayak, *Product Juggernauts: How Companies Mobilize to Generate a Stream of Market Winners* (Boston, MA: Harvard Business School Press, 1995, p. 91).
3. The term product(s) includes products and services.
4. D. Leonard and J. Rayport, Spark innovation through empathic design. *Harvard Business Review*, **72**: 6, November–December (1997), 102–113. The authors indicate that observation of existing customers can be a powerful source for new-product ideas and improvements.
5. E. von Hippel, S. Thomke, and M. Sonnack. Creating breakthroughs at 3M. *Harvard Business Review*, **77**: 5, September–October (1999). Looking for lead users is a powerful notion for discovering sources of new-product opportunities. The broad market may not be interested in the innovation but lead users have a unique need that could start a trend.
6. The Smart Car is a two-seat vehicle, weighing approximately 2000 pounds (900 kg) and having dimensions of 5 ft × 5 ft × 6 ft (1.5 m × 1.5 m × 1.8 m).
7. S. Pugh, *Creating Innovative Products Using Total Design* (Reading, MA: Addison Wesley, 1996, pp. 187, 197, 355). Reverse engineering is a well-established concept that suggests that engineers take the competitors' products apart to determine the parts and components and to ascertain how it was manufactured. Pugh was a world-renowned new-product design expert who suggested a more-complex approach using parametric and matrix analyses to determine market gaps (functional problems).
8. This construct is derived from: G. Bounds, An extension to Westinghouse: journey of quality. In *Cases in Quality* (Homewood, IL: Irwin, 1996, p. 80).
9. H. Wildermann, New challenges for procurement in the automobile industry. Technische Universität München, 1998. This information was obtained during meetings with faculty at the Technical University of Munich, June 19–24, 1999.
10. Formal analysis should follow the methodologies spelled out using statistical analysis. Such methods are provided in various textbooks on the subject. It is not the aim of this book to cover these methods.
11. See: D. Rainey, *Sustainable Development: Inventing the Future through Enterprise Management and Technological and Product Innovation* (to be published 2005). Sustainable development is a far-reaching construct that cuts across many sectors of the global communities of nations, governments, non-government organizations (NGOs), markets, customer groups, and other constituents. Sustainable development focuses on collaboration and cooperation among the groups since effective solutions have to embrace the social, economic, and environmental objectives as well meet the strategic needs of business entities. The crux of sustainable development from a business perspective is to focus on future technologies and new products that have been developed using criteria that specify outcomes that are

balanced in terms of business objectives and the needs of all of the constituents, both in the present and in the future. Sustainable development requires significant changes in how technologies and products are developed. It means that the underpinnings for development have to be based on a broader array of considerations and that the analyses used for making determinations and decisions have to include every possible input and output from cradle to grave, and all of the associated impacts and implications.

5 Concept Development and Selection (Phase 2)

Introduction

The primary result of the Idea Generation Phase is an "approved" list of acceptable candidates indicating their fit into the organization's criteria and their potential to succeed in the business environment. Idea generation produces ideas that usually lack full definition. This seeming weakness is actually one of the strengths of the new-product development (NPD) process. It is simple and cost-effective to produce a myriad of ideas during the Idea Generation Phase. The scope is limited and the critical objective is to select potential candidates for further analyses and development. In most cases, it is easy for an organization to discern which ideas should move forward.

The Concept Development and Selection Phase expands the rudimentary perspectives of the Idea Generation Phase into comprehensive new-product candidates based on sufficient analyses that the product, market, marketing, production, and financial dimensions can be defined and articulated. The primary objectives are to assess the potential of each of the candidates and to determine which ones should be developed into new products. Concept development and selection involves the transformation of new-product ideas into fully articulated concepts that can be ranked, screened, and selected for succeeding phases. It converts the basic elements of the new-product ideas into a comprehensive understanding of the business opportunities based on an assessment of the internal and external dimensions.

The selection activities include the screening of the concepts using selected metrics, and evaluating the implications on the internal and external dimensions of enterprise-management model (EMM). The actual screening criteria used are based on the business reality of the NPD situation. The number of concepts selected is dependent upon the capabilities and resources of the organization and the criteria for managing NPD programs.

Concept development starts with a simple translation of the ideas into basic concepts. A concept includes the product specifications from a customer's perspective, a preliminary view of the marketing program for supporting commercialization, the general scheme for producing the product, and the financial implications of the new product and the NPD program. It establishes the details about the intended market segment and the product attributes based on customer needs and wants, the fit into the business environment, and the supporting structures required for ensuring success. A concept is a more-comprehensive view of the proposed new product including the target market segment, the product's position in the segment, its competitive standing with respect to other offerings, and its impacts on stakeholders. The concept also includes how the new-product opportunity relates to supply networks, related industries, and the infrastructure. It gives a preliminary view of the possible marketing communications techniques, a review of production alternatives, an initial assessment of the financial aspects for supporting the NPD program, and the expected goals to be achieved. If there are a large number of ideas, the initial step might include filtering mechanisms to eliminate the candidates that obviously do not make sense, as more details become apparent.

Concept development defines the product/market concept in totality, and its relationship with the business environment. Concept development integrates the other external dimensions with the product and market dimensions. A fully developed product/market concept consists of an understanding of the external factors within the proposed deployment of the internal dimensions. The purpose is to develop sufficient specificity that the potential of the concept(s) can be assessed.

Concept selection allows management and the participants to evaluate the available new-product candidates and determine those opportunities that warrant the continuing investment of time and money. The outcome of concept selection is a number of new-product opportunities that are deemed worthy of investment. The goal is to determine which of the concepts fit the needs and objectives of the enterprise. The bottom line is to select the few from the many and to devote the attention and resources to the design and development of those opportunities that are best suited to the needs of the business environment, and the capabilities and objectives of the organization.

Chapter 5 includes the following topics and learning objectives:

- Understanding the meaning of a concept and its essential elements.
- Articulating the process-flow elements to assess and develop the concepts.
- Identifying the means to screen concepts and select the most viable candidates.
- Understanding the concept selection process.

Concept Development and Selection Phase flow chart

The flow chart

The aim of the Concept Development and Selection Phase is to provide a clear picture of the new-product opportunities and their implications. The process flows from open-ended ideas to the well-defined product/market concepts. At the end of the phase, the organization should have sufficient understanding of the process and the requirements that it is willing to invest into the NPD opportunities selected for further definition and development. The process also defines why the unsuccessful candidates were not selected. As the phase proceeds, the organization should gain confidence that it is not making a “type-1” or a “type-2” error. A type-1 error involves selecting the wrong candidate, leading to failure in the market. A type-2 error involves not selecting the right candidate; therefore, missing a significant opportunity for achieving success. Having a well-defined NPD process and following the prescribed elements of Phase 2 should increase the probability of being successful. However, no system is perfect and mistakes are made.

The Concept Development and Selection Phase includes concept development, concept assessment, concept screening, and concept selection. Concept development includes selecting the product/market segment(s), identifying customer wants and needs, establishing the target specifications, and determining the product/market concept. The product, marketing, production, and finance elements are analyzed and stipulated as part of the concept development. Concept assessment includes evaluating the new-product concepts in terms of the non-market-related external dimensions. Based on the assessment of the external dimensions the product/market concept is refined and the concept is fully developed from internal and external perspectives.

Concept screening involves determining the merits of the product/market concepts, determining or confirming the selection criteria, and ranking the candidates. The selection step includes determining the viable concepts and selecting the concepts that are to continue in the NPD process.

Figure 5.1 provides a simplified flow chart of the Concept Development and Selection Phase. It includes the elements of the generic process.

Overarching perspectives of concept development

Overview

The development of the product/market concept focuses on determining the product/market position that establishes the strategic and operational direction for the concept. The product/market concept focuses on what customers need and what the product form, function, and fit have to be to meet these requirements. The concept is often expressed in terms of specifications that link customer needs with the physical characteristics of the product. (The combination of product characteristics and the benefits provided are referred to as attributes.) Product attributes include the features that provide the function, and therefore offer customer benefits.

E. Raymond Corey offered an outstanding view of a product for thinking about the implications of a new product:[1]

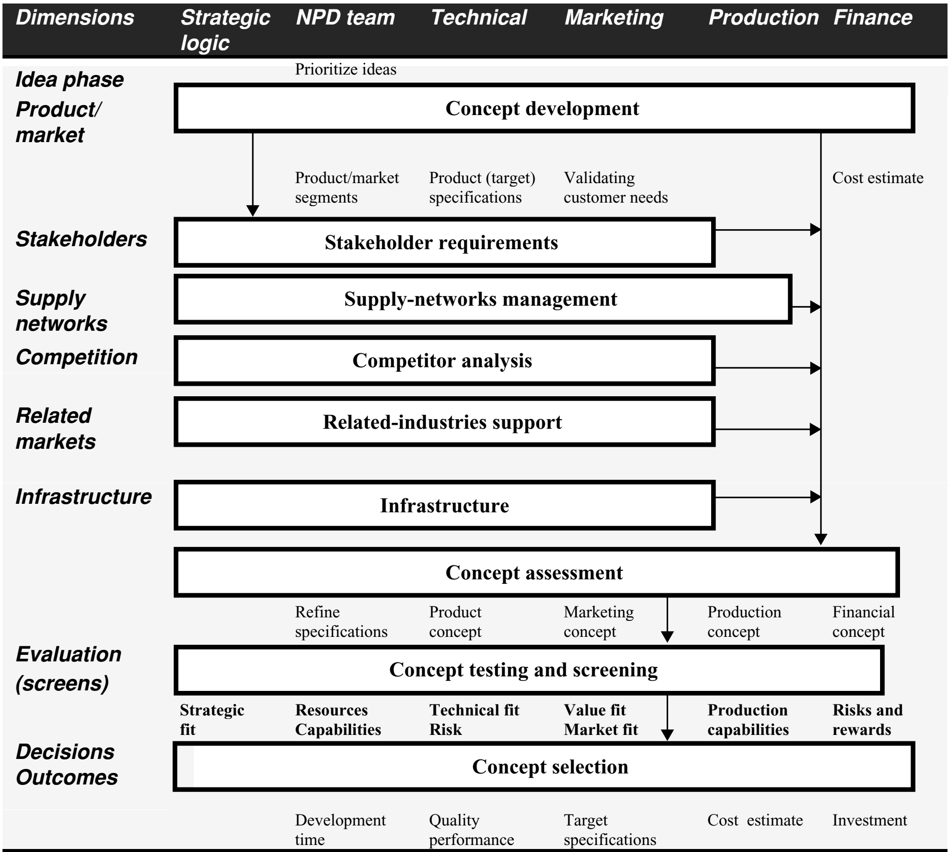


Figure 5.1 Concept Development and Selection flow chart (Phase 2)

- A product is the total package of benefits that the customer buys when making a purchase.
- Product meaning must be defined in terms of buyer benefits.
- The product package will have different meanings to different groups of potential buyers since buyers in different market segments are likely to rank the importance of various product attributes differently.
- The product is not a given in marketing strategy formulation; it is a variable.

As discussed in Chapter 4, a product has both tangible and intangible attributes that meet the specific and underlying needs of customers. The tangible and intangible attributes include positive and negative elements. Product characteristics are selected based on their positive attributes (intended or desired characteristics), but often there are negative attributes; these are typically the unintended consequences or burdens associated with the positive aspects. Every product has all four aspects. Good concepts and designs tend to maximize the positive and minimize the negative. Table 5.1 provides a simple example using an automobile.

Table 5.1 *Attributes matrix of an automobile*

Attributes	Positive	Negative
Tangible	Full size with six seats	High gross weight and poor fuel efficiency
	Eight-cylinder engine with high performance	High emissions affecting ambient air quality
	Luxury interior with leather seats	High costs and depletion of resources
Intangible	Esteem provided to owner	High taxes and insurance costs
	Mobility, freedom, and pleasure	High fuel consumption and environmental burdens
	Economic growth and progress	Social costs of depletion of petroleum

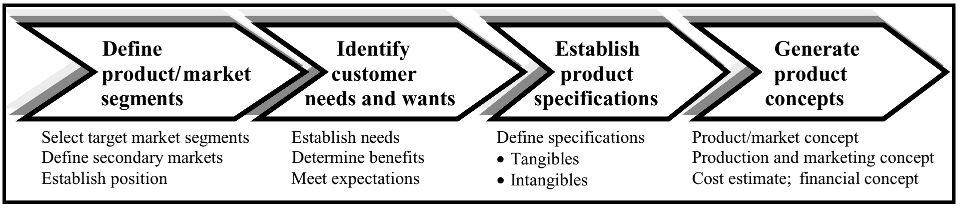


Figure 5.2 The concept-development step

The main goal from the product/market perspective during concept development is to develop a package of product benefits, functions, and features that are the most attractive to the majority of potential customers. Corey's point that market selection and product planning must go together suggests that tailoring the product package for a specific market segment is critical for success.

Concept development includes selecting the target product/market segment, identifying and verifying customer needs, defining the product package in terms of product specifications, and defining the estimated cost of the product. Outstanding product specifications are obtained by meeting customer needs and market requirements with superior core capabilities, and intellectual and creativity capital, while minimizing the negative aspects. Figure 5.2 outlines the elements in the process and the flow of activities during concept development.

The choice of a target product/market segment is a pivotal decision in the process. It should be based on the essential external and internal dimensions that provide the most benefits to the organization and its customers. Such logic suggests that two different companies with an identical product might select an entirely different market segment based on their different strengths and weaknesses. In some cases, secondary market segments are also defined and assessed. While this approach seemingly makes sense and provides a contingency or back-up plan, it does require time and effort to define fully the additional product/market segment and its situation in terms of the

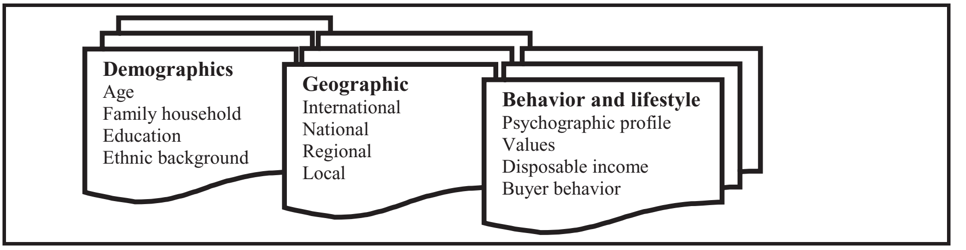


Figure 5.3 Selected market-segmentation categories

external dimensions. The benefits of such an approach have to be considered in terms of increased investment of time and money.

Defining the product/market segment

The market segment is defined in terms of demographic aspects, geographic location, and buyer behavior characteristics. In some cases, the choices are straightforward, based on the attributes of the product and the benefits that it offers potential customers. For example, Honda's Insight automobile is intended for a select group of consumers that are seeking the environmental benefits of a fuel-efficient, low-emissions vehicle, and are willing to cope with having only two seats.

Defining the product/market segment depends on the type of market and the needs of the customers. The standard market categories of consumer, industrial, and government can be further subdivided into market segments.

Consumer markets are typically segmented according to demographic aspects and/or geographic location. Demographics play a powerful role in predicting how potential customers perceive the product and how they shape their basis for decision making. Industrial markets are segmented by applications and buyer behavior. Government markets are usually defined in terms of purchasing protocols established by the governmental entity or by very specific mandates that have to be followed. Figure 5.3 shows a broad view of some segmentation schemes.

The essential questions for the new-product situation are: how to segment the market and how to address the market segment(s)? The related question is: What are the appropriate characteristics that provide the best definition of the product/market segment(s)? Generally, these questions require market research to establish the characteristics of the existing market. The analysis of the information and data offers answers to the questions. Often there is a set of solutions. One possible solution set is to amalgamate two or more segmentation schemes into the final choice. The selected market segment might be the intersection of the segments. It may be a certain age group; with a certain disposable income range; living in a specific region of the United States, Europe, or Asia. Indeed, the actual market segment is often further refined to focus on a select group of potential customers who appear to exhibit homogeneous traits. For example, the target market segment might include college-educated females between the ages of 25 and 44 years, who have a disposable income of more than $50,000, and who live in Germany. Automobile models are normally characterized in terms of a product/market definition of age category, disposable income, and lifestyle. While such a definition is very specific and tends to eliminate many individuals from the selected population, the specificity of the market segment gives the NPD team an excellent understanding of how to deal with the target. The more defined the market segment is, the easier it is to develop the marketing message(s) for the potential customers. Moreover, the easier it is to develop the proper product characteristics; to understand what the cost structure has to be, based on an acceptable market price; and to determine the operating and financial requirements.

With a more-precise definition of the target market segment, the product/market concept can be developed in detail. The greater the understanding of the definition of the market segment, the more likely it is that there will be convergence between what the product/market concept is and how it fits into the business environment and the strategic and operational framework of the company. For example, the market segment related to industrial equipment for biotechnology companies tends to be located on the east and west coasts of the United States and is usually concerned with process safety, quality, value, and reliability.

Identifying and validating customer needs

Identifying and validating customer needs and wants is the next critical step. Market-research techniques used during the concept-development step are similar to those described in Chapter 4. The art of validating customer needs and wants during concept development is in interpreting customer and market information and data to determine what customers truly need, and then prioritizing the results. If the needs and wants are known – or are readily available through a literature search or other existing sources – the process is relatively simple, requiring the extraction of the appropriate information and the articulation of the position statements. While there may be subtle differences between the activities during idea generation and concept development, the critical difference rests in the confidence in the organization's knowledge about the market segment(s) and the specific details. During idea generation, it is usually adequate to have just a broad understanding of customer expectations because of the potentially large number of candidates and the basic goal to quickly reduce the list to those worth the time and effort to develop into concepts. In such cases, the needs and wants of potential customers were not fully articulated, necessitating additional effort during concept development. If the details are not available, it is often necessary to conduct market studies to learn what benefits customers expect, and how to translate customer needs and wants – and their related expectations – into product attributes so that a clear understanding of the product/market concept unfolds. However, the actual effort is often complex.

Customers typically have multiple needs and wants which have to be analyzed and prioritized into a hierarchy. Customers seek benefits. They want solutions. Their needs are expressed explicitly and implicitly. Needs and wants are multifaceted and include tangible and intangible considerations. The tangible characteristics provide the functionality. The explicit needs are usually obvious and the ones that include the "must-have" functions and features (benefits). For example, a family car or van "must have" six to eight seats. The implicit needs are more difficult to determine. They include the "would like to have" and/or the latent aspects that are often not easily articulated. The customer may want a certain solution to a problem, but the situation is based more on a burden than a required function or a feature. For example, in the United States, the doors on the standard automobile lock automatically when the car is put into drive, but the doors do not unlock automatically when the car is shut off. This creates a burden if the owner tries at a later time to open one of the passenger doors and it is locked.

The process of identifying and validating customer needs is supported by several analytical techniques that facilitate the discovery and determination of the customer's perception of the product. One of the most frequently used approaches is the notion of the "voice of the customer" (VOC), which is an integral part of quality function deployment (QFD). QFD is a sophisticated technique used to identify, prioritize, and translate customer needs into design (product) characteristics and manufacturing requirements, and build them into the product. VOC describes the "whats" (attributes) that customers are seeking and provides a sense of their relative importance (prioritized). QFD focuses on determining customer needs, translating customer requirements into product specifications (the "hows").[2] QFD is covered in the next section and in more detail in Chapter 7.

Empathic design is an innovative technique used to ascertain latent customer needs or to discover new ways that customers use or would like to use a product. Through empathic design, observations in a customer's environment provide information about the actual applications of the products and the benefits of the functions and features. As described in an article, "Spark innovation through empathic design,"[3] Dorothy Leonard and Jeffrey F. Rayport suggest that existing customers may use the product in novel and unexpected ways that provide opportunities for new products or for the repositioning of existing ones.

Seeking new-product opportunities: empathic design

Customers can become so accustomed to certain deficiencies in a product or service that they never bother to ask market researchers for an improved alternative. Eventually, working around the inconvenience becomes a habit, and customers forget that they are being forced to behave in a sub-optimal manner. Consider, for example, the product developer from Hewlett-Packard (HP) who was observing a surgeon in an operating room. A television monitor allowed the surgeon to guide his scalpel inside the patient's body, but as nurses and others involved in the operation walked around the room, their bodies would periodically block the surgeons view. No one had ever considered this problem, but the HP product developer viewed it as a new-product opportunity. The result was a wearable monitor; a lightweight helmet that projected images of the surgery just in front of the eyes.

If the market place lacks even the most primitive form of the product type, market research will be of little use. For example, consumers did not ask for radio broadcasts in the early twentieth century because they simply did not know the technology was feasible. At the time, radio technology was used only for sending Morse code and point-to-point voice messages. It was not until 1915 – when David Sarnoff (the Radio Corporation of America [RCA] David Sarnoff Research Center was later named after him) suggested that radio could also be used to broadcast news, music, and baseball games – that the home-radio industry was born.

It is also important to understand the circumstances that prompt customers to use products. Sometimes products are used in unexpected ways, and understanding these "triggers of use" may identify product redesign and new market opportunities. For example, during development of the HP 95/100 LX series of personal digital assistants (PDAs), HP was careful to incorporate the computing power of Lotus 1-2-3 spreadsheet software into their design. When HP researchers observed consumers actually using the product, they learned that users valued the personal-organizer software at least as much as having spreadsheet capability.

General Mills discovered an unexpected trigger when it performed field research on Cheerios cereal: the breakfast cereal was also very popular as a toddler snack food. Parents had learned to carry a bag of the cereal with them because the small, neat shapes made a perfect snack for young children. Consider another example of a product being used in unrelated circumstances. The brand manager for a spray-on cooking oil company became curious when he noticed his neighbor coating the bottom of a lawnmower with the product. Evidently, the neighbor had discovered that the cooking oil prevented cut wet grass from sticking to the bottom of the lawnmower, thus avoiding unwanted interruptions.

Source

Leonard, D. and J. F. Rayport, Spark innovation through empathic design. *Harvard Business Review*, **75**:6, November–December (1997), 102–113.

The bottom line is to develop a sustainable position by selecting the most advantageous market segment(s) and to provide attributes that exceed expectations. Customer requirements should be stated in terms of what they mean to the customer, not what they mean to the producer.

The process also includes benchmarking other products and companies to discover innovative products and techniques that provide new solutions or opportunities for dealing with existing situations or evolving trends. Innovations developed in one industry may offer significant advantages when adapted in other settings. Many innovations are a result of the transfer of technology from one industry to another.

Establishing product specifications

Product specifications are based on what the customer needs and wants, and how the producer or service provider can meet the expectations. Product specifications describe what the product has to provide and define the product characteristics so that the product can be produced. They include the technical requirements used to design the product, and the physical and psychological characteristics. Product specifications tend to evolve during the NPD process. They are the integration of customer needs with the technical realities of product design and production requirements. The initial specifications developed during idea generation and concept development are typically the target specifications. Target specifications combine the hopes and wishes of customers with the desires and practical aspects of the technical capabilities and resources of the organization, along with the marketing and financial implications.

Target specifications reflect contributions from potential customers (market research), the development team, and the supporting internal and external participants. They might include overly optimistic requirements (functions and features) that have unacceptable costs or consequences. Target specifications are not always achievable. The cost associated with providing a given feature or function may be prohibitively expensive. Maytag's Neptune line of clothes washers provides high efficiency and water savings. Customers want the improved efficiency, but they may not be willing to pay the higher prices. Such innovations tend to become more acceptable as prices decline.

The target specifications are actually the preliminary specifications based on inputs from the market segment and the business environment. The specifications are refined throughout the NPD process as subsequent information and analyses necessitate modifications. The target specifications should include both tangible and intangible aspects. They should be analyzed based on competitive products and defined in both absolute and relative terms. For example, product performance can be stipulated as having the capability to deliver exactly a given outcome. An electric drill provides 19.2 volts and rotates at 600 r.p.m. In other cases, the metric might be stated on a relative basis. The position of the new product might be defined as being between the high-end and the low-cost product.

Characteristics should be stated in qualitative and quantitative terms. The relationship between needs and product characteristics can be graphically displayed using a simple two-dimensional matrix. The method includes a comparative analysis between the new product and its competitors; and benchmarks with respect to ideal requirements, government standards, and/or other important measures for success. If a more-elaborate approach is required, QFD can be used during concept development, but is typically used only after concept selection. Since QFD involves sophisticated techniques and time-consuming activities, its use is often delayed until there is a significant commitment to the new-product opportunity. QFD is used frequently during the Concept Development and Selection Phase for those new-product situations that have high uncertainty and/or risks or if there are relatively few options and the concept is more likely than not going to proceed to the design phase. The development of the high-thrust jet engine (Pratt & Whitney and General Electric) for the new Airbus A380 is an example. Given that the development program is expected to cost $1 billion, the developers want to ensure that, very early in the NPD process, they clearly understand the requirements. Conversely, if there are large numbers of new-product concepts with relatively insignificant implications and impacts that have to be evaluated, the use of QFD is often deferred to the Design and Development Phase.

Cost estimate (cost model)

Estimating the cost of a new product is complicated and requires detailed information and data about the product specifications, engineering details, and production requirements. The latter is generally available only during the Design and Development Phase. However, a cost estimate is essential for decision making during the Concept Development and Selection Phase. The lack of detailed information is not a reason for avoiding the issue. It is imperative to establish a cost target. For many products, cost depends on volume; therefore, several volume points have to be used to obtain a proper understanding of the cost implications.

The simplest view of a target cost is:

$$\text{Target cost} = \text{Price} - \text{Gross margin}$$

This simple version is based on the assumption that there is a prevailing market price established by competitors or customers and that the expected gross margin has to be sufficient to cover operating expenses and provide a profit. The target cost determined by this approach is an average cost over a given time period.

The slightly more-complicated approach is to determine what the costs for materials and components, fabrication, and assembly would be at several volume points. This model is expanded in Chapter 10 to provide a detailed perspective on estimating product cost. The estimate is based on establishing the cost for supplier-based purchases and production costs at selected volume points. Costs tend to vary with the number of units produced. For instance, bulk purchasing lowers the “per-unit,” or variable, costs. Table 5.2 provides a simple illustration of the cost-to-volume relationship that exists for many materials, parts, components, and labor that are used to produce and assembly the final product. Care has to be taken not to assume that lower costs are always obtainable. Table 5.2 provides an overview of a simple hypothetical case. The cost of the product includes a standard material (one kilogram), a single component, and assembly labor

Table 5.2 *Estimated unit cost based on assumed volume points*

		Volume point					
		1,000		10,000		100,000	
Cost elements	Qty per unit	Per item	Total	Per item	Total	Per item	Total
Material	1 kg	$3.00	3,000	$2.00	20,000	$1.00	100,000
Component	1	$8.00	10,000	$4.00	40,000	$3.00	300,000
Assembly	$10.00 per hour	1 hour	10,000	0.5 hour	50,000	0.5 hour	500,000
Total cost			23,000		110,000		900,000
Unit cost			$23.00		$11.00		$9.00

at $10.00 per hour. The product cost is $23.00 per unit at 1,000 units; $11.00 per unit at 10,000 units; and $9.00 per unit at 100,000 units.

The table provides a view that is more appropriate for derivatives or those product concepts where there is sufficient information about the materials, components, and expected manufacturing requirements; this information is usually based on the "bill of materials"[4] and the production process for similar products.

Target-cost models can be derived from an analysis of the product characteristics taken from QFD if it is available. Such an approach provides a more-comprehensive perspective of the expected unit costs, but it also involves a more-elaborate construct of the product and cost situation. New-to-the-world product types usually necessitate more-sophisticated techniques during the early phases. Without a thorough assessment of the opportunity, and an understanding of the cost implications, it is difficult to judge the merits of such situations.

The cost model used during the Concept Development and Selection Phase is based on the primary objectives of the NPD process. If time and money are the primary considerations, simpler models are employed. If risk management and minimizing uncertainty are the key drivers, then the sophisticated models should be used. The answer depends on complexity and the tolerance of risk and uncertainty.

Concept assessment

Overview

The concept-assessment step includes a thorough analysis of the external dimensions to ensure that all of the significant external factors have been considered and that there is integration of essential external factors with the elements of the concept development. The purpose of concept assessment is to incorporate the effects, impacts, and implications of the non-market-related external factors so that a balanced concept is determined, providing a clear understanding of the merits of the new-product opportunity.

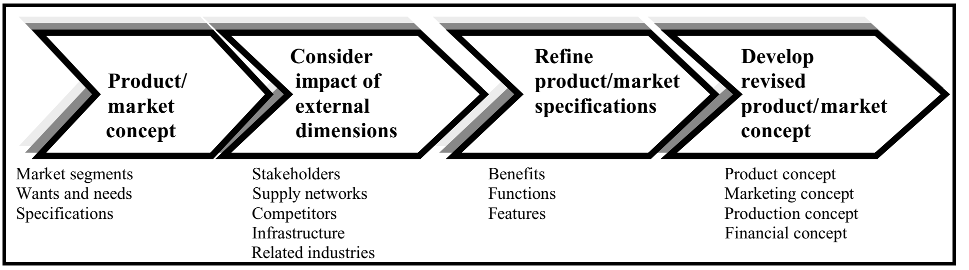


Figure 5.4 The concept-assessment step

Concept assessment is a refinement of the concept-development step based on external considerations. Effective concept assessment takes an enterprise view of all of the participants and constituents, their needs and contributions, the consequences of the NPD program, and the opportunities for improvements. Figure 5.4 indicates the essential elements.

Stakeholder assessment

The inclusion of stakeholder considerations into the NPD process is a profound change in thinking about what it takes to develop a successful new product. During the last decade, organizations have recognized that they have responsibilities for ensuring that the needs of stakeholders are also included in the analyses of a new product.[5] The philosophy of customer satisfaction has been expanded to include stakeholders as well. Stakeholder assessment continues the analysis performed during idea generation, it covers more elements and drills into additional details.

Stakeholder assessment is the ongoing effort to map and prioritize the important issues, explore the effects and their impacts, and determine what courses of action should be taken to deal with the potential consequences. The purpose of the assessment is to understand the external requirements and to respond to the needs of the public, special-interest groups, government agencies, and other stakeholders. The following are some examples of questions pertaining to stakeholder issues which should be addressed:

- Are there laws and regulations that spell out requirements affecting product specifications and the viability of the product concept?
- Are there industry standards that have to be incorporated into the design?
- Who are the stakeholders that have to be considered?
- What are the most important issues?
- Are there special requirements mandated by cultural considerations, special practices, or prevailing social norms?
- Are there special-interest groups that have a concern about the product or its impacts? What are the most important concerns?
- What are the concerns about potential liabilities, especially product liability?

Managing stakeholder expectations is based on the premise that the best product design balances the social, economic, environmental, and product/market relationships so that there is a sustainable interface between the dimensions.[6] The primary goals are to improve the positive outcomes from social, economic, and market perspectives, and to reduce the negative impacts and consequences of products and processes. Appropriate new-product strategies must satisfy not only the economic and functional objectives of the design specifications, but they must also encompass solutions for social, economic, and political problems as far as is possible and/or realistic.

Supply-networks management assessment

During concept development, supply networks present opportunities to contribute to the fundamental goals of the NPD program through innovative materials and components, and relationships. The principal suppliers can also become partners in the design and development of the new product. The suppliers may take on the responsibilities for designing and delivering a significant part of the requirements. Such determinations are usually made during the Design and Development Phase; however, in certain cases the selection of key suppliers and their scope of supply are locked-in early in the NPD process so that the relationship can be enhanced and the overall investment by the organization can be reduced or better managed. Such relationships make a new-product concept feasible by increasing the funding for the program (additional funds provided by suppliers). Sikorsky Aircraft used several critical suppliers who contributed financially and technically to the development of its civilian helicopter, the S-92.[7]

The early involvement of essential suppliers provides valuable input to the process, including better estimates for the cost of materials, parts, and other products and services, and details about the availability and timing of the flow of goods. The supply of materials and components can be categorized according to their importance to the design and build process. The highest levels of importance are assigned to the strategic materials and components, including items that are substitutes for the traditional inputs; strategic materials and components are those that are critical to the design. The decision to use a Pentium 4 microprocessor is a strategic design decision in the development of a new personal computer. Such a decision affects almost everything during the subsequent phases. It has impacts on the design and its cost, the marketing program and the pricing strategy, the production process and the value of the inventory, and the financial plan and the requirements for capital. High-cost or long-lead-time items also have significant impacts on the decision-making process; therefore, they require analysis and consideration before the concept(s) is finalized. Such items have a dramatic effect on pricing and margins, as well as on the production system.

The other categories are less critical and can be dealt with as the design matures. Figure 5.5 provides a perspective on the categories of importance when considering the inputs from the supply networks.

Criticality	Critical items for design	Critical items for build	Non-critical for design	Non-critical for build
Category	Strategic materials and components	High-cost or long-lead-time items	Standard materials and components	Commodities
Priority	Highest	Very high	Important	Less important
Timing – phase	Concept Development	Program Definition	Design and Development	Pre-commercialization

Figure 5.5 Supply-networks hierarchy and considerations during the Concept Development and Selection Phase

Supply-chain considerations for critical items include seeking options for troublesome issues, finding alternatives for unfavorable supplier situations, determining whether to make or buy the item(s), and establishing strategic relationships with critical suppliers to stabilize cost or availability problems.

Many organizations have a tendency to delay making supply-networks assessments and determining how to handle critical issues until later in the NPD process. While the concern of premature disclosure of the new-product concept is a legitimate issue, the failure to take on such issues early enough in the process often constrains the design and creates potential difficulties. For example, given that titanium is in short supply and that it is expensive, a product concept based on titanium metal automatically builds in downstream implications requiring early and ongoing management attention.

Competitor assessment

Competitor assessment is a primary technique for understanding the business environment and the fit of the product concept into the market segment. The target market segment and the competitors serving the segment help to define the product/market concept. When selecting a target market segment for the new product, the competitors that serve the segment are also selected.

The important questions pertaining to competitors during concept assessment are:

- Who are the most significant competitors serving the primary market segment?
- What are their strengths and weaknesses?
- What are the advantages and disadvantages of their products that are similar?
- What are their anticipated responses to the new product(s)?
- What constraints or limitations do they impose?

The strengths and weaknesses of the principal competitors offer challenges and opportunities. Often in an NPD situation, the developer wants to find a gap in the existing competitive picture or to exploit the weaknesses of competitors when refining the product/market concept. Effective competitor analysis includes identifying their current position and strategies, assessing their current capabilities and resources, and anticipating their future strategies; the essential elements are given in Table 2.9 in

Chapter 2. Competitor analysis also builds on the information and analysis performed during idea generation.

The initial step is to list the existing or potential competitors. If the list is extensive, it can be prioritized to reduce it to the most-critical competitors or those that best represent the competitive situation. Identifying the current competitors is usually easy; determining the potential competitors is obviously more difficult. From the list of competitors, the next step is to select those that provide the greatest insight into the product/market concept. The objective is to enhance the product/market concept, not to become overly concerned about competitors. An expected outcome of the competitor assessment is to ascertain the most appropriate means for differentiating, from a customer's perspective, the new-product/market concept from the competitor's. A comprehensive assessment of the advantages and disadvantages of competitive products in the intended market space provides a means of gaining additional insights. During the assessment, it is crucial to be realistic about the positions that competitors occupy and the space available for another product. Their success, or lack thereof, sheds light on the competitive scene and the possibilities for achieving success in the market segment. It also provides information about current design options, how products are produced, what marketing programs appear to be successful, and what the financial returns are.

Information about competitors is usually readily available in the form of advertising, product literature, labor contracts, patents granted, articles in trade journals, etc. Other rich sources of information include exhibits at trade shows, reports to government agencies, industry reports, independent surveys, and media reports. The most prolific source is the Internet. Most large companies have web pages explaining every facet of the company and their products.

The goal of the analysis is to learn as much as possible about each of the competitors. Decisions about positioning the new product in the competitive arena should be based on credible and current information. However, other NPD goals – such as rapid time to market and low development costs – play a significant role in determining how extensive the competitor assessment should be during the Concept Development and Selection Phase. Furthermore, an important part of the assessment is to gain insights into the product/market concept. It is critical to understand that the principal purpose of concept development is to present a comprehensive view of the opportunity so that the organization can be confident of its concept screening and selection process. If there are missing details pertaining to competitors, it should be noted and the analysis completed during subsequent phases.

Table 5.3 offers some additional insights into what to include in the competitor analysis and the relationship between these elements and market information. The aim of the table is to show that many of the elements conceived during concept development can be validated by real-world information. For example, if all of the competitors are realizing gross margins in the 30% range, it is probably unrealistic to assume that the

Table 5.3 *Competitor-analysis elements and market information*

Area	Competitor aspects	Market information
Design	Number of new products introduced Percentage of revenue from new products	Customer acceptance of innovation Rate of innovation
Product	Quality programs Technical capabilities	Quality requirements Product sophistication
Market	Market shares Sales growth	Market size Market growth rate
Production	Capacity Production costs Locations	Power of buyers Price sensitivity and range Logistical aspects
Marketing	Marketing programs Promotion/communication Distribution channels Pricing policies	Market information requirements Customer needs Acceptable channels Acceptable pricing
Finance	Cash flow Returns on investment Gross margins	Investment requirements Measures of success Leverage for R&D and marketing
Business	Business strategy Leadership	Direction and opportunity Customer requirements

new product will have a 50% gross margin unless the organization has overwhelming strategic or technological advantages or benefits.

Infrastructure and related-industries assessments

The infrastructure and related industries provide support for the product. The essential questions relate to the identification and assessment of the specific requirements that are absolutely necessary for the new product to succeed. The basis for the assessment is identical to that discussed in Chapter 4 as part of idea generation.

Refinement of product specifications

Based on the analyses of the concept-assessment step, the product specifications are refined to incorporate insights gained during the analyses. This activity often requires the organization to adjust the product characteristics and their fit with the external business environment. One of the typical problems is the struggle between desired features and benefits, and the associated costs. The refinement of the product specification represents the fine-tuning of the product/market concept. It includes meeting customer needs, responding to the expected responses of competitors, incorporating the expectations of stakeholders, and being in concert with the other external dimensions. The value proposition again plays a significant role in the determination of the positioning of the product/market concept. In terms of product costs and expected prices to the customer,

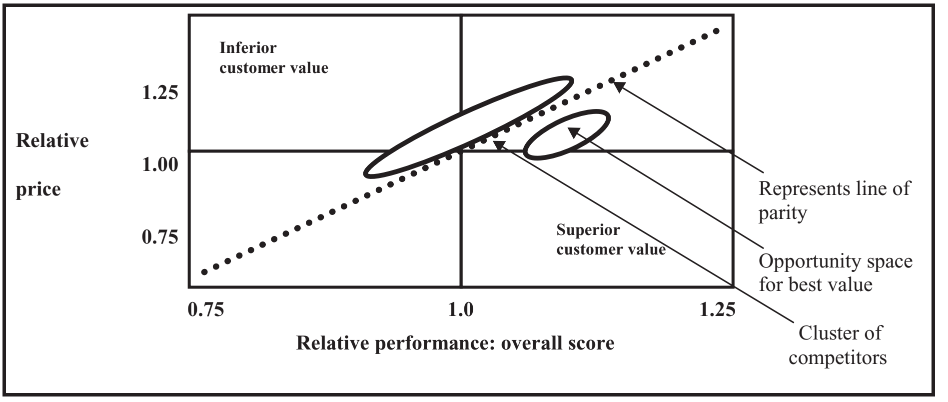


Figure 5.6 Customer-value map[8]

the product/market concept has to be positioned favorably with respect to its benefits and features vis-à-vis customers' expectations and competitor positions.

A two-dimensional map of the position of the product/market concept in the market segment, in terms of performance-to-price ratio, may furnish insights into the viability of the selected position. Figure 5.6 is an excellent example of effective positioning of a new product using a relatively simple customer-value map. The solution space that is superior to all of the competitors is to the right of the parity line. The product/market concept should be positioned reflecting the new-product strategies, the needs and wants, and the competitive alignments. The graph indicates an opportunity space representing best value; the dotted line represents parity. Products on or near the parity line have comparable value, suggesting that the competitors in the cluster shown on the map are equivalent. Any product positioned significantly below the line offers better customer value, and, therefore, theoretically has a competitive advantage.

The refined product specifications should include the technical characteristics as they relate to customer needs and as modified by external dimensions and the cost implications of each of the requirements. The refined specifications reflect the adjustments made to accommodate all of the internal and external requirements.

The revised product/market concept

The revised product/market concept reflects all of the analyses and choices made during concept development and assessment. It includes the refined product specifications and the selection of the target market. The primary outcome is the product/market concept detailed to the extent that the organization can make a determination about its potential. The main components of the concept are the following:

- ***Product/market concept***. This indicates the technical and market feasibility of the concept and its merits from internal and external perspectives. It includes the target market segment and the product specifications. It also includes the cost-estimate model, showing the cost breakdown structure for the product and indicating how the cost structure varies with cumulative volume.

- ***The marketing concept***. This conveys the primary marketing objectives and strategies for the product/market concept and the proposed marketing plans for the development program. It generally includes the significant marketing-mix elements and their role during the NPD process. The main considerations are the pricing strategy and the marketing campaign during launch. It reflects on the feasibility of executing the marketing program in the light of external factors and achieving success.
- ***Production concept***. This reflects on the production requirements and resources needed to execute the production plan. It assesses the core capabilities of the organization and the productive assets related to the new product. It examines the internal manufacturing processes, the supply networks, and alliances for determining the viability of the resources to produce and deliver the product.
- ***Financial concept***. This explores the core financial objectives and requirements, and their relationship to the product concept. It examines the financial projections of the revenues, gross margins, cash flows, and potential earnings. It also identifies the total investment required to fund the program and the payback period necessary to achieve positive results.

The product/market-concept statement can take many forms, from open-ended format tailored to meet the specific requirements of an NPD opportunity to well-documented requirements spelt out using a preset format. Either approach, or anything in between, may provide the framework needed for achieving results. Generally, new-to-the-world product opportunities follow the former and the other new-product types follow the latter. The former is more project oriented while the latter is more process oriented. As stipulated earlier, the focus of this text is on a process orientation providing guidance for those NPD programs that follow predetermined pathways.

If a specific format is desirable, Table 5.4 provides a simplified format for summarizing the product/market concept.

Although the form seems to be the same as for idea generation, generally there is a significant amount of additional detail available for a concept. The most critical information pertains to the main elements of the external and internal dimensions. The concept may be presented for screening using a document of four to ten pages summarizing the most important points.

Concept testing and screening

Concept testing

Concept testing uses simple product/market tests to determine the viability of the product in the market segment. Assuming that only the hypothetical aspects of the concepts

Table 5.4 *Simplified standard form for summarizing the product/market concept*

Title of concept	
1. Description	What is the product/market position? How does it fit the strategic logic of the organization? What is the value proposition? Identify the principal strategies for commercializing the concept?
2. Target market segment(s) and product/market strategies	What is the target market segment(s)? What are the principal needs and wants? What are the essential attributes of the proposed product? What are the target specifications? What is the cost estimate? How does the concept fit into the market and what are its main benefits? What is the product position and how can the market be reached?
3. Business environment and competition	What are the most important factors of driving forces in the business environment? Identify the most important business conditions and trends affecting the idea. Who are the most important competitors? How is the concept different from the competitive offerings? What are the expected competitor responses?
4. Critical factors for success	Identify the most important factors for achieving success. Identify the means for designing and marketing the new product. Specify the product/market concept; the marketing concept; the production concept; and the financial concept.
5. Main barriers to success	What are the major opportunities or constraints related to the external forces? What are the most critical factors and limitations? Who or what stands in the way?
6. Main financial considerations	Estimate the expected product costs; expected sales volume; and projected revenue. Estimate the total required investment. Estimate the net present value or internal rate of return.
7. Risk factors	What are the most significant risks?
8. Time-line	Determine the expected development cycle. Identify the expected launch date.

are available during the Concept Development and Selection Phase, the testing of the product is generally based on a description of what is intended as opposed to what is. More details can be provided through drawings, artist renditions, or computer-aided diagrams. There are numerous approaches used to obtain inputs on the potential of each concept. The simplest method is to query selected employees about the concept. Their responses provide insights about the potential of the product without risking having competitors obtain information about NPD plans. As with most methods, there are advantages and disadvantages to using employees. Employees might be biased toward having many new-product opportunities. They may be inclined to overstate the positive aspects and underestimate the negatives of the new product. Knowing the culture of the organization helps to determine the suitability of the approach.

Potential customers are often valuable contributors for testing new-product candidates. They represent real users; their views are based on the business environment and market perspectives. However, as with employees, great care has to be taken to ensure that the information gleaned is representative of the true market conditions and not just the preferences of the selected individuals. Customers who are willing to contribute their time to such afforts have preferences that may adversely affect the validity of the test. Concept testing is often performed using customers who are linked through strategic partnerships or supply relationships. While such partnerships provide advantages such as better security of the information and knowledge involved, there may be a tendency to promote new-product candidates that are favorable to the preferred customers and less advantageous to their competitors or others. There are always pluses and minuses to be assessed.

The aim of concept testing is to quickly and easily obtain sufficient information about customer preferences to facilitate the screening process. Unlike the objectives of testing during the later phases, approximate inputs are generally sufficient to discern judgements about the candidates. Even the successful candidates from the concept-testing step have the potential to be eliminated following subsequent testing and decision making.

Concept screening

The concept-screening step is the appraisal of the product concept(s) to determine whether there are compelling reasons why the organization should invest in the new-product opportunity. Screening identifies the opportunities that merit the organization's attention and commitment of time, effort, and money. The purpose of concept screening is also to weed out the product/market concepts that are unsuitable or incompatible with the organization's strategies and goals, that are not in line with its competencies and capabilities, that lack sufficient market potential, or that have negative consequences that might have an impact upon stakeholders or the reputation of the organization.

Screening should be viewed as a positive activity used for improving the probability of selecting and developing successful new products. In most situations, there is a hierarchy of criteria used to determine which candidate(s) are suitable for selection. This can take the form of meeting or exceeding specific requirements in terms of metrics or matching the preset stipulations for new-product opportunities. The screens are often presented as a list of critical categories with specific metrics that the organization has to achieve.

The screening criteria tend to vary considerably depending on the significance of the NPD program, its implications for the success of the organization, and the risks involved. Generally, the strategic fit, the size of the investment, the complexity of the product, and the significance of the NPD program play the most important roles in determining the type and number of screening criteria. The background of the company, its strategic logic, and the requirements of the market are also critical determinants in choosing the criteria.

Organizations tend to keep their screening process as simple as possible. A modest NPD program that fits into the existing product line and is based on a request from important customers is typically a straightforward situation requiring only a small number of screening criteria. A simple assessment of the required resources and an adequate financial return may be sufficient to pass the screening step.

However, large, complex programs representing significant commitments often require a substantial screening step with many criteria to ensure that there is an appropriate fit with the strategic and operating requirements of the organization. Screening is just one of many steps in the NPD process that examines the worthiness of a new product opportunity. Given that speed to market is an important requirement in today's business environment, an organization has to balance thoroughness with speed, as stated earlier. The more comprehensive the screening process is, the more time it takes to complete the NPD process.

The screening process often focuses on the fundamentals of strategic logic, market suitability, product viability, marketing compatibility, production capability, and financial feasibility. The value proposition provides an overarching view of the potential of a product/market concept. If the candidate creates value for the market segment and the other related external dimensions, then this may be a compelling indication that the candidate is viable. The notion of balance again has to be addressed in making appropriate decisions. Although it is often difficult to articulate and measure, learning may be a key criteria as well. Organizations often invest in new-product opportunities that have high risks or low probabilities of success because there is recognition that the investment contributes to organizational learning that has future benefits. Such views are particularly appropriate for new-to-the-world-product situations. For example, the early cellular telephones did not attract a large customer base, but the later versions have taken a significant percentage of the overall telecommunications market. Learning creates opportunities for future new products.

Table 5.5 *Product/market-concept screening criteria*

Category	Criteria	Type of metric	Example of target
Strategic fit	Mission	Relatedness to mission	100% linked
	Strategies	Strategic position	6 months lead
	Objectives	Rewards vs. risks	30% IRR
	Alignment	Fit with capabilities	100% aligned
Resource/technical capabilities	Related to portfolio	Direct technical fit	Exact fit
	Product differentiation	Uniqueness	No other form
	Performance	High level	2 × improvement
	Unit cost	±10% of target	Exactly on target
	Technical capabilities	Leverages strengths	100% leveraged
Value creation and market potential	**Value proposition**	Value vs. alternatives	Best in class
	Market attractiveness	Market size and growth	20% growth rate
	Performance to price	Functions and benefits	2 × improvement
	Life-cycle implications	Window of opportunity	At least 5 years
Stakeholders	**Key issues**	Environmental impacts	0 impacts
	Laws and regulations	Compliance and permits	100% compliance
	Standards	Required approvals	100% compliance
	Product liability	Exposure to claims	No exposure
Competition	**Expected responses**	Response time	6 months
	Intensity	Strengths of competitors	Few competitors
Infrastructure	Internet links	Customer access	100% connectivity
Related industry	Software support	Help services	100% support
Marketing	Pricing	Reference price	50% improvement
	Promotion	Leverage with existing	80% identical
	Distribution channels	Leverage with existing	100% identical
Production capability	Process capability	Leverages existing capability	No new resources
	Supply chain		50% leverage
Financial	Revenue projections	Sales size and growth	+2 × existing
	Margin expectations	Gross and net margins	30% gross margin
	Required returns	IRR/NPV	40% IRR
Risk	Technical/market	Low risk	Equals investment
	Business	Reputation	No impact
Program	**Development time**	Time to launch	>18 months
	Development cost	Total investment	>than $2 million
	Recovery	Payback	2-year payback

There are many screens used in screening processes. The criteria for the screening process should be predetermined and be based on the most crucial factors affecting the NPD reality of the organization. Balance is important and generally there are between four and ten screens. Too few screens leads to a potential skewing of the results. Too many screens increases the complexity of making decisions. Table 5.5 identifies some of the screening criteria used to evaluate new-product opportunities.

Strategic-fit and alignment screens

Without the strategic logic, it is difficult for the participants to understand the "why" question. The "strategic-fit" screen provides answers to the most profound questions. Why invest into this opportunity? What does it mean to the success of the organization and its people? Without understanding how the product/market concept fits with the strategic direction, most of the other screens do not mean much. The strategic-logic screen evaluates the product/market concept as it relates to the vision, mission, strategies, objectives, and direction of the organization. The screen is intended to ensure that the new-product opportunity fits the strategic logic and that management commitment can provide the necessary integration to proceed in a unified direction, to coordinate the NPD process, and to achieve the desired results.

The "alignment" screen explores the organizational fit and whether the elements are in line with the direction set forth for the NPD program. Alignment of the intellectual capital with the resources and the capabilities of the organization are essential for ensuring that everyone is moving in the right direction. Alignment is often an intangible and difficult-to-measure screen. It examines the willingness and preparedness of the entire organization to accept and integrate the initiative into its portfolio of programs and activities.

Resource-availability/capability screen

The "resource-availability/capability" screen provides a sense of the ability of the organization to execute the program based on existing and potential resources. The screen starts with a resource assessment based on the requirements mapped out from the product/market concept, the production concept, the financial concept and the refined specifications. Are the required resources available and are they adequate to meet the needs of the program?

The commitment of resources is a vital step in achieving results during the NPD process. A product/market concept has little meaning to an organization unless the people have the appropriate resources, willingness, and capabilities to execute it properly. Each new-product opportunity requires a critical mass of resources to achieve the desired results. Critical mass suggests that resources should be concentrated on the new-product/market concepts that present the best opportunities for achieving success, and that the resources must be decisively committed in sufficient strength, and at the right time, to ensure positive outcomes.

Resource limitations tend to have a negative effect on the viability of a new-product opportunity and often mean that the probability of success is less than acceptable. In such situations, management might explore alternative courses of action to overcome the weaknesses. Given that resources tend to be limited in most cases, the organization must focus its strengths on the primary requirements of the NPD programs and must select those product/market concepts that represent the best use of resources and capabilities. Allocating resources hardly guarantees positive results, but without the appropriate commitment, failure is often the norm. The resource-allocation process must ensure that the resources are adequate for the needs.

The capability screen examines the skills, knowledge, and competencies of the people available to participate on the NPD teams and the supporting personnel. Do they have the means and capabilities to implement the program? Are there missing participants, especially in the critical skill areas? Are there gaps in the skill set necessary to complete the program?

The resource-availability/capability screens explore the adequacy of the resources to execute all of the requirements inherent in the product/market concept. They focus particular attention on the special or unique requirements of the new product opportunity. If there are insurmountable resource requirements, the probability of succeeding may be extremely low and the risk may be too high.

Technical-fit and technical-capability screen

Technology and technical capabilities provide a complex and delicate balance in meeting the requirements of managing an NPD program. The management of technology, technological change, and innovation are essential determinants for NPD effectiveness. The organization has to have the ability to manage the technical requirements and to minimize the risks associated with the technologies and processes used. The implementation of new technologies often changes the entire nature of the business structure, the practices, the management of the processes, and the relationships in the organization. The "technical-fit" question focuses on whether the organization has the technical expertise or can improve its technical knowledge base and transform itself to richer levels of technological sophistication and organizational learning?

The screen examines the product/market concept in relation to the existing product portfolio. It explores the similarities and differences. How can the new product be differentiated from the current product lines or from the competitor's version? Is there an ability to create superior product performance based on the current concept?

The unit cost of the product is a critical consideration, especially for products with long life cycles. Can the product be produced and delivered at an acceptable price to the customer? Does the cost structure provide sufficient margin so that there is adequate cash flow to fund the appropriate level of marketing programs?

Value-creation and market screen

Successful new products create value for the customer as well as the producer/provider. The "value-creation and market" screen examines the value proposition. Will the investment create sufficient value? Is there is sufficient market potential for the product/market concept? Does the new product have the potential to satisfy the needs and objectives of all of the internal and external participants? Value creation and market potential are interrelated. They are addressing the same general questions. The screen focuses on the potential to excel with customers and satisfy their needs and expectations. It explores the value that is created relative to the options that customers have from existing or anticipated products.

The attractiveness of the product/market is one of the most important concerns regardless of the product type or the market segment served. Market attractiveness relates to many parameters, including the size of the market segment, its growth potential, its seasonal variations, long-term stability, sensitivity to pricing, product-differentiation requirements, purchasing patterns, etc. The following are some additional important questions:

- Are the prospects for achieving the sales projections acceptable?
- Is the expectation for value (performance-to-price ratio) acceptable to the market segment?
- Is the expected life cycle of the product adequate to justify the investment of time, money, and intellectual capital?

The quintessential aspect of market acceptance is meeting the needs, wants, and expectations of customers, both implicit and explicit. The screen should determine the likelihood of meeting customers' expectations for a new product in the particular category. There are always unmet needs and wants with respect to existing products. Yet, customers often have to have incentives to seek an alternative. This means that the new product has to create much more value than the old one in order to entice customers to switch. The essential question is: Does the product present a significant improvement compared with existing products? Depending on the product type, there is often a perception about the amount of improvement necessary to shift demand to the new product. Intel's Moore's law is a recognition that the rate of improvement has to be two times to generate enough interest in the new platform to justify the investment.

The fact that all parties have to benefit from the new product plays a critical role in determining whether the product/market concept has the potential to be successful. Value creation suggests that all parties have to be enriched by the investment in the new product, not just the producer.

Stakeholder-impact screen

The "stakeholder-impact" screen is one of the most difficult to generalize, since the critical issues are usually dependent on the actual NPD situation. This screen examines the potential impacts of the product and the related processes, and the possible implications on the whole of the enterprise. The purpose of the screen is to assess the negative impacts on stakeholders so that management is assured that there are no significant problems. It attempts to minimize mistakes or oversights by understanding all of the impacts – including social, economic, political, environmental, and technological – and determining whether there are unacceptable risks to external parties.

The screen explores the possibilities of potential liabilities that might minimize the benefits of the new-product opportunity or turn certain advantages into disadvantages. Obviously, the most significant impact would be the tarnishing of the organization's image and reputation in the market(s) or community(s). A blemish on the good name and reputation of the organization may have serious negative consequences, this could overwhelm the perceived advantages associated with launching a new product.[9] The stakeholder screen might address questions related to the impacts and risks of the new-product opportunity. Some of the key questions are:

- Are there any significant stakeholder issues that reduce or dissolve the viability of the opportunity?
- Are there any potential product-liability exposures?
- What are the major constraints imposed by the external business environment that could have a significant impact on the success of the new product?
- Are there any laws and regulations that could have any effect on the present or future viability of the new product?
- Are there any special-interest groups including non-government organizations, consumer action groups, environmentalists, etc. that might oppose the new product and its implications?
- Does the new-product opportunity expose society, or any individual therein, to any unreasonable health and safety risks?

The screen should ensure that the new product is not causing the organization to assume potential risks, liabilities, or problems that are beyond the normal or reasonable levels of the business. The review should identify and weigh the important concerns, and stipulate the organization's position pertaining to each item.

Infrastructure and related-industry screens

Like the stakeholder screen, "infrastructure and related-industry" screens are varied and virtually impossible to discuss from a generic perspective. The notion of alignment plays a role. Some of the most important questions are:

- Is the new product aligned with the infrastructure and related industries?
- Are there significant weaknesses in the infrastructure, or with related industries, that have to be overcome?
- Is it possible or reasonable to correct the deficiencies?
- What are the most crucial elements and will they have positive or negative effects?

The screens include the most important of the elements from an infrastructure and related-industry perspective. It is difficult to be comprehensive given the wide variations in possible issues and challenges. The key is to discover the vital few that provide a sense of whether there are difficulties or not. Generally for incremental changes, there are relatively few concerns because the new product is directly related to the existing ones.

Competition screen

The "competition" screen is broad. It examines the number and power of the existing and potential competitors. Some of the most important questions are:

- Is there a competitor with overwhelming power and resources who can easily emulate the new product and render the organization's initiative ineffective?
- Does the window of new-product opportunity have sufficient strength to establish a sustainable base against competitors?
- Can a critical mass be achieved in the market to obtain a sustainable market share?
- What are the probable responses of the significant competitors?

The aim of the screen is to evaluate and avoid positions that cannot be sustained in the market. Situations where competitors have the strength to imitate the new products and bring exceptional resources to bear are the principal concern.

Marketing screen

The "marketing" screen examines the ability to market the product/market concept effectively. It determines whether the selected marketing mix is suitable for the new-product opportunity. If new marketing means are required, the screen explores the viability of applying the new mechanism given the resources and capabilities of the organization. Key questions include:

- Does the new product require marketing techniques and distribution channels that are difficult to acquire and support?
- Are the existing marketing mix and distribution channels suitable for the new product?
- Can customers be reached using the prevailing marketing programs or does the new product require new approaches?
- How long is it expected to take to build a base of sustainable customer demand?
- Is the required time within the time allocated for the program to achieve success?

The review of the marketing aspects again depends on the actual situation. Many variables play a role in screening the marketing strategy and program. The screen should contain the essential elements of the NPD program and ascertain whether the program is feasible or not.

Production-capability screen

The "production-capability" screen is simple. It explores the productive resources available to produce the product, and their adequacy. It examines the internal or external means for building the product or having the product produced.

- Can the product be produced using resources that are currently available and possibly underutilized? (Internal or external.)
- Is there a sufficient knowledge and resource base for the production of the product?
- Are the critical raw materials available from reliable suppliers at reasonable prices/terms?
- Are the supply networks adequate to meet the requirements of the new product?
- Can the production capability meet the product specifications on a timely basis?
- Can the quality goals be achieved on a consistent basis?

- Can the new product be produced within the unit-cost projections outlined in the cost model?

The bottom line to this screen is related to the adequacy of the production and supply-networks' resources and capabilities. Are there barriers to effective production of the new product?

Financial screens

The "financial screens" are often the dominant criteria used in selecting the candidates. The first question below relates to the total investment required for commercializing and sustaining the new product. The investment includes the funds for development, marketing, and production, and the working capital to sustain the product before achieving breakeven point in the cash flow.

The primary financial screens relate to the conventional means of determining the financial feasibility of a program. Some of the essential concerns are:

- Are the funds available to support the program?
- Are projected revenues and cash flows sufficient to cover the costs of goods, the operating expenses, and the investment?
- Can the unit-cost projections, based on assumed volume relationship, be achieved?
- Are the gross margins sufficient to cover the expenditures required for marketing and distribution, and still earn a suitable profit?
- Is the internal rate of return on a discounted-cash-flow basis capable of covering the cost of capital and meeting the expected return?
- Is the net present value of the new-product venture acceptable?

The answers to the questions depend on the level of involvement and risk. Simple programs may be acceptable, if they meet the minimal financial requirements of the organization. More-complex programs with higher risks and higher reward expectations may have to meet more-stringent metrics to pass the screen.

Risk screens

Risk is an inherent part of new-product development. The questions include: What is acceptable risk that is prudent given the potential reward? What is beyond the range of acceptability? Risks are the ever-present concerns about the uncertainties of the development courses of action. The primary considerations are the technical risks associated with the design and development of the product and the market risks associated with market acceptance and potential. The risk of serious damage to the enterprise is also an important consideration. Risk-management aspects were covered in Chapter 1. Additional details are discussed in Chapters 10 and 12.

Program screens

The "program" screens examine the ability of the organization to execute the program on time and within the expected development costs. Failure to achieve time-to-market

Types of screens	Market-oriented screens	Business screens	Priority
External focus	Value creation Market attractiveness Potential liabilities Market risks Competitive response Stakeholder issues	Strategic fit Technical risks Organizational capability Development time Total investment Breakeven	**Higher** ↓ **Lower**
Internal focus	Unit cost Product performance Marketing capabilities Quality capabilities	Financial returns Development cost Resources availability Production capabilities	**Higher** ↓
Priority	**Higher** →	→	**Lower**

Figure 5.7 Product/market-concept screens

goals usually affects the development costs and the time to breakeven. As the program is stretched out in time, the probability of success based on the original metrics changes and, typically, the change is negative.

The program screens are based on all of the other screens and are often the final screens that determine whether the program should go ahead or not. Hard guidelines are difficult to suggest since it is not easy to define how far from the target is too far. It is often a matter of judgement.

Summary of concept screening

The discussion on screens suggests that the number of screens used to determine which opportunity should be pursued is extensive. The number of screens and the screening process itself are dependent on the actual new-product opportunities and the organization's preferences and capabilities. For a relatively small program, a modest number of screens might be used to select appropriate product/market concepts. For more-complex situations, a "balanced-scorecard" thinking might apply. The past perspective of concentrating only on financial screens may lead to serious difficulties. The limited (short-term) view of the product/market-concept's potential might skew the selection process toward opportunities that present short-term results at the expensive of value creation, portfolio balance, competitive response, etc. A more-complex screening program may mean that strategic issues drive a significant portion of the organization's future position and its success rather than product delivery requirements. Given that most organizations have guidelines pertaining to the screening process, the issues involved are probably easier to manage in the real world of product development.

Figure 5.7 provides an overview of the product/market-concept screens and their relationship with the product/market aspects and the business/program aspects.

Concept selection

First cut

Concept selection is a complicated and worrisome process that ultimately translates into “go/no-go” decisions. There are various means and techniques for ranking and rating the new-product concepts. Most are similar to the construct used in Table 4.6 for rating new-product ideas. Since the number of new-product concepts is usually significantly less than the number of ideas, there is generally a willingness to invest more time and effort in determining which candidates proceed to the next phase and which candidates are recycled or terminated. Not only are there concerns about the time and money for screening and selecting the candidates, but concept selection is also a critical point in the NPD process for ensuring that the overall choices are synchronized with the goals and strategies of the organization. If the NPD process has been executed according to the prescribed guidelines, the correct choices are usually apparent. However, there is always a concern about making type-1 or type-2 mistakes; these mistakes result in, respectively, selection of the wrong candidate or discarding an acceptable candidate.

The selection process can be facilitated by the construction of a graphic that displays the essential screens or metrics on a “radar scope.” Figure 5.8 depicts the screens and the results for a given product concept. Such a device would be constructed for each product/market concept and the results compared. Caution has to be noted when using any such technique for comparative analysis. There is always the possibility of being misled by the graphic. For example, the graphic does not indicate the relative importance of each metric. A more-elaborate construct should be used for more-complicated situations.

The “radar-scope” device is most useful in eliminating the poor candidates that are not good fits with the needs and direction of the organization. It might reduce the number of candidates to a more-reasonable number, which allows the evaluation to continue using more-customized approaches.

Final selection

The final selection of the product/market concepts is dependent on the investment resources of the organization and whether the process is one of choosing candidates as they become available or whether the selection is part of the NPD program conducted on a periodic basis. If the process is ongoing, the selection is based on those candidates that meet the criteria and whether there are resources available for development. If the selection is part of a periodic process, the candidates are often ranked and examined in terms of fit, market viability, leverage, need, risk, and reward.

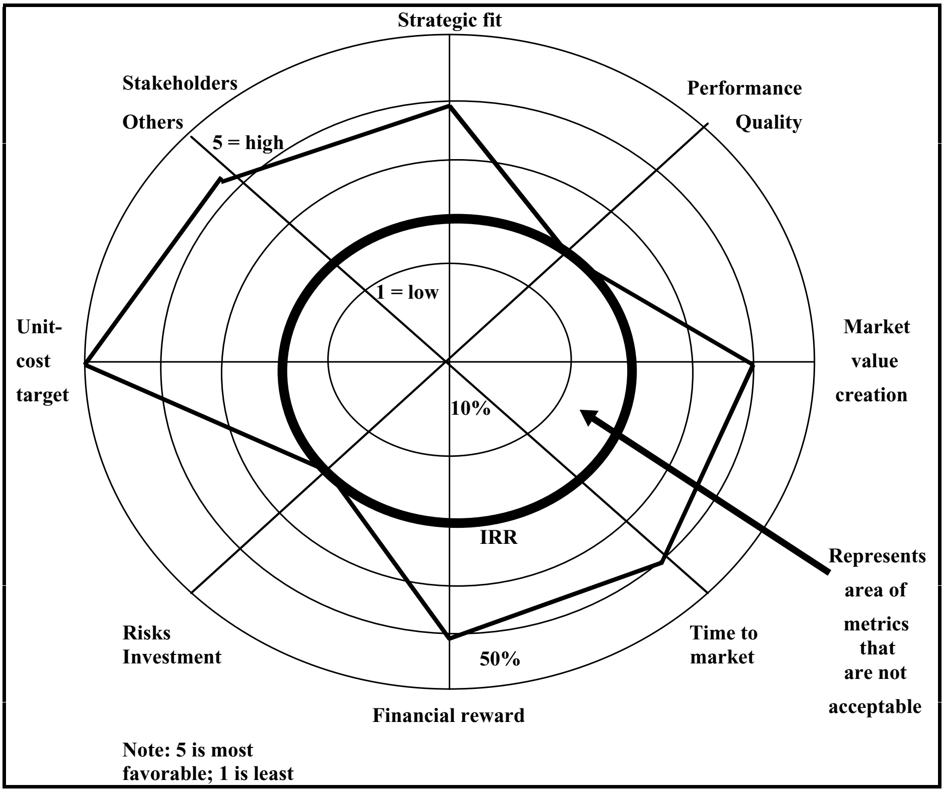


Figure 5.8 Radar scope for concept screening and selection (an example)

Table 5.6 *An example of a list of selected candidates based on a balanced-portfolio perspective (selected criteria only)*

Metric	Strategic fit	Product fit	Investment	Financial	Risks
Criteria	**Leveraged**	**Fits existing customers**	**>$500,000**	**30% IRR**	**Low risk (investment)**
Candidate					
A	100% leverage	100% existing	$400,000	28% IRR	Low
B	Fills a gap	New demand	$550,000	35% IRR	Moderate
C	Diversification	All new	$750,000	80% IRR	High

As the selection moves toward the final decision-making step, it becomes more difficult to generalize on the approach. Judgement and intuitive sense play vital roles in making the choices. The decision makers typically have a solid understanding of the need to balance the expected outcomes. Indeed, the notion of the balanced scorecard is usually used intuitively for determining the final choices. The list of selected concepts is typically a myriad of expected outcomes rather than each one fitting into a tight match with the criteria. Table 5.6 provides an example.

The product/market candidates listed in Table 5.6 are very different from each other. Such a selection process might be viewed as a portfolio approach where 80% of the candidates fit the prescribed criteria and 20% are exceptions based on the need to balance long-term results or provide the means for diversifying the portfolio.

It is important to realize that the techniques used to evaluate the candidates are just tools for facilitating decision making. They are not necessarily rules for making decisions. The actual decision making process tends to be open-ended with management and the participants adding their insights and judgements into the final equation. It requires the personal commitment of the people involved, who must have in-depth knowledge of the prevailing business environment. Again, selection is generally based on the experience and perspectives of the people, not hard rules.

Synthesis

The final step is to synthesize all of the information and decisions about the concept(s) into a document that can be used as input for the Program Definition Phase. Most of the information necessary follows the construct in Table 5.4. Synthesis is necessary to ensure that concepts are aligned and that the NPD process continues to the next phase without any loss of time and momentum.

Summary of the Concept Development and Selection Phase

The Concept Development and Selection Phase translates the singularity of idea(s) into a fully defined, described, and understood concept(s) that can be analyzed and screened. Concept(s) describe the new-product opportunities in terms of product/market position, customer and stakeholder needs, marketing approaches, production processes, and financial implications, and the external dimensions. Based on the information and decisions made during the Idea Generation Phase, the main steps include: (1) concept development, which focuses on understanding the needs and positioning of the product in a target market segment; (2) concept assessment, which focuses on analyzing the external impacts of the new product and determining the internal program elements; (3) concept testing and screening, which focus on ranking and evaluating the candidates; and (4) concept selection, which focuses on choosing the best candidates to proceed to the subsequent phase.

The methods used to analyze and develop the concept(s) are dependent on the business environment and the type of new-product opportunity. Incremental innovations usually require simple analytical techniques; radical improvements or dramatic changes require methods that are more sophisticated. The basic philosophy is to do everything necessary to make good choices. However, it is a balancing act between doing too much for an opportunity that will be discarded and not enough for the candidates that have been selected but where lingering doubts remain. The more time and money invested into the candidates, the better the understanding of their potential and viability. While such investments make sense and reduce uncertainty and risks, the negative side is delaying time to market and consuming resources that do not contribute to building value.

Most organizations have well-defined NPD processes that clearly specify the process elements and decision making criteria. Such constructs help to alleviate indecision and force the process ahead. Concept selection is a pivotal point in the overall NPD process. The investment prior to that point tends to be minimal, whereas the investment for the downstream phases usually become increasingly significant. Having a well-tuned Concept Development and Selection Phase can save time and money.

Notes

1. E. R. Corey, *Industrial Marketing: Cases and Concepts*, 4th edn (Englewood Cliffs, NJ: Prentice-Hall, 1991, pp. 5–6).
2. Read: J. R. Hauser and D. Clausing, House of quality. *Harvard Business Review*, **66**:3, May–June (1988), 63–73.
3. D. Leonard and J. F. Rayport, Spark Innovation through empathic design. *Harvard Business Review*, **75**:6, November–December (1997), 102–113.
4. Bill of materials is the identification (listing) of all of the materials, parts, components, and suppliers that are required to produce the product.
5. J. Smuelson, and B. Birchard, The voice of the stakeholder. http://www.strategy-business.com/press/article/03311. The Aspen Institute is a strong advocate of stakeholder-based management methods and practices.
6. This perspective is the foundation for sustainable development.
7. Sikorsky has relationships with Mitsubishi Heavy Industries (MHI) of Japan and several other suppliers.
8. B. Gale, *Managing Customer Value: Creating Quality and Service that Customers Can See* (New York: Free Press, 1994, p. 46). The graphic was derived from Gale's concepts.
9. A Price Waterhouse Coopers study on sustainability indicated that corporate reputation was the most important factor when considering stakeholders: A. Savitz, *Price Waterhouse Cooper's 2002 Sustainability Survey Report*, August 2002.

6 NPD Program Definition (Phase 3)

Introduction

The new-product development (NPD) Program Definition Phase (also referred to as the Definition Phase) elaborates the purpose, philosophies, policies, and guidelines of the NPD program. It defines the plans, practices, and performance measures for managing the NPD process and the related program aspects from conceptualization to commercialization. The purpose of the Program Definition Phase is to formulate and articulate a management framework that highlights the essential requirements; identifies the activities, actions, and decision making elements; and spells out the expected outcomes. The aim is to provide a clear understanding of the flow of the NPD process for all participants and to ensure that the organization has or can obtain the necessary capabilities and resources to complete the NPD program.

Given the enormous variations in new-product types and market characteristics, the NPD process has to be tailored to the business situation, the organization, and its capabilities and requirements. The scope of the NPD program and the methods employed are generally based on the established practices of the organization as they relate to the business environment. However, for most companies, the NPD process is well defined and is used from program to program with only small modifications arising from lessons learned and insights gained about the business environment.

Program management usually relates to decision making authority and the integration of the elements through the alignment of the participants and resources. It sets the stage for planning, communications, execution, and control. It defines the program elements; stipulates the philosophies, policies, and practices; and provides the organizational interactions. The philosophies specify the values and cultural aspects; the expectations of management; the program's fit into the overall strategic context; and the fundamental expectations in terms of compliance with laws and regulations, standards, and continuous improvement. The philosophical aspects are based on the strategic logic as discussed in Chapter 2.

Management policies are basic organizational drivers that provide guidelines and directives in broad-enough terms for decision makers to exercise appropriate discretion.

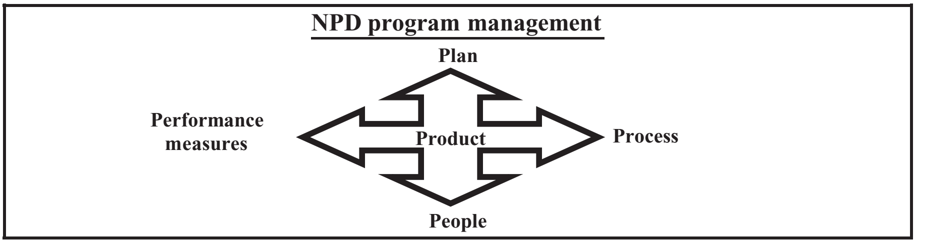


Figure 6.1 A simplified view of the elements of NPD program definition

Well-formulated policies and procedures provide support for efficient, effective, and consistent operations. It is difficult to create policies and procedures for every possible aspect of the NPD situation. Indeed, most companies minimize procedural approaches for new-product development because they are generally static. NPD programs require flexibility, creativity, and agile decision making to the extent possible. Management should set a framework covering the basic requirements of the concept, and then let the organization decide what works best for them. Articulating practices can take many forms.

The essence of the NPD program planning is based on process-management thinking. Process management is a detailed and focused approach for establishing NPD plans, managing people, and obtaining desired performance, as discussed in Chapter 1. It employs standardized elements and process flow while maintaining an atmosphere of creativity. By creating uniform standards, methods, and practices, valuable time and resources are focused on achieving results in the most efficient and effective manner. Process management tends to minimize redundancy and to reduce the probability of omitting essential requirements.

Figure 6.1 depicts a simplified version of the essential elements of the framework.

In essence, program management specifies the underpinnings for planning the NPD program and specifies how management expects to execute the program. The four critical areas include:

- ***The program plan and the required investment – defining a game plan***.
- ***The scope and cycle time of the program – articulating the NPD process***.
- ***The organizational design – engaging the people***.
- ***The risks and rewards involved – establishing the performance measures***.

Process mapping provides the flow elements and dictates the interactions between the participants. Performance measures provide an ongoing sense of progress with respect to goal attainment and organizational achievement.[1] Success requires mechanisms for obtaining outstanding results and for building excellence into every activity. The mechanisms are as follows:

- Communications ensure that everyone is informed about the objectives and guidelines and how everyone contributes in meeting the expectations and priorities.

- Actions at every level must be integrated into a single system.
- Standards and measures examine results on an ongoing basis to ensure correct outcomes or to take immediate corrective action to cure defects.
- Recognition and reward ensure that everyone is encouraged and motivated to practice in accordance with the standards established by management.

The Program Definition Phase focuses on the NPD process and the related NPD program. It provides the specifications for the process. Whereas in this book, the Program Definition Phase is positioned as Phase 3, in many NPD situations it is the first or second phase. The more complex situations (such as developing new-to-the-world products) necessitate addressing the elements of the Program Definition Phase during the early phases of the NPD process. In other cases, especially where there are established guidelines for developing new products, the Program Definition Phase is eliminated altogether since the elements are embedded into the standardized NPD process.

The objective of the NPD process from the start to the end is to employ best practices and provide outstanding value and quality. The Program Definition Phase identifies and maps out the definitive steps necessary to achieve speed, thoroughness, collaboration, and control. This includes defining and integrating the organizational aspects. The Program Definition Phase identifies the links in the overall NPD process. It describes the subsequent activities after the conceptual level as the process makes the transition to the operational level.

Chapter 6 includes the following topics and learning objectives:

- Understanding how to establish program definition.
- Articulating the process-flow elements to define the NPD program.
- Determining the appropriate set of performance measures and metrics.
- Developing the game plan and the financial models.
- Establishing a definitive NPD framework.

The Program Definition Phase flow chart

The cross-functional team generally has the responsibility for transforming the selected product/market concept into a new product. The team is often organized and operating before the beginning of the Idea Generation Phase, but the actual perspective depends on the situation. However, for the sake of thoroughness, the organizational design as discussed herein is included as part of the Definition Phase.

Achieving the objectives of the program depends largely on the game plan and the stipulated elements of the NPD program. The central challenge is translating customer needs, product/market concepts, and product specifications into an understandable flow of analytical steps, management decisions, and action plans.

The Definition Phase does not have to take a significant amount of time. Organizations with well-defined NPD processes (created over time) can usually map out the main

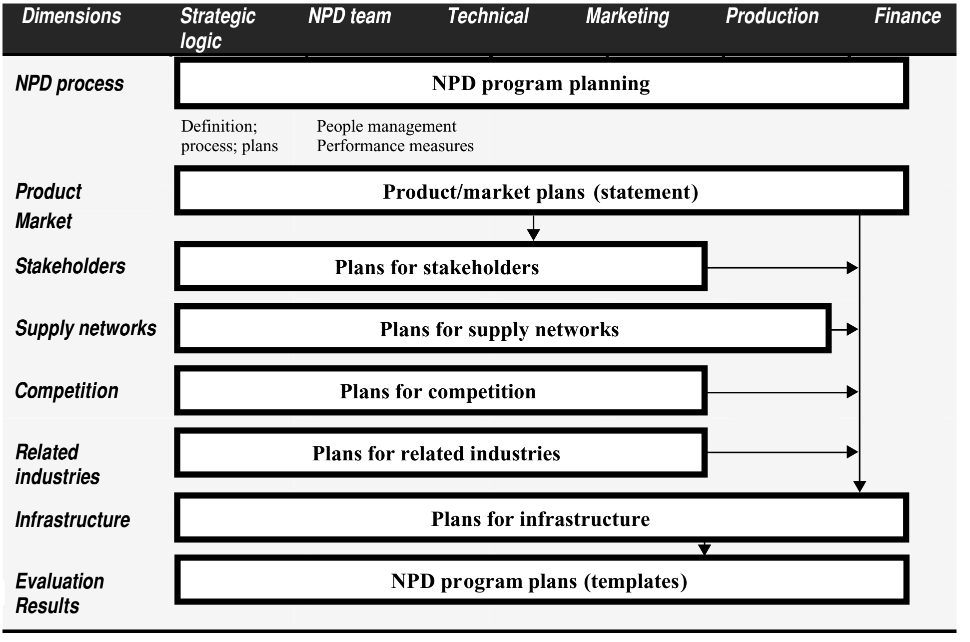


Figure 6.2 NPD Program Definition flow chart (Phase 3)

elements of the Definition Phase in hours or days rather than weeks. The objective is to have a game plan that highlights the pathway to success without being overly restrictive or controlling. The game plan is simply the means to get to the end of the process. The game plan outlines the scope of the program using the "phases and reviews." It defines and sequences the required activities, and provides the program schedule based on the time estimates for the various activities. Figure 6.2 depicts the essential elements of the Program Definition Phase.

NPD program planning

Overview of process management

Process management provides the definitive approach for managing NPD programs that have common elements with existing or previous NPD efforts, especially when there is a related family of products. For example, in the automobile industry, new models are introduced approximately every five years. Process-management techniques are used because the new models are generally replacements and refinements based on existing technologies and practices.

Process management reduces the variations and uncertainty because the standard elements become well known to the organization. By creating a standardized framework for new-product development, valuable time and resources is focused on the specific needs of the program. Management of time and resources is critical for ensuring that programs achieve their objectives. Continuous improvement means that over the course of many programs the organization is able to develop best practices and create uniformity of action leading to optimal results.

NPD programs often use the "phases and reviews" structure for managing the program.[2] The phase and review methodology divides the process into discernable phases allowing the participants to focus their attention on completing specific elements of the phase. As discussed in Chapter 3, an important principle associated with the phase and review approach is that the reviews are the control and reporting mechanisms for improving the probability of achieving successful outcomes without hindering progress of the NPD program. If the reviewing authority is not pleased with the results, deficiencies are identified and corrective actions are taken. If resolved, the process continues to the subsequent phase. If the deficiencies are significant and beyond a reasonable resolution, the program might be terminated at that point, or time is allowed for resolving the problems. While it is costly to terminate programs, the risk associated with continuing may not acceptable. Indeed, the phase and review approach saves time and money because it addresses questionable programs and deals with the difficulties during the earlier phases, rather than every program reaching commercialization before defects are discovered.

When there are high levels of uncertainty and a lack of previous experience, project-management techniques may be more suitable for the NPD program. In such situations, standard processes may not be evident or feasible. Project-management methodology is typically tailored to the specifics of the project, thereby providing more flexibility and creativity. NPD programs related to the development of new-to-the-world products based on new-to-the-world technologies are beyond the scope of the methods discussed in this chapter because they are dependent on technological-innovation methodologies and project-management techniques. However, many corporations are also using process-management thinking for such programs. Organizations tend to employ process-management approaches when there is a repetitive nature to the NPD programs. The methods and techniques used during the development of previous products can be used to develop the next new product.

Program definition

The precursor to program definition is to select or affirm the program framework. The framework provides the participants with a comprehensive view of the NPD program and how the internal and external elements are linked. This step includes the NPD process selection – the definitive approach for managing the NPD program. For many organizations, the selection is straightforward. The organization or team follows the corporate model, making only a few minor modifications.

Program definition includes statements or overviews pertaining to the product/market perspective, the mission of the program, objectives and strategies, insights about external factors, and the investment commitment. The product/market statement is the product/market concept(s) as refined during the concept-selection process. It includes concept synthesis and the revised product specifications. The program mission, objectives, and strategies are identical to the formulations discussed in Chapter 2, except that they pertain to the specifics of the NPD program and not the entire enterprise. The objectives provide the NPD targets; the strategies provide direction. The external factors are summary statements relating to the key factors of the business environment and the industry analysis in Chapter 2; see Table 6.3 at the end of this chapter.

The investment statement delineates the cost of capital and the requirements of the organization for making investments. It focuses on the financial implications and the funds required for supporting the program.

NPD program plans

The program plans provide the detail information and assessments allowing the participants to understand the scope of the program and its flow. They are high-level structures, giving a breakdown of the important elements by area, describing the essential requirements in each of the internal dimensions. The areas focus on the elements that can make or break the game plan. They establish the basis for determining the activities and provide a systematic methodology for understanding the opportunity and mapping out the essential decisions leading to a precise definition of the program. The NPD plans include the following:

- Organizational plan.
- Product/market plan.
- Marketing plan.
- Production plan.
- Financial plan.

The plans become the definitive business plan for analyzing and developing the new product. They include a thorough assessment of the external dimensions and provide the high-level view of essential requirements. They cover the entire time horizon of the NPD process. The plans ensure that the process is inclusive and seamless during the implementation (operational level) phases. The plans are the culmination of the conceptual level, providing the organization with the details for determining program activities and the schedule of their execution. In most cases, the plans are fully developed at the end of the Concept Development and Selection Phase. Outlines for each of the plans are provided in Table 6.3 at the end of the chapter.

NPD program planning

The prime step for program planning is to define the NPD effort. By defining program elements and establishing or refining the basic framework, the organization and the

NPD team understand what is required. The Definition Phase maps out the game plan and the NPD process, identifies the activities and the participants – their roles and responsibilities – and determines the performance measures.

A fundamental objective of most NPD programs is to reduce the time it takes to commercialize the new product. Achieving this objective requires a robust plan for executing as many activities as possible on a parallel basis. The notion of concurrent development suggests that activities are performed simultaneously, using an interdisciplinary team to ensure that speed, precision, and thoroughness are balanced.[3] Care has to be taken because simply compressing development cycles at the expense of thoroughness or accuracy often leads to difficulties downstream, increasing both the overall time to completion and the total investment required.

The NPD program and the NPD process are broken down into sub-processes based on the type of tasks to be completed and the resources required. The sequence of the sub-processes has to be mapped out to determine which ones are dependent on each other. The dependent tasks are sequenced in series; the independent ones are sequenced in parallel based on the flow of their precursors. The sequencing of activities is usually performed using a phase-by-phase approach.

Once the NPD process has been identified and the relationships between the elements spelt out, the next step is to estimate the time required for completing each task and the resources necessary for its execution. Based on these estimates, a preliminary development cost can be determined. The availability of resources may affect the actual flow of the activities, influencing both the time and cost estimates.

Process management provides participants with the mechanisms to identify and define the process and sub-processes used to execute the program, to orchestrate the means of managing complex activities through cross-functional teams using a common methodology, and to facilitate analysis by using well-understood tools and methods. Many organizations have well-defined protocols for developing new products. The essential elements in each phase are stipulated in precise terms indicating "what" has to be accomplished and "who" is responsible for ensuring that the elements are completed and that results are obtained. The protocols include specifications for the review at the end of each phase.

Using the concurrent-development construct, program planning identifies the essential activities required to implement the overall NPD program and the elements within each of the area plans. The focus is on ensuring that all activities are clearly defined and mapped out.

Program planning establishes the primary relationships for the core requirements of the program. This is a critical requirement if the management system focuses on project-management methodology. For such cases, *A Guide to the Project Management Body of Knowledge*, by the Project Management Institute, presents an effective model for managing projects.[4] For process-management methodology, the elements are based only on the essential aspects of program planning. The following are the key elements for process mapping:[5]

- ***Activity definition*** – identifying the specific activities that must be performed to produce the various project deliverables.
- ***Activity sequencing*** – identifying and documenting interactivity dependencies.
- ***Activity duration estimating*** – estimating the number of work periods required for completing individual activities.
- ***Resource planning*** – determining what resources (people, money, equipment, and materials) and what quantities of each should be used to perform activities.
- ***Schedule development*** – analyzing activity sequencing, activity duration, and resource requirements to create the schedule.

The activity-definition step requires input from all of the participants playing a significant role in the program. With a clear understanding of the activities, the next step is to correctly sequence the activities within each phase and throughout the program. The intent of parallel processing is to maximize the number of concurrent activities in order to reduce time to market. Obviously there are limitations to the number of activities that can be performed on a concurrent basis. There are many tasks that cannot be started until a previous activity has been completed. For example, concept testing must follow the concept-development step because the product/market concept has to be fully defined before there is any value in testing its feasibility in the market.

The identification of the activities and the sequencing process necessitates estimating the time required to perform each activity. Using predecessor information, activities can be structured into a complete program. By starting as many activities as early as possible, the total time to complete the program can be minimized.

Once the activities are sequenced and the time required for completing the activity has been estimated, the entire schedule of all activities can be finished. The next step is to assign the required resources. The most important assignments are for the individuals or participants who must ensure that the activities are performed and the deliverables are obtained.

The NPD program is the game plan with a schedule of activities sequenced to minimize the time required, and with the appropriate resources assigned. Based on the process model, a Gantt chart can be used to identify key elements, the time duration, and the resources required. Milestones may identify the critical points in the process or when important decisions are to be made.[6] If the NPD process is sufficiently detailed, such charts may be unnecessary because the process provides the flow. Indeed, the aim of process management is to minimize such constructs.

The reviews at the end of a phase (or at the end of a "critical step" within a phase) are often identified as milestones ending one phase and beginning another. Process management enables participants to ensure that progress is achieved and that the essential activities of a phase are completed before moving on to the next phase.

The mapping out of the program in terms of activities, sequencing, time estimation, resource planning, and schedule development is only done to the extent necessary. Again, process-management methodology simplifies most of the requirements since there is an existing template to follow. Assigning participants and developing the actual calendar schedule are often the most crucial aspects because they have to be determined for each program since they are subject to change from program to program.

People management

Because of the emphasis on speed and quality, many organizations give the authority for product development to cross-functional teams. The team participants are empowered to respond to insights and suggestions from customers, stakeholders, suppliers, competitors, and each other, thereby improving both product and process performance. The pressures to reduce NPD cycles, leverage resources and technologies, and lower both development costs and the unit cost of the new product mean that organizations have to achieve more with fewer resources and achieve results more quickly than in the past.

The team structure, which may include customers and suppliers, provides the means for integrating the participants into a cohesive force. It is the team that delivers the results. The team has to be informed of the requirements, the flow of the activities, and the direction that the program is moving. Such communications contribute to success or failure; poor communications are always blamed for failures. Cross-functional teams tend to be more collaborative, thus improving communication between the participants and ensuring that the essential elements are included in the plans and the implementation phases of the process. The relationship between the participants can be highly structured in terms of procedures and practices, or open-ended with a high degree of flexibility. There may not be a single right answer. The structure should support the game plan. When the risks or product-liability concerns are significant – such as with a pharmaceutical product, an automobile, or a helicopter – a highly structured approach may be preferable. Flexible structure is more appropriate when creativity is important.

Leadership is an essential part of people management for the team and its members. Sometimes an individual participant assuming the role of team leader instead of a more formal mechanism, such as program manager or project manager, may be appropriate. A team leader is often more of a facilitator who guides and empowers the team members to become more creative and productive. The leader tends to identify with the team and is closely aligned with its members. In most cases, the team leader is responsible to the steering committee or senior management. In certain cases, the team leader reports to a program manager who has the ultimate responsibility for dealing with higher-level management. The program manager provides the means for dialogue between the team and senior management.

Selecting performance measures

Overview

Establishing the metrics of the NPD program is always a critical step. Metrics provide early warning about whether the overall program, or a subset thereof, is meeting

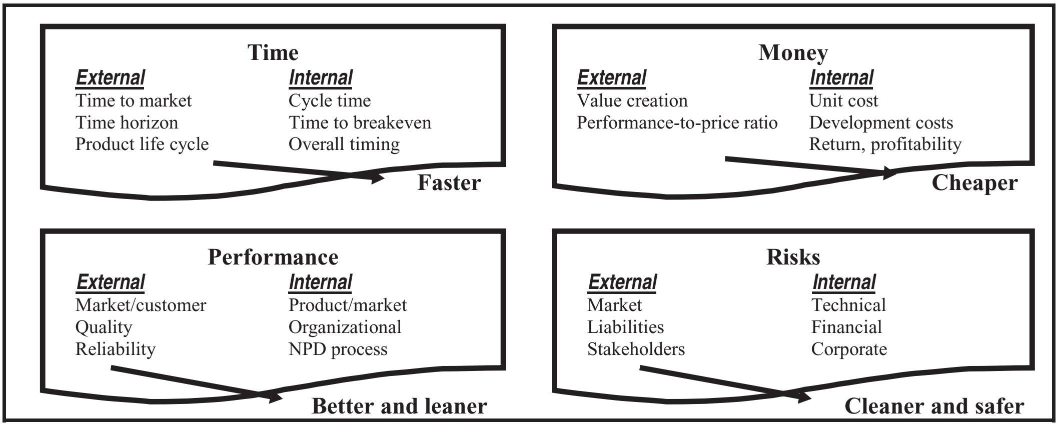


Figure 6.3 The essential NPD metrics

expectations at any point in time. They are usually based on the objectives of the NPD program and the strategic goals of the organization. Metrics are measures that provide an indication of probable success. The performance measures selected to track the progress of the NPD program often correlate with the screening criteria used to determine which product/market concepts justify the organization's time, money, effort, and assumption of risk.

Performance measures evaluate progress in terms of a balanced view of satisfying expectations of the business environment and meeting internal requirements. The measures should relate to the external view of potential customer and stakeholder satisfaction and to the internal perspective of effective management of resources and corporate assets. In very simple terms, the new product and the NPD program have to provide a solution that is better, cheaper, faster, leaner, cleaner, and safer than previous solutions. The metrics are linked to the screening criteria in that they serve as a means of discerning whether the NPD program is on track and whether it is expected to meet both the internal and external expectations. However, the primary purpose of the metrics is to provide a means of determining whether the new product is going to be successful. While screening criteria examine the global picture from a strategic perspective – i.e. fit, leverage, and alignment – metrics are intended to be leading indicators of the prospects for success.

Metrics monitor the most crucial variables with respect to the product and the program to provide a continuous sense of the progress being made. Figure 6.3 provides a view of selected measures.

Time is one of the most important metrics. The faster the NPD program is developed and implemented the less vulnerable the program is to the changes in the business environment during the development cycle. The time metric relates to the other critical metrics. In many cases, adding time to a program means adding money. If the time to market is extended, the time to breakeven is also extended, changing the time value of the investment. The failure to achieve the targeted time to market may allow a competitor to be the first to the market, capturing the early-market-share advantage and possibly becoming the overall leader.

Money is always a powerful metric. Economics plays a significant part in determining success or failure. If unit cost is higher than expected, the competitive position and the customer-derived value may change dramatically. If prices are forced upward, the performance-to-price equation suffers, reducing the viability of the product from a customer's perspective. Higher prices often translate into lower sales volume and revenues. Higher unit costs diminish pricing options. If market prices are constrained, higher costs translate into lower gross margins and lower profitability. Lower gross margins reduce the funds available for marketing and other operating expenses. All of these factors have negative effects on the return on the investment. Most importantly, the value proposition provides a critical measure of the impact on all participants. Value drives customers and the solutions they seek.

Performance is an essential product metric. The performance metric includes the critical product characteristics and benefits that are absolutely required by markets and customers. Quality is an area where the requirements constantly change due to competitive pressures and customer perceptions. The expectations include better quality, enhanced reliability, and improved longevity. Performance also relates to the program and people. Improvements are expected across the board.

Risk deals with the uncertainties involved in new-product development. There are program risks associated with the capability to design the product, to produce the product in a cost-effective manner, to develop the market, and/or to establish a successful marketing program. In addition to program-related risks, there are risks associated with the uncertainties of the business environment. The product may have a defect leading to product-liability claims. The product or the production processes may have environmental impacts, effecting stakeholders and creating liabilities; cleaner and safer products are expected.

Performance management means tracking and achieving the objectives and goals. One of the main goals is continuous improvement. The following are examples of NPD product and process goals:

- ***Reduce time to market***. Achieve new product launch in 24 months and improve the NPD capability to 20 months for the next program.
- ***Reduce unit costs***. Lower product costs by 10% and improve production capability to achieve an overall cost reduction.
- ***Improve performance and quality***. Achieve quality improvement of 10% and enhance production capability by 5%.
- ***Enhance financial outcomes***. Achieve a 30% return on investment by controlling the investment and improving cash flow.

The measures become the mechanisms to ascertain if the NPD program is tracking on course. If the actual values are in line with the metrics, then the program has a high probability of being within an acceptable range. However, if one or more of the metrics are trending toward an extreme point, it indicates that the variance from the established plan is drifting out of control.

Managing NPD using performance measures and metrics

The key to success, from a management perspective, is to focus on accomplishments and the deliverables, not on the tasks themselves. Outcomes are the essential requirements, not completing activities. The activities provide a sense of "what has to be done," but the realization of goals is the essential management mechanism leading to success and competitive advantage.

Performance metrics are the means for determining how well the program is proceeding. Accurate and timely information is critical for maintaining control over the program. Tracking actual achievements against the game plan helps evaluate how well things are going. If problems or concerns are detected, an early warning system using metrics allows the team or management to take corrective action before the situation becomes out of control. Measuring performance on an ongoing basis is essential for effective management of the NPD programs, and a critical factor for keeping the NPD process on track. The philosophy for managing performance is simple: discover potential defects before they become a serious threat to the success of the new product and the NPD program. Niccolo Machiavelli articulated this perspective almost 500 years ago:[7] "Problems are difficult to detect during the early stages, but are easy to cure; however, during the later stages, they are easy to detect, but difficult to cure."

The purposes of the performance evaluation system are to:

- Articulate the essential areas that focus on the road to excellence.
- Measure performance.
- Identify the need for the required resources and results.
- Determine the need for process improvements.

Communications are essential. The most important element is providing a clear understanding about expectations to all of the participants. Performance evaluation offers a balanced multi-dimensional approach so that improvements made to achieve an objective in one area are not made at the expense of performance in another area.

Much of the information and data to support the performance-evaluation process – such as risk assessments, financial data, and market data – usually exist as part of the routine operations of the organization. Information and data of verifiable quality can be used to provide a reasonable basis for evaluating performance. Appropriate quality assurance must be in place to ensure the validity of the data collection methodologies.

Each major category should have one or more performance indicators (PIs) to measure the performance. The selection of relevant metrics requires general guidelines so that there are clear instructions on how the process works. The primary function of the PI guidelines is to assist in the implementation of the process. The PI might be used to highlight the high-risk aspects of the category. They might be representative of the category, providing a general indication of progress. The PI system should fulfill the following requirements:

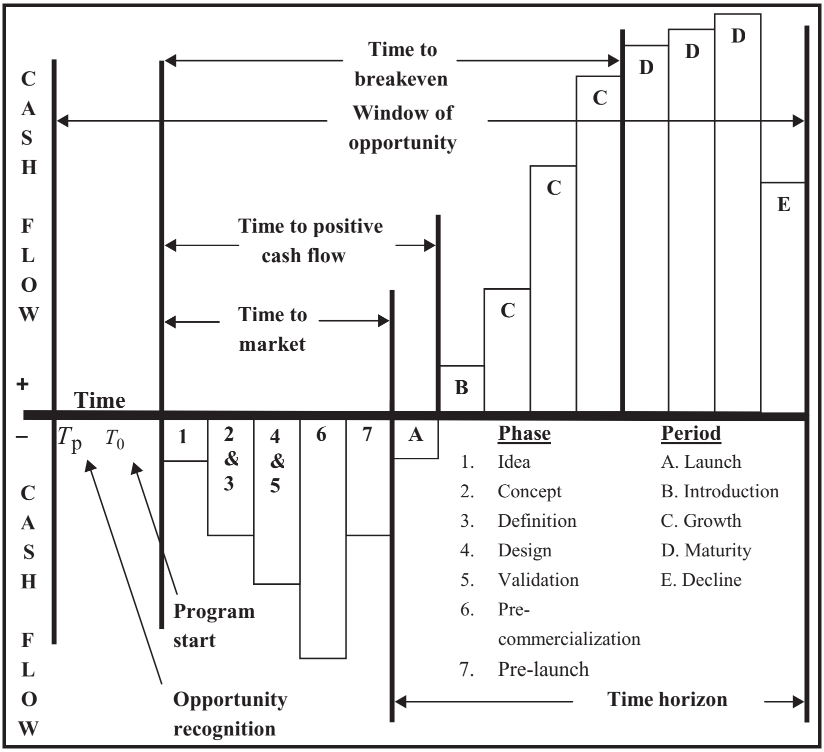
- It should be compatible with the NPD process and promote the attainment of objectives.
- It should be selective, concentrating on measuring areas that are principal causes of significant concerns or potential problems.
- It should be verifiable and usable through self-assessment.
- It should allow for comparison with other companies via benchmarking.

The critical step is matching the goals with the PIs. Indicators have to provide a sense of short-term progress as well as long-term potential. The basic approach is to select a reasonable number of indicators that offer a balanced view of the progress being made. Some indicators present an adequate reflection of where the program is, but not where it is heading. Tracking time to market is an outstanding metric for determining whether the program is on schedule or not, but it does not offer a comprehensive view of the potential for success of the product, unless there is a small window of opportunity. On the other hand, unit-cost projection does not tell much about the program's status, but is a good indicator for the probability of success of the new product. The unit-cost metric is especially efficacious for long-life-cycle products.

The general approach is to explore the application of various metrics that could be used for a program and condense the list to key indicators that provide a concise view of the performance over time. In many situations, between 8 and 12 performance indicators are sufficient.

Time metrics

Timing is a critical factor. This is particularly true for seasonal consumer products. In many industries, there are norms for new-product launches. Automobiles have historically been introduced in September or October. Toys are usually timed to take advantage of holiday gift-giving at the end of the calendar year. Timing is often a strategic consideration that goes beyond the calendar perspective and examines the new-product position vis-à-vis other new-product introductions by the organization or competitors and the cyclical aspects of the market. Timing is related to market acceptance and customer awareness. A new product may be too early, ahead of its time. Prodigy, the Internet provider, is a good example. When Prodigy was commercialized in the 1980s, there were insufficient home computers and limited Internet access to provide the base necessary to justify the investments made at the time. Obviously, with the dramatic growth of the Internet during the late 1990s, its vision and products had correctly anticipated market needs. They were just premature.



Example: investment equals the development expenses during Phases 1 to 7 plus the losses incurred during the initial launch period A. The positive cash flow during periods B and C equals the investment plus losses; therefore, the breakeven occurs during the growth period. The time horizon is the period from the launch to the end of the product's life cycle or it is the planning period for the new product. T_p is the time when the new-product opportunity becomes apparent. T_0 is time when the NPD program starts.

Figure 6.4 Critical time and financial metrics

Figure 6.4 provides a graphical representation of the time metrics. The **time horizon** for an NPD program is the projected time that the new product is viable in the market. For planning purposes, it is assumed that after the time horizon ends, the product has to be replaced by another, requiring a new investment. The time horizon for most new products (based on incremental improvements or changes) is typically between three and five years depending on the life cycle of the product, competitive actions, and technological innovations. In many cases, the time horizon is an industry norm. For example, in the automobile industry, new models are generally introduced every five years, plus or minus a year or so.

The time horizon is often difficult to track; therefore, it is not one of the easiest metrics to use. However, it does provide a sense of the dynamics of the market. A negative shift of the time horizon tends to indicate that the market opportunity has declined in terms of the time for recovering the investment. It obviously has a big impact on the return-on-investment calculations.

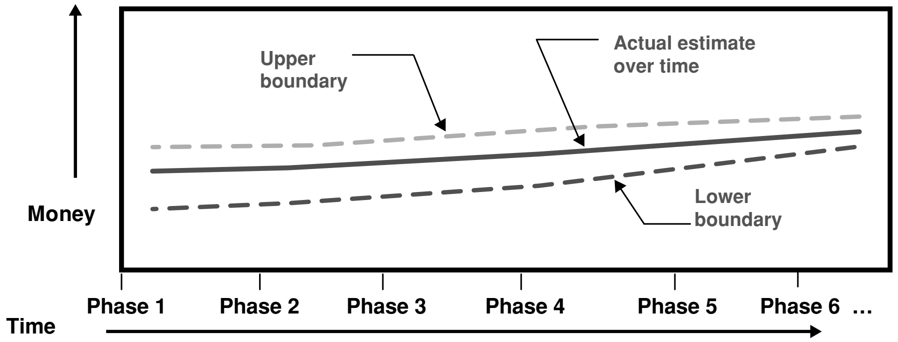
Time to market is the time between the start of the NPD program and the launch date. It depends on the point in time when revenues are generated from the sale of the product to customers who intend to use the product for their purposes, applications, or products. Time to market is critical for short-life-cycle products; therefore, it is an excellent metric if the time horizon is less than three years. However, it is a powerful metric because the longer the time, the more money required for the investment. Greater investments translate into lower probabilities for achieving an appropriate rate of return.

The **window of opportunity** is the total time available to exploit the new-product opportunity. It is the time available from the very beginning of an opportunity until the time it dissipates. This includes the time spent at the beginning to reach a decision to take action. If the window of opportunity is fixed, suggesting that the time horizon is fixed as well, then the time-to-market metric becomes an important tracking indicator for management to keep the NPD program on course. It is obvious that if the time-to-market period is extended in these situations, then the time horizon for exploiting the opportunity is commensurately reduced, having a profound impact on the financial outcomes.

The **time to breakeven** is one of the most important metrics of new-product development. Indeed, it involves the important principle that most NPD programs follow. The principle is simple: it costs money to make money. New-product developments requires investments of time and money during the NPD phases and early commercialization; this investment only starts being recovered after cash flow turns positive. Moreover, an NPD opportunity requires making an investment, with the probability of losing the investment, in order to have the potential of achieving a significant reward if the NPD program is successful.

Time to breakeven is the point after commercialization when the cumulative positive cash flow equals the total investment. The total investment is the sum of the development costs incurred during the conceptual level, the design, the marketing programs, capital required for production resources, and the activities during pre-commercialization, plus the losses incurred during the early commercialization phase. Breakeven is stipulated in terms of time and volume. The important question from a financial perspective is: When does the program break even (in months and money) after launch? From a production perspective, the question is: What is the breakeven cumulative volume?

The **time to positive cash flow** is a related metric. Prior to that specific point, funding is necessary to subsidize the product in the market. There is insufficient gross margin available or the volume is too low to support the operating expenses deemed appropriate for maintaining a viable presence in the market. The time to positive cash flow occurs before the breakeven point, providing an early means for determining the potential success of the product. It indicates that the market is sustaining the product financially.



Note: this line of thinking is similar to the constructs of control charts. The upper and lower boundaries may be developed on this basis plus or minus a given percentage variability or standard deviation.

Figure 6.5 Unit-cost estimate over time versus upper/lower acceptance limits

Money metrics

Unit cost is one of the primary metrics; it underpins pricing. Unit cost is determined up-front during the conceptual phases and is refined during the design and validation phases. The unit-cost calculations are difficult at best. During the conceptual level, there is generally a lack of sufficient technical detail. The cost estimate is based on the initial product specifications using historical cost information from the existing databases or from external sources such as suppliers. Such cost estimates lack the rigor necessary to have a high level of confidence, but the result is usually within a reasonable range, say ±10%, to provide guidance for developing the game plan. Unit-cost calculations are refined over time, especially during the Design and Development Phase when engineering data become available to support a rigorous calculation of cost as it relates to volume. Unit-cost values are typically stated based on projected cumulative volume.

Unit-cost estimates can be tracked from the idea generation through the commercialization using the construct of upper and lower boundaries as seen in total quality management thinking. Based on an acceptable unit-cost position at the beginning of the program, the trend in the expected cost structure offers a significant measure of the potential success of the new product. If the trend moves toward the upper boundary of the acceptable cost structure, it suggests that the product may not be feasible or that there is insufficient gross margin available to execute an effective marketing program. If it moves toward the lower boundary, it may indicate that a critical element(s) was left out.

Figure 6.5 shows an example. The actual range between the upper and the lower boundaries varies depending on the type of NPD program. The range is smaller for a derivative or for replacement of an existing product, which has to fit into a well-known market situation, and larger for a new-generation or new-to-the-world product where there is greater uncertainty about market requirements. Regardless, the metric allows management and the participants to understand the potential impact of changes in cost projection.

Generally, lower costs are good news. However, if the cost estimate is too close to the lower boundary, it may indicate that the cost estimate is faulty or something has been left out that should have been included. Thus, if the estimate trends outside of the acceptable region, action should be taken to ensure that the program is still feasible.

The unit-cost metric provides a strong signal about the viability of the product. It is easily tracked and gives tangible evidence about the financial implications. The fact that the cost structure changes over the course of the NPD program is not always a problem. Higher costs may reflect the fact that the product offers higher value.

Value is a customer-driven metric that requires ongoing tracking. The metric depends on the pricing strategy that the company plans to use during the early commercialization and beyond. Value is what the customer perceives based on the performance of the product and the total investment that the customer has to make to acquire the benefits of the product. It is based on the value proposition discussed in Chapter 2.

Performance-to-price ratio is a metric that changes based on the pricing strategy and the cost structure. It is actually a simpler form of the value proposition. It is useful because often it is easier to determine the calculation for performance-to-price ratio than it is to calculate value. While the prices of a new product are subject to the pricing strategy of the organization, which has the flexibility to change its price to suit market conditions, there are limits to the price range that is acceptable. The price that the company plans to use, vis-à-vis competitors' pricing, is a useful measure and can be tracked to determine if the position selected for the new product remains attractive over time.

Figure 6.6 indicates how a viable product can lose some of its attractiveness as competitors reposition their products. The selected position of the company's new product at the beginning of the NPD program provided a superior performance-to-price edge over the three competitors. The new product would occupy a position that was clearly different from the competitors with equal performance to the top performing competitor (competitor B) and a significantly lower price. However, after competitors introduced their new products, the space to be occupied by the company's new product has become crowded. Competitor B has been able to lower its costs and price while maintaining excellent performance. Competitor C has been able to improve its product performance while maintaining its cost structure and pricing. The new program has to be re-evaluated to determine the action needed to improve the prospects of success.

Investment Funding or **development cost** is a critical metric because it affects the funding sources and the attractiveness of the financial returns. Development costs should be calculated on an activity basis per period. Cost estimating involves determining the cost elements for the resources and efforts required for executing the program.

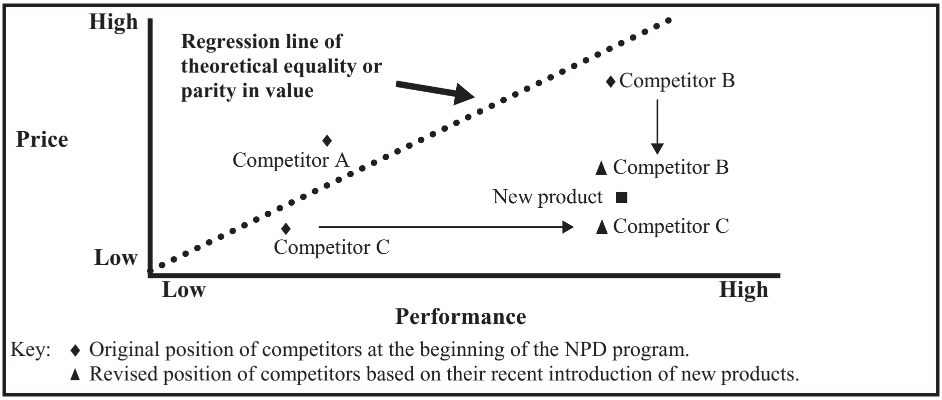


Figure 6.6 Two-dimensional matrix of product attractiveness versus competitors in terms of price-to-performance ratio

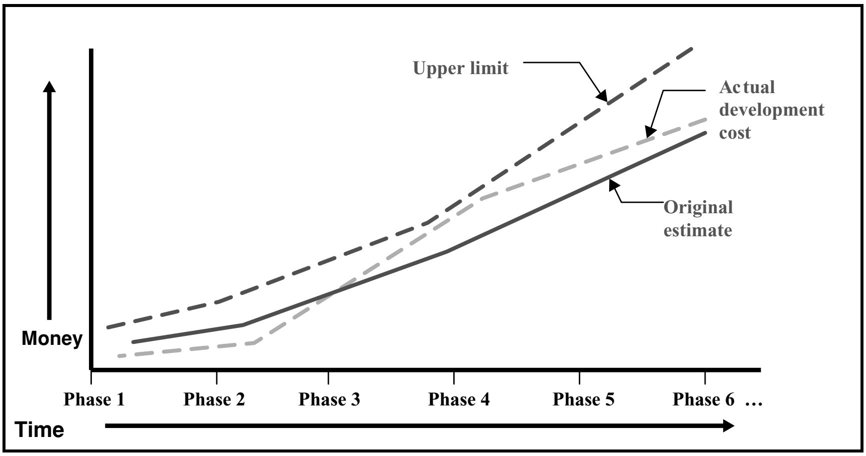


Figure 6.7 Development cost (investment) over time

The metric is based on the orginal estimate and an upper limit for the development costs at any given point of time. If the upper limit is reached, this suggests that the cost variation has now significantly changed from the original estimate and that management's attention is warranted; corrective action may be necesary. The upper limit may be a plus 10 to 20% variation. It might also be plus two standard deviations of the original estimate.

Figure 6.7 shows the tracking of development cost (investment) over time. A lower limit may be established as well if there are concerns about missing elements. The method can be based on statistical methods. Regardless of the method used for constructing the diagram, the concept is the same. As long as the program is running within an acceptable range of the estimate, the situation appears to be in line with expectations.

If the program significantly exceeds the estimate, action is required. The logic follows constructs of total quality management.

From a financial perspective, **return on investment** is probably the universally accepted technique for measuring the feasibility of NPD programs. The internal rate of return (IRR) measured on a discounted-cash-flow basis provides a primary indicator of the financial value of the program. The IRR has to exceed the cost of capital, adjusted for risk, and meet the expectations of the company for its investments, considering the type of program and the risk factors involved during its execution. High risk requires higher reward.

IRR is a good metric because it takes into consideration many of the other metrics. If development costs increase, then the investment amount used in the IRR calcualtion is higher, resulting in a lower return. If time to market is delayed, then the discounting factors reduce the value of the positive-cash-flow streams in the future, thus reducing the calculated returns.

Other metrics include **payback period** and **net present value** (NPV). Payback period is the breakeven point from a cumulative cash flow basis. The NPV is the discounted cash flow of the sum of the investment and the positive and negative cash flows. The NPV is dependent on time to market and the window of opportunity. If time to market is delayed, the NPV is reduced because of the discounting factors.

The financial metrics are defined and explained in more detail in the supplement to this chapter.

Performance metrics

Performance metrics focus on the specific objectives of the new product and/or program, relating to the mission statement and the targeted benefits. These measures are the most difficult to determine because there are no well-established views on what constitutes acceptable outcomes. The metrics have to be selected on a case-by-case basis. The general areas that should be covered relate to the conventional parameters of markets and customers, product attributes, quality, reliability, organizational effectiveness, and process improvement.

Performance metrics should incorporate the following principles; they should be:

- ***Results oriented*** – measured by outcomes for meeting product and program objectives.
- ***Relevant*** – focused on important product or program parameters that are critical for success.
- ***Representative*** – selected on the basis that they are indicative of the broader attributes of the product and program.
- ***Reliable*** – supported by accurate data that are readily available and consistently applied over the length of the program.

Good performance measures focus on outcomes that are relevant to the accomplishment of the essential goals of the program and the desired attributes of the product.

The market/customer measure should demonstrate that the organization can achieve the design configuration and meet customers' expectations because the essence of the product and program attributes are in line with the desired specifications.

Primary-outcome measures focus on what the market wants and what customers need. The metric might be a single requirement that is crucial for the success of the new product. It is often the "make or break" attribute. For example, the weight/size of the telephone might be the critical factor that has to be met in order to achieve the other requirements. Size correlates with ease of use and functionality; therefore, achieving the performance metric means that other essential parameters are positively influenced as well.

Quality measures are always excellent indicators of success. The primary step is determining what is "critical to quality."[8] Based on the selected quality requirements, quality measures offer a reliable view of many other critical factors. Perceived quality links product attributes, value, and customer satisfaction. Quality is a source of obtaining enhanced value by reducing cycle times, improving productivity, enhancing flexibility, increasing yields, reducing costs, and improving image and reputation.

Quality is measured in qualitative and quantitative terms. Qualitative measures are often demonstrated relative to competitors, such as better than competitors or superior to competitors "A" and "B." Quantitative measures are expressed using defects per million. The objective might be to achieve six-sigma capability (3.4 defects per million opportunities). This measure can be tracked over the course of the NPD program to determine its outcome. Based on historical data, it can be inferred that failure to reach the target will have a known impact on other outcomes such as unit costs, wastes, productivity, yields, and customer acceptance. Quality measures are powerful indicators of the overall success of the program.

Reliability is an outcome measure that is extremely difficult to determine and manage during the NPD process. It is time dependent and viewed from the customer's perspective long after the product has been launched. It is often measured by the mean time to the first failure, the mean time between failures, or the failure rate per unit of time. Reliability becomes more critical as the expense associated with the lack of reliability increases. The cost of downtime and maintenance increases the total cost of ownership, reducing the value and attractiveness of the product. Reliability problems translate into defects.

Reliability is one of the key elements measured during product testing, both alpha testing (in-house) and beta testing (customer). Any indication that the product has questionable reliability provides an early warning that products may have serious defects, affecting the probability of being successful in the market.

Organizational-performance metrics may be used to follow the organization's ability to achieve objectives over time. The NPD process depends on the creation and exploitation of knowledge to think beyond the known, and to solve difficulties as they arise. New products come from the creative minds of the participants. There should be a metric to ensure that the organization has the capability to take on the additional challenges as the program makes the transition from the conceptual level to the operational level. It is essential that the participants have the skills and knowledge to make the transition from phase to phase. Measuring organizational performance is a difficult, but necessary, task.

Risk metrics

New-product development faces a myriad of risks. Risk is based on uncertainty and the possibility of failure, resulting in losses and liabilities. Uncertainty is due to lack of information and knowledge about the implications of decisions and the future developments pertaining to the situation – including the technical, market, stakeholder, and financial aspects.

The purpose of the **technical (product)-risk** metric is to understand the primary sources of product-related risks and liabilities and to mitigate their impacts and consequences over the development cycle. The initial step in managing risks is to understand fully the types of risks involved in an NPD program and their implications. There are generally four levels of technical risks: risks that are inherent to the product; risk associated with design defects; risk associated with manufacturing mistakes; and risks associated with product/market applications. There are always inherent risks (first level) with the NPD process that cannot be avoided including the negative side of every product. A simple example is gasoline. Gasoline is one of the most frequently used products in modern society, yet it is an extremely hazardous and dangerous substance; generally, society has learned how to manage the risks.

Second-level risks include design defects due to the failure to have certain necessary features, to meet the generally accepted standards, or to apply properly the technical specifications. The third level is the failure to manufacture the product properly. The fourth level is the failure to provide adequate information, instruction, or warning about the appropriate use of the product. Any one of the technical risks may lead to product-liability problems.

Market risks are associated with uncertainties about market conditions and trends. The market may not be completely understood, leading to difficulties of misapplication. The product may be poorly positioned or positioned in the wrong market segment. The market requirements could change during the development period; thus, the product fails to meet the new expectations.

The following are examples of market-related risks that lead to failures:

- ***Insufficient market potential for the product configuration*** – the Iridium case described below is an example (the product was conceived in the 1980s and marketed in the late 1990s).
- ***Inability to meet customer needs*** – the electric vehicle (too expensive and too little power and performance).

- ***Inappropriate marketing program*** – the Dot.com companies failed to build adequate awareness and acceptance of their products and services (using advertising to sell rather than building long-term awareness).

Market risks are extremely difficult to track with any single metric. Market size and growth rate are important. Understanding and prioritizing customer needs are critical. There may be a single need that sets the stage for the others. Such a need can be tracked and can provide insights about the direction of customer acceptance. Gillette's Mach III placed emphasis on the ease, comfort, and safety of the shave from the customer's perspective. Failure to significantly out-perform existing razors would affect the market potential for the new product, since it would be highly unlikely that customers would be willing to pay more for the same results. Tracking the benefits through the various testing modes was an effective means of determining the potential for success.

Stakeholders play a vital role for all new products. There may be a stakeholder group whose acceptance of the product is imperative for success. The attainment of their satisfaction may be a precursor to the viability of the new product.

Financial risk has historically been used as a means of monitoring the potential success of the new product and the program. Financial risk is usually viewed in terms of the probability of losing the investment. It may be stipulated as a set amount of money. Indeed, financial risk may be tracked as a subset of the probability of exceeding the development costs or the probability of not obtaining a minimum level for return on investment. Financial risk is broader than the investment risk, since NPD failures may have implications for the entire enterprise by damaging its reputation and having impacts on other product lines.

The Iridium satellite-telephone debacle

In the late 1980s and early 1990s, Motorola engineers envisioned a global, satellite-based, wireless phone system that would allow users to receive and send calls anywhere on the planet, including dense jungles and "urban canyons." The system, dubbed "Iridium," would utilize a constellation of 66 telecommunications satellites orbiting the planet at 17,000 m.p.h (27,000 km/hour). Motorola and its partners began launching the Iridium satellites in 1995, and the system was completed in 1998, at a total cost of $5 billion.

The Iridium project was fraught with serious technical and quality problems from the very beginning. The phone itself was comparatively heavy – one pound (0.5 kg) – versus two ounces (0.06 kg) for a typical cellular phone. The handset was also large, being about the same size as a brick. Users complained of poor transmission quality, low completion rates, dropped calls, and conversations that would cut in and out. The handset itself was expensive, $1,500 (down from an initial cost of $3,000), and airtime charges were very high, ranging from $4 to $9 per minute. In addition, line of sight was required between the handset and an orbiting satellite, so users could not make calls from inside buildings or cars.

Overseas promotion efforts were hampered because many of Motorola's international partners had minimal experience of high-technology telephone equipment. For example, in Venezuela, the partner's primary business was dairy goods. In China, selling and promotion tasks were left to the control of government officials. It is not surprising, therefore, that of the estimated 1.5 million potential subscribers, only 63,000 customers eventually signed up for the service.

In July 1999, Iridium failed to make a $90-million bond payment. It filed for bankruptcy protection in August, prompting Motorola to pull the plug on the entire project. Motorola announced in August 2000 that it would begin controlled "deorbiting" and destruction of the 53-ton (48-metric-tonne) satellite network. The system, orbiting 485 miles (777 km) high, was costing Motorola several millions of dollars a month to maintain. But in November 2000, a New York bankruptcy-court judge approved a $25-million offer, from investor and aviation-industry veteran Dan Colussy, to purchase the Iridium name and $5-billion worth of space and ground assets, including the operations center in Leesburg, Virginia. Colussy would become chairman of the newly formed company, Iridium Satellite LLC.

In December 2000, the Defense Information Systems Agency (DISA) signed a two-year deal with Iridium Satellite LLC for $72 million to operate a Defense-Department-owned Iridium gateway in Hawaii. The deal guaranteed Iridium a maximum of 20,000 users, and covered up to 60% of Iridium's operating costs. Government users would pay $1,465 for newer handsets that were smaller and lighter than the original "brick." This new phone can be modified with an encryption sleeve that meets the Pentagon's standard for secure communications.

The latest Iridium operations strategy is to compete in several niche markets, including satellite Internet services for remote locations, aviation applications like Honeywell's "Airsat" aviation phone, and the mining and oil-drilling industry. Unlike the original Iridium, the new company is not trying to compete against the world's existing telecommunications structure, but is hoping to appeal to organizations that operate beyond the world's telephone lines. The company claims to require only about $80 million a year to break even.

Ironically, after the events of September 11, 2001, interest in hand-held satellite phones surged, primarily because just after the terrorist attacks landline and cell phones quickly became unusable. Iridium executives claimed that during the week of September 17th, system utilization was up 25% and new activations were four times greater than the previous week.

Sources

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Summary of selected metrics

While the measurement system forms the core of NPD program accountability and control mechanisms, there are inherent limitations in the actual use of metrics. The most important points to bear in mind are that metrics neither resolve difficulties nor ensure success. They are simply indications that a condition is occurring that requires attention or that the situation appears to be as expected or not. Also, metrics cannot account for all of the potential impacts affecting program outcomes. They reflect on the composite effects of selected internal and external factors that typically have strong influences on results. Metrics can provide a substantive and analytical basis for determining whether or not corrective action is required. For example, if the development cost exceeds the upper boundary at any point, an alarm is sounded and management attention is given.

The overall value of the measurement system is dependent on the quality of the individual metrics. The bottom line of performance measurement is to improve the outcomes of the NPD process and to facilitate decision making by providing clear metrics on how well the program is progressing. It is about learning, not controlling. Knowledge about the realities of the program from both internal and external perspectives reduces uncertainty and enhances decision making. Performance measures should focus on short-term improvements in the new product to increase the probability of being successful; they should also focus on the long-term perspectives of the NPD program to meet the company's goals and customer's expectations.

For the sake of simplicity, Table 6.1 provides a summary of the common metrics, their potential usefulness, and the advantages and disadvantages of their applications.

The metrics provide the means of monitoring the NPD process on a continuous basis. The ultimate goal is to satisfy customer and stakeholder needs in innovative and unique ways. The managerial challenge is to achieve the correct balance between all of the competing requirements. The primary requirements for new-product development are achieving the time-to-market objective; having an acceptable, if not superior, product with an excellent unit-cost position; meeting the development-cost (investment) target; achieving a satisfactory financial reward; creating superior value, performance, and quality; and managing risks over time. In many situations, it is not possible to accomplish all of the objectives. It becomes imperative to examine the relationships between the product/market objectives and the overall goals of the program. In reality, the objectives and the related metrics must be considered as a set of targets and measures that are interrelated. There is a natural tension between some of the metrics requiring an ability to discern between them or prioritize them.

Table 6.2 provides some insights about the primary metrics and their implications. The implications of the assessment are that the development team and management must determine the best course of action for a program based on a balanced view of the potential impacts. Decisions are based on analysis and experience. They are also based on the leadership skills of the management team.

Table 6.1 *A perspective on common NPD metrics*

Metrics	Application	Advantages	Disadvantages
Time to market (program)	Primary program metric related to the strategic position of the new product. Important for short-life-cycle products, like computers and electronics.	Leading indicator pertaining to the probability of being competitive, meeting financial goals, managing investment funding, and exploiting the opportunity.	Tends to emphasize speed at the expense of thoroughness. May take priority over the cost-effective development of the product.
Time to breakeven (financial)	Primary financial metric suggesting how long it will take the investment burden to be lifted from the company.	A simple measure that is easy to calculate. It offers insights about the assumed risk vis-à-vis the external environment.	Lagging indicator that may not show a problem until after the new product has been launched.
Time horizon (product)	A rough-cut metric that provides a sense of the duration of the opportunity. It does reflect changes in the business environment.	A simple measure providing insights about the opportunity from a historical perspective.	Lagging indicator that may not show changes until it is too late. Very difficult to determine precisely where the life cycle is at a point in time.
Unit cost (market, product and financial)	A primary metric that has a direct impact on the financial and market viability of the product. It impacts many of the marketing programs.	A leading indicator that can be continuously monitored to determine the probability of succeeding. Higher unit cost reduces the gross margin and profitability.	Unit costs are often difficult to determine for new products during the early phases. Unit-cost calculations are dependent on the accounting system, which can skew results.
Development costs (program, financial)	A primary metric that impacts the value of the new product and impacts the financial metrics. Higher development costs require improved returns to justify the investment.	A leading indicator that can be tracked on an ongoing basis. Variance to the established metric is easily determined and corrective action can be taken.	Must be balanced with the time-to-market metric; especially for short-life-cycle products where the opportunity may dissipate quickly.
Net present value and IRR (financial)	A primary metric that measures the value of the program in terms of meeting financial goals. They reflect the cost of capital and the value of money.	Relatively simple and well-understood measures of the potential for success. Expressed in the language that most managers understand and on a comparative basis relating programs to each other.	It is often a lagging indicator manifesting difficulties only after they are full blown. The calculations are dependent on the assumed time horizon. May tend to understate the value of long-life-cycle products.

Table 6.1 (*cont.*)

Metrics	Application	Advantages	Disadvantages
Quality (product, NPD program)	A primary metric that measures the ability to meet customers expectations.	It is a leading indicator. Conformance to product quality requirements has to be built into the product. If the new product is not in line with the expectations of customers, the product may not achieve sales projections.	Quality is difficult to track during the early phases of the program. Quality measures become more meaningful after the design and development.
Product performance (product, market)	A primary metric that measures the ability of the product to meet customer expectations.	It is a leading indicator. The ability to deliver the attributes that customers need is critical to success. Tracking the right attributes provides mechanisms to monitor the potential for success.	It is difficult in some cases to pick the most important attributes to monitor. There may be features and benefits that are more important to customers.
Technical risks (product, financial)	A primary metric that focuses on the negative side of the NPD program. It examines the ability to execute the technical requirements.	The metric provides a balanced view. It forces participants to think about the negative implications.	It is difficult to measure. It may not provide a continuous insight into the probability of failing to achieve the technical requirements.
Financial risk (financial, program)	A primary metric that focuses on the probability of failing to meet financial requirements.	The metric provides a balanced view. It forces participants to think about the negative implications.	It is difficult to measure. It may not provide a continuous insight into the probability of failing to achieve the financial requirements.

Plans for the external dimensions

Overview

Based on the concept assessment, the plans for engaging and managing the external dimensions are prepared or validated during the Program Definition Phase if they were not developed during the earlier phases. Such plans involve the strategies and action plans for managing the requirements of the selected market segment and the associated stakeholders, who are directly or indirectly related to the new products, and the dynamics of the business environment. On the negative side, the plans include how to deal with the implications and impacts of the principal competitors. Competitors tend to respond

Table 6.2 *Implications of changing a metric or missing the most important metrics*

	Impacts of changing the target	Implications
Development cost/ investment	Increase development costs to cut development time; to improve product performance; to lower unit costs; to lower risks due to obtaining additional knowledge, thus, reducing uncertainty; may require additional sources of funds.	Means that the investment is higher; improved performance has to translate into market success or the IRR and NPV will be lower; may have an impact on unit costs if higher development costs are built into product cost structure.
Development time	The prospect of missing the market introduction date requires additional resources or time for deployment of resources; seasonality issues may become important; may affect other development programs.	Competitors may assume the lead; the ability to generate profits may be significantly diminished; the time horizon may be reduced, lowering NPV and IRR; time to breakeven increased.
Unit cost versus volume	Higher unit costs may have an impact on market potential with lower customer perceived value and lower gross margin.	Negative impact on profitability; may reduce the funding for marketing programs; provides competitors with leverage for their pricing.
Product performance	Poorer performance and/or quality mean less value; lower market attractiveness; lower quality often means higher costs, and higher risks and liabilities.	Market potential diminishes; higher rates of quality defects translate into higher production and warrantee costs, and lower profits; impact on customer value and financial outcomes.
Risk and liabilities	Higher risks mean greater probability of failure; higher liabilities translate into higher life-cycle costs; lower profits, and a less-sustainable position.	Lowers the overall value of the program; risks may reach unacceptable levels.

to new initiatives by introducing their own new products or by counter-attacking with their arsenal of existing products and strategies.

While market-related forces and stakeholders are often the most crucial dimensions from a strategic perspective, relationships with related industries and the infrastructure are important considerations that are typically neglected until after commercialization. The game plan should include establishing linkages with the most critical entities, which provide supporting functions for the success of the new product. Similarly, the infrastructure often provides absolutely necessary communications or logistical links that are pivotal in making the game plan work.

Supply networks are often included in the planning process because they are directly related to the internal dimensions, especially the production processes. Whereas supply networks are an inherent part of the enterprise they often are taken for granted. As discussed in Chapter 5 under the section "Supply-networks management assessment," the early determination of the roles of essential suppliers and distributors is critical for ensuring that the ingredients for success are available.

The exact method of incorporating the external dimensions into the game plan depends on the organization and how it deals with such factors. The approach used in this text is to embed the strategies and actions plans related to the external dimensions within the specific action plans for the internal dimensions. While there are advantages and disadvantages to creating separate sections for the external dimensions, integrating the external dimensions within the internal dimensions of the game plan focuses attention on those responsible to ensure that the given external dimension receives its appropriate consideration. For NPD programs, market-related aspects (market segments, stakeholders, related industries, and competition) are included in the product/market plan (Section 3 of the templates in Table 6.3). The action plans pertaining to supply networks and the infrastructure are included in the production plan (Section 5 of the templates).

Product/market plan

The product/market plan is the most important because it establishes the foundation upon which the other dimensions are built. It provides the definition for the entire game plan and the focus for the new product. Since most of the elements of the product/market plan have been discussed in previous chapters, this section considers strategic intent, market context, and product architecture. The product/market plan outlines the key decisions relating to integrating the strategic aspects, the product, and the market segment into a holistic solution.

The strategic intent involves the overarching "why" question. The question relates to the strategic fit of the product within the company. It also relates to the selection of the target market segment. The choice of the latter should be based on the company's ability to serve the market better than anyone else. Strategic intent focuses on the product/market position(s) that the new product intends to occupy, which lays the basis for the specific functional plans of the organization. It provides the underpinnings for determining the new-product strategies and the action plans.

The selected market segment(s) provides the context for the other key external dimensions. The key questions include: who, what, when, and how?

The product architecture focuses on the design characteristics of the product. It involves material selection; packaging options; resource utilization; and the determination of features, functions, benefits, and detailed specifications of the product. Product architecture is based on the product specifications derived from customer contributions and the capabilities of the organization.

Selecting the market segment is the initial operational step in determining the plan. The second step involves positioning the product within the market segment. The third step is differentiating the product relative to the competition. This includes defining its strategic advantage(s) and articulating a clear message about its attributes. For example, Budweiser is the number-one-selling beer in the United States. It is positioned right in the middle of the market space for beer in terms of taste and price. It has the largest market share of the largest segment of the entire market. Budweiser's position (market space) gives it the power that it enjoys. The product is differentiated through clever advertising and marketing messages that suggest fun and entertainment.

The product/market plan includes the following key elements:

- The selected target market.
- The product/market position.
- The product/market strategy(s).
- The product program, including architecture and design.

An outline for the product/market plan is given in Section 3 of Table 6.3.

Plans pertaining to stakeholders

Meeting the needs of stakeholders is much more difficult than meeting those of customers. Stakeholders tend to be more diverse and their expectations are often less apparent. Stakeholder needs can be divided into two categories: explicit and tacit. The explicit needs include those mandated by government entities, those required by an industry standards group or other sanctioning organization, information solicited by reporting organizations, covenants specified by financial institutions, and many others. Examples of the aforementioned include:

- Preparing an environmental pre-manufacturing notification or obtaining an environmental permit from the appropriate regulatory agency. For example, constructing a new production facility may require permits to build and permits to operate.
- Filing the proper documentation pertaining to the standards organization to verify that the product meets the requirements of the sanctioning body. For example, electrical devices require Underwriter's Laboratory approval.
- Submitting documentation about the product to inform stakeholder groups about the characteristics and performance of the new product. For example, J. D. Powers tracks design and performance information pertaining to automobiles.
- Filing documents with banks to provide them with the information stipulated in loan agreements.

Most of the explicit needs are straightforward in terms of what has to be done. In most cases, the explicit needs are "must-do" requirements that are specified by the stakeholder organization. Preparing plans to fulfill the requirements simply means addressing the mandates of the sanctioning organization. However, completing such requirements is not always easy.

Tacit needs are much more difficult to characterize. Such needs are often open-ended without clear definitions about what has to be done. The planning process might include the following:

- Identify the most important stakeholder groups and define their issues and agenda items.
- Prioritize the list of stakeholders and determine the most crucial issues as they relate to the new product. Identify the key people within the stakeholder organization and determine how to open a dialogue with them.
- Identify workable solutions that meet stakeholder expectations.
- Prepare plans for the implementation of the issues and agenda items. Prepare supplemental plans for all of the other items on the priority list.

The plans include detailed statements about the action plans. Depending on the strategies and the complexities of the issues, the action plans may run concurrently with the development of the NPD process. This approach is particularly useful if there are concerns about the feasibility of the new-product opportunity. If there are significant risks that the NPD program might be terminated, the company may not want the stakeholder plan to be completed ahead of the actual development of the new product. On the other hand, it may be imperative that stakeholder-related issues, especially mandates, are addressed early in the process so that they do not hold up commercialization of the new product.

Plans pertaining to supply networks

Supply networks are vital to the success of any NPD program. From an enterprise perspective, they should be treated as internal participants if their contributions are strategic in nature. The planning for the contributions of supply chain (suppliers) and distribution networks (distributors) should begin as soon as the requirements are defined and become important in the NPD process. In most cases, only the strategic materials and components are initiated during the Concept Development and Selection Phase. Most of the considerations pertaining to supply networks are included in action plans executed during the Design and Development Phase. Planning for distributors follows a similar approach to that for suppliers.

The company can obtain a competitive advantage by adapting an effective supply-network strategies that improve efficiencies, effectiveness, linkages, and waste reduction. Plans for supply networks involve identifying the most important suppliers and distributors and determining the critical materials, parts, and components and the most crucial links to potential customers. The plans should include actions to streamline supply chains, to cut costs whenever possible, and to select new suppliers and form new relationships that facilitate interactions and communications.

Improving the supply networks depends on integrating them as part of the NPD process, planning supply-chain operations, and enhancing the early visibility of changes in the concept(s) or product design(s). Supply-chain management includes the following elements: purchasing, supplier management, outsourcing, resource planning, and sourcing. The primary supply-chain objective is to support business operations with the best products and services at the lowest cost and highest quality. The challenge is to initiate innovative approaches to achieve the financial and operational goals of the NPD program and to implement the best practices available.

In planning for the supply-chain-related aspects of the NPD process, the fundamental steps include: setting goals; mapping the process flow; evaluating the existing and potential capabilities of each supplier; identifying internal and external needs for materials, parts, and components; developing a master plan; establishing procedures and guidelines; setting priorities; resolving conflicts; and evaluating performance. It includes planning for logistics. Logistics management is the process of planning, implementing, and controlling the effective flow and storage of goods and related information from point of origin to point of consumption. Logistics include: customer service, forecasting, inventory management, materials handling, information processing, packaging, parts and service support, traffic and transportation, warehousing and storage, and reverse logistics.

Actions and counter-measures to neutralize competitors

Based on the competitor assessment, the company may plan actions to counter the effects of the expected competitor responses. The first line of action is an aggressive campaign to launch the new product and occupy a commanding space in the market segment. The notion that the best defense is a good offense is the obvious. The product/market strategies of leadership and positioning are central to achieving a solid solution.

The long-term strategic proposition is to solve difficulties, to meet the present and future needs of the business environment, and to discover and exploit opportunities before they become obvious or mandated; and to do so ahead of expectations and competition. While it can be argued that a company chooses its own destiny with respect to new products, there are limitations to the choices that may be available. Product/market strategies focus on shaping or reshaping the opportunities and challenges in a way that benefits the strategic position of the company and the new product. They define a distinctive scheme for establishing product delivery strategies that set direction, speed, and movements; and define the required capabilities, systems, and actions to stay ahead of competition.

On a product and process basis, Kim Clark and Steven Wheelwright's research showed that fast-cycle competitors significantly out-performed slow-cycle competitors.[9] More importantly, the slow-cycle competitor became hopelessly behind in a relatively short period of time in a fast-paced business environment. The compounded effects of steady gains that are superior to the accomplishments of the norm provide a basis for achieving competitive advantage, and superior positions and capabilities.

The most important elements of mapping out counter-measures are to list the main competitors and identify their expected responses. The product can be positioned in a part of the market segment where it is costly or impractical for a competitor to follow. For example, Boeing chose not to follow Airbus's new product venture into the "Super Plane," the 550-seat Airbus A380. The costs and risks were too high, especially knowing that Airbus was going to be ahead of them. Another strategy for pre-empting competitors involves selecting positions that are on the fringes of the market segment. Sam Adams beer successfully introduced its products by avoiding positions that would be in direct competition with Anheuser-Busch.

Plans for related industries and the infrastructure

The practical aspects of managing implications for related industries and the infrastructure are handled on a case-by-case basis. There may not be a prescribed approach for detailing the requirements. Related industries often represent strategic allies of the new product. Their fit into the new-product equation depends on the strengths and weaknesses of the product position. In some cases, related industries perform a complementary service that is not essential. For example, "car-wash" services are nice but they are not critical to automobile manufacturers. On the other hand, gasoline stations are pivotal. Products and services from related industries might be the primary focus with the new product being secondary. For example, is the Sony CD player the prime reason for the purchase, or is the music on the CDs the primary reason? Understanding the relationships and improving them are the most important factors.

Program definition depends on identifying the most crucial support products and services, and finding the major opportunities and barriers for achieving desired outcomes that warrant special attention. The action plans include building relationships and supporting the activities. A similar approach can be used for the infrastructure.

NPD-process templates and definitive NPD frameworks

The definitive game plan

Many corporations have NPD guidelines that provide definitive instructions for developing new products. The definitive game plan can be articulated using simple flow charts similar to the constructs described in the chapters of this book. An NPD manual that defines the roles and responsibilities of the key participants, or gives templates identifying the most important elements, provides a definitive means of articulating instructions and guidelines. Each has benefits. Templates can systematically guide the participants through the planning and implementation processes. Worksheets can direct the participants through the NPD process and ensure that the essential elements are covered. Process flow charts, worksheets, and templates can be used together to provide a flexible structure for mapping out the requirements.

The diversity of the approaches makes establishing an NPD process with a common format very difficult. The essence of the NPD game plan is to partition the complex requirements for planning and implementation into discrete and manageable elements.

The templates in Table 6.3 offer a detailed framework for managing the planning aspects of the NPD process. The templates are provided as a framework that can be modified based on the specific needs of the NPD situation and organizational structure. The guidelines attempt to capture the essential requirements of the NPD planning process, but they are not intended to be comprehensive or to cover every situation.

The NPD team and program management are responsible for ensuring that all of the requirements have been identified and that there is a game plan for achieving necessary outcomes. The NPD teams are responsible for the deliverables and for the final results. The templates provide the basic elements for developing an NPD game plan. The following are the essential sections of the plan:

- Business overview.
- NPD program and organizational design.
- Product/market plan.
- Marketing plan.
- Production plan.
- Financial plan.

The result of integration of the separate plans is in essence a business plan for developing the new product. While large corporations may follow well-defined NPD manuals that spell out everything, small companies and entrepreneurial efforts may not have the luxury of preparing precise methodologies and may find that the templates are exactly what they need.

As NPD plans and programs are implemented over time, opportunities for standardization and replication in common areas should be addressed and built into NPD manuals, worksheets, and templates. The basic methodology is to define general approaches and elements, leaving the specific details to the teams. In this way, management has a definitive planning construct for high-level decision making, which facilitates understanding of the review process and helps ensure thoroughness. This provides the flexibility to the team to develop the details as required at lower levels.

Table 6.3 *Simplified template for NPD game plan*

Key element	Section 1 Business overview outline
	Process elements
1.0 Company situation and background	Identify the company and its background: (a) General description: lines of business and product lines. (b) Geographic reach (international, national, regional). (c) Technological capabilities and innovation. (d) Market scope (markets, segments, customer base). (e) Capabilities and resource base (people, facilities, capital). (f) Core competencies and core capabilities (strengths and weaknesses). (g) Product portfolio (strengths and weaknesses). (h) Reputation and image.
2.0 Mission statement, goals and objectives, and strategies	Identify the internal drivers for new products: (a) Vision and value statements. (b) Mission statement. (c) Goals and objectives for new-product opportunities. (d) Strategic direction and fit for new-product development.
3.0 Product/market statement	Identify the existing markets served. Identify the major driving forces on the markets. Describe the prevailing value proposition. Describe market and customer characteristics. Identify the principal needs and wants of customers: (a) What are market requirements? (b) What are the ideal product characteristics? (c) What means are used to communicate with the market?
4.0 Business environment factors	Identify and list the most significant external factors facing the company and its efforts to launch a new product: (a) Economic factors. (b) Social and political factors. (c) Technological factors. (d) Ecological factors.
5.0 Industry analysis	Describe the industry structure: (a) Identify the competition (strengths and weaknesses). (b) Determine ease of entry/exit. (c) Describe risks involved in conducting business.
	Section 2 NPD program and organizational-design outline
1.0 Organization design	Identify the organizational approach used for the NPD program: (a) Describe the team structure, if a team model is used. (b) Describe the steering committee (management review).
2.0 Values and philosophy	Describe the core values of the NPD organization. Identify the NPD philosophies, policies, practices, and performance measures.

Table 6.3 (*cont.*)

3.0 NPD process	Describe the NPD process. Describe the management review process. Identify the typical lead-times for similar new products.
4.0 Program objectives.	Identify NPD objectives: (a) Speed and timing of the program measured in terms of calendar dates. (b) Breakeven in terms of units and time. (c) The development costs of the program, measured in terms of total investment and total dollars committed to complete the program. (d) Level of risk and probability of success.
	Section 3 Product/market-plan outline
1.0 Strategic alignment	Summarize the essential determinants from the strategic plan and situation analysis. The strategic alignment provides the logic pertaining to the fit of the new product into the strategic plans of the organization and/or its product portfolio.
2.0 Market-segment selection	Define the selected product/market segment: (a) Demographically. (b) Psychographically. (c) Geographically. (d) By applications. Describe the segment and its history. Identify stage of life cycle.
3.0 Product/market objectives, targets, and metrics	Identify product/market objectives, targets, and metrics used to guide the development program and to determine its direction and achievements: (a) Identify the primary goals of the new-product program. (b) Identify the technical and market objectives (quality, performance, value, cycle time, development cost). (c) Determine the targeted unit cost. (d) Specify the critical factors required for success. Identify the key metrics that are to be measured and monitored on an ongoing basis to determine the track that the NPD program is achieving. These are the primary determinants for success.
4.0 Product/market strategies	Identify the primary product strategy: (a) Product/market leadership? (b) Related product strategies.
5.0 Product/market positioning	Identify the main customer needs and wants (expressed and latent). Describe the mechanisms to differentiate the new product. Describe the new product's fit into the market segment.
5.1 • Target product/market	A key to success is positioning the product in a viable product/market segment. Describe the product/market concept: (a) Identify the driving forces. (b) Identify the key features and functions of the new product.

Table 6.3 (*cont.*)

	(c) Relate the features to customer benefits. (d) Describe the value-creation aspects. (e) Identify the limitations of the new product?
5.2 • Product specifications	Identify the product specifications from the perspectives of the producer and the customer.
5.3 • Customer analysis	Identify and specify customer requirements: (a) Who are the most important potential customers? (b) Who are the early potential buyers? (Lead users.) (c) What are the mechanisms that customers use to make a purchase decision? How do they decide? What is the typical behavior pattern (frequency, quantity, and timing)? What are the applications? (d) Why do they select a particular product? What channels do they use to buy the product? (e) How are they affected by marketing approaches?
5.4 • Market-segment assessment	Analyze the market attractiveness of the target product/market segment: (a) Scope, size, shares, and growth rate of market segment in terms of key competitors (three to five years history). (b) Market forecasts and trends in demand for the next three to five years. (c) Identify seasonal or cyclical trends. (d) Marketing programs used to satisfy market demand. This includes pricing levels, distribution channels, advertising, promotion, and selling practices.
5.5 • Competition analysis	Identification of the main competitors for the segment. List the most significant competitors who might be a barrier to success: (a) How do competitors design, produce, market, finance, and manage their products? (b) What are their main strengths and weaknesses? Core capabilities? (c) How will they respond to the new product? (d) What are their future strategies likely to be? How will they respond? (e) What are their marketing practices? (f) How do competitors design and develop new products?
5.6 • Stakeholder issues	Identify the most important stakeholder issues: (a) Laws and regulations. (b) Special-interest groups. (c) Product liabilities.
5.7 • Related industries	Identify the most crucial support products and services. What are the major opportunities and barriers for achieving desired outcomes that warrant special attention?
6.0 Product-design elements	Outline the major design and development program elements used to launch the new product. Prioritize the list of program elements.
6.1 • Product architecture	Outline the main elements of the product architecture: (a) Features, functions, and benefits provided and product characteristics. (b) Brand identity, package, labeling, and appearance. (c) Services and related after-market products.

Table 6.3 (*cont.*)

6.2	**• Performance**	State the most important performance aspects of the new product: (a) What are the most important performance parameters? (b) How does the product contribute to customer satisfaction?
6.3	**• Value creation (performance to price)**	Identify the value that the new product offers customers. Is the value created worth the cost and/or investment? Prepare an economic analysis of the new-product opportunity.
6.4	**• Quality**	Identify the quality requirements for the new product. Does the new product have the potential to meet or exceed customer quality expectations? What are the essential drivers? (a) Conformance and ease of use. (b) Reliability, durability, serviceability. (c) Health and safety. (d) Aesthetics.
6.5	**• Technology selection**	Outline the critical technologies used to design and produce the product and its related processes: (a) Identify the prevalent product and processes, their life cycles, and the improvement rates. (b) Determine the typical lead-times to design and develop new products. (c) Determine the relationships between products, processes, and families of products and services.
7.0	**Risk assessment**	Identify the major technical risk factors: (a) Product/market risks. (b) Financial and business risks. (c) Technical risks.
		Section 4 Marketing-plan outline
1.0	**Strategic alignment**	Summarize the essential determinants from the strategic plan relating to the marketing plan and programs.
2.0	**Marketing-related objectives**	Identify marketing objectives used to guide the development program and to determine its direction and achievements. Identify the critical marketing objectives: (a) Market penetration rate. (b) Revenue streams. (c) Market shares.
2.1	**• Product objectives**	Identify product objectives: (a) Market penetration rate measured in terms of sales per month; per year. (b) Cost of product, measured in terms of dollars per unit at specific volume levels. (c) Target product specifications.
2.2	**• Marketing-mix objectives**	Identify marketing-mix objectives: (a) Branding objectives. (b) Pricing objectives. (c) Promotion objectives. (d) Distribution objectives.

Table 6.3 (*cont.*)

2.3	**• Financial objectives**	Identify financial objectives: (a) Breakeven in terms of sales revenue and volume. (b) Targeted internal rate of return and NPV on discounted-cash-flow basis. (c) Targeted profitability and gross margins.
3.0	**Product/market strategy**	Identify how the product fits into the market segment and the position of the product.
3.1	**• Pricing strategy**	Determine the role that pricing plays in the success of the product: (a) What is the price elasticity of demand? (b) What pricing strategy should be selected? Penetration pricing is used to stimulate demand. Skimming pricing is used to generate short-term profits.
3.2	**• Distribution strategy**	Describe the distribution channels selected to launch the product. Determine the best distribution approach and what is required to support the distribution channel.
3.3	**• Promotion strategy**	Describe the promotion strategy used to initiate and maintain the flow of information and communication between the organization and the market segment.
4.0	**Marketing-program elements**	Outline the major marketing programs used to launch the new product. Prioritize the list of programs.
4.1	**• Product**	State the most important features/benefits of the new product. How does the product contribute to customer satisfaction?
4.2	**• Pricing**	Identify the pricing scheme used to launch the new product. How will it change over time? How will it contribute to success?
4.3	**• Advertising/ promotion**	What are the key communication methods for promoting the new product? How do they relate to the targeted customers and market segments? How do they support the distribution of the product? (a) Advertising/promotion plan. (b) Channel promotion plan. (c) Merchandizing plan (point of sales). (d) Internet plan. (e) Public relations plan. (f) Media plan – press releases. (g) Trade shows and conferences.
4.4	**• Distribution**	What are the support mechanisms for the distribution channels?
4.5	**• Selling**	What are the sales programs? (a) Sales literature – catalogs, price sheets, fact sheets. (b) Internet pages; sales samples; service manuals. (c) Terms and conditions. Who is responsible for the selling effort? (a) Sales force, representatives, agents, etc. (b) Internet. (c) Support services.
5.0	**Budgets**	Identify the financial resources required to support the product launch. Specify the budget required for the marketing program: advertising/ promotion, distribution, Internet, selling.

Table 6.3 (*cont.*)

	Section 5 Production-plan outline
1.0 Strategic alignment	Summarizes the key determinants from the strategic plan and situation analysis. How is the new product linked to the existing resource base of the organization? Does it leverage existing core capabilities?
2.0 Production	Identify the key requirements for producing the new product. What has to be produced in-house? What can be outsourced? (a) What are the required facilities? What type of equipment? Other resources? (b) What are the appropriate processes.
3.0 Process strategies	Identify the key approaches used to produce the product. Define the process specifications. (a) Process selection. (b) Make or buy. (c) Process plans and analyses. (d) Equipment selection. Identify the inventory requirements. Determine the cost implications.
4.0 Process programs	Outline the major production programs used to launch the new product. Prioritize the list of programs. Design for manufacturability. Raw-materials and supply-network aspects. Quality plan. Waste minimization and waste management.
4.1 • Economics	What are the manufacturing and/or purchasing costs to build or buy the product? What are the cost drivers? What are opportunities to reduce the costs? How does costs vary with: quality? volume? yields? productivity? capacity utilization?
4.2 • Inventory	Identify the inventory requirements to support the product launch. What is required to sustain the distribution channel?
5.0 Supply networks	Identify the most important relationships for the new product. What are the most critical (strategic) materials, parts, and components? Are there any materials availability issues? What are the logistical requirements?
6.0 Infrastructure	Is the infrastructure adequate to provide the necessary information and materials flow? Is the infrastructure adequate to meet the logistical requirements?
7.0 Investment	Identify investments required to produce the new product: (a) Facility. (b) Equipment. (c) Tooling, training, etc.
8.0 Risk assessment	Identify the main elements of risk.

Table 6.3 (*cont.*)

	Section 6 Financial-plan outline
1.0 Strategic alignment	Summarizes the key determinants from the strategic plan and situation analysis. The strategic alignment provides the key financial requirements for the organization.
2.0 Investment	What are the significant areas that require investment? What is the maximum allowable investment? Is there a minimum?
3.0 Financial objectives, targets, and metrics	The financial objectives are quantitative metrics used to evaluate the program and to determine its direction and achievements. Identify the main financial objectives: Return: Profitability? Cash Flow? What is cost of capital? (a) What is the ideal breakeven point? Time? Volume? (b) What is the time horizon of the investment?
4.0 Financial requirements (budgets)	Identify the major requirements for capital: (a) Development – product and marketing. (b) Capital equipment. (c) Working capital/inventory.
5.0 Financial implications	Outline the major tools and techniques used to evaluate the feasibility of a new product.
5.1 • Revenue generation	Based on the sales forecast, what are the expected revenues over time?
5.2 • Cost of goods	Based on an assumed volume and cost structure, what is the cost of goods sold? How does it vary over time?
5.3 • Gross-margin analysis	What is the potential gross margin for the product? Is it sufficient to allow for an aggressive marketing campaign?
5.4 • Net income	What are the net income projections for the new product? What is the profit potential?
5.5 • Cash-flow projections	What is the internal rate of return? What is the present value of cash flow from the investment? What is the long-term position?
6.0 Sensitivity analysis	What are the implications of the following: (a) Reduced price? (b) Higher cost of goods sold? (c) Volume is lower than forecast? (d) Shorter life cycle (time horizon)? (e) Longer development time? (f) Higher development costs (investment)?
7.0 Risk assessment	Identify the main elements of risk. What is the risk-to-reward ratio?

Summary

The Program Definition Phase translates the selected concept(s) into actionable plans. Planning for product innovation requires a holistic view and analyses of the inputs and outputs of the entire enterprise. Product development uses an integrated, systems approach to create an alignment between the external implications and the internal resources and capabilities of the organization. It takes an enterprise view of all of the participants, and their needs and contributions, the consequences of processes used to create new products, and the associated opportunities.

The game plan is defined through well-articulated templates or similar approaches to describe the key elements of the requirements. The most important aspects for implementation are the utilization of process-management techniques and people-management practices. The NPD process is tracked on a continuous basis using performance measures. Performance evaluation is the process of measuring, assessing, and describing NPD performance against guidelines and objectives. Effective performance evaluation provides management and the team with a process for tracking the stated goals and expectations of the product creation process and comparing them with the actual results.

The next four chapters provide additional details pertaining to the elements identified in the templates. The chapters follow the major product/market, marketing, production, and financial-management templates.

Notes

1. Generating value is the key for achieving success. As AT&T discovered in a pivotal study during early 1990s, a company must go beyond simply satisfying customers; customers must be delighted. Delighted customers remain loyal, permitting retention of the customer base.
2. As previously discussed in Chapter 3 there are many similar constructs for dividing the program into manageable and discrete parts, and providing an ongoing means for evaluating results.
3. The notion of concurrent development is further defined and discussed in Chapter 7. The popular construct of concurrent engineering is used to expand this notion.
4. Project Management Institute, *A Guide to the Project Management Body of Knowledge* (Philadelphia, PA: Project Management Institute, 1996). This is an effective guide for providing the essence of project-management techniques.
5. *Ibid*., p. 31.
6. Gantt charts are used by several project-management-software providers including Microsoft Project. A Gantt chart indicates the time-line for activities, the relationship with other activities that precede or follow, the time duration for each of the activities – including start and end dates or times, and the people responsible for the actions.

7. N. Machiavelli, *The Prince* (Bantam Classics, 1984, p. 147).
8. "Critical to quality" is the General Electric perspective of the most crucial factors. It is a six-sigma approach.
9. S. Wheelwright and K. Clark, *Revolutionizing Product Development, Quantum Leaps in Speed, Efficiency and Quality* (New York: Free Press, 1992, p. 23).

Supplement to Chapter 6
Overview of financial-management techniques related to new-product development

By Lou Gingerella

Introduction

Finance and financial management are about *the money*. The capitalist economic system is based on a risk-to-reward quotient. Organizations assume risk with the aim of receiving a commensurate reward. If an investment opportunity does not provide an appropriate reward given its risk, it will not attract investors or sponsors until it does. Some investment opportunities wither on the vine because the reward cannot be demonstrated to be sufficient given the apparent risk. Other investment opportunities that meet this challenge will receive the necessary financial backing of management or investors, thereby allowing them to go forward with planned activities. Basic finance provides a better understanding of the value of innovation and financial performance measurements.

The financial rewards and penalties are typically measured in two ways: How valuable is the investment today compared with when the initial investment was made? How much income has been or will be generated from this investment? Ultimately, how much income is received from an investment *and* how much future income one anticipates receiving from the investment, *as compared with all other alternatives*, determines its current value.

This supplement provides an overview of some of the basic tools needed to quantify the value of an investment. It begins by examining how to value a firm and then how to determine the value of a new-product development (NPD) program. It does not matter whether the investment being considered is the purchase of stock in a publicly traded corporation, an investment into plant and equipment, or an NPD program. The techniques used to measure the investment are the same.

Investment money is a resource like any other and must be viewed as being both scarce and valuable. It stands to reason that the investment that is demonstrated, through proper measurement techniques, to be the one most likely to reward its investors generously will indeed be the one most likely to be funded.

Measures of success

Market value and economic value added

Typically, investments are made to enrich the investors or NPD program sponsors. Philanthropic reasons aside, that's what it's all about. Therefore, it is safe to say that a business, the firm, exists to satisfy the objectives of the shareholders. The wealthier its owners become because of good deeds or activities, the more successful the firm is viewed as being. While financial accounting techniques measure the "book" profits and worth of a company – that is to say what the financial statement reports – rarely does that translate to what the firm is worth "on the open market." The open market for publicly traded firms means the stock market. More often than not, what the market says a company is worth means more than what the financial statements say a company is worth.

Wealth is measured by comparing the provided investment with that investment's current value at a future point in time. The difference is called the "market value added (MVA)."

$$\text{Market value added (MVA)} = \text{Market value of investment} - \text{Investment supplied}$$

For example, on December 31, 2002 Procter & Gamble (P&G) had a market value of \$115 billion while its shareholders had invested \$14 billion.[1] The difference (\$101 billion) is the MVA for the firm. P&G investors provided not only the money invested into the company by purchasing its stock, but also they contributed the retained income (money left in the business for management to use for new investments). The MVA may be viewed as a premium. The greater the premium, the greater the wealth generated for investors.

The market rewards success and penalizes failure. A negative MVA can and does happen. Why should the market value of firms differ? In large part it has to do with how much money (profits, cash, return) the firm has generated *and* how much it is likely to generate in the future *as compared with other alternative investments.*

How then do investors collectively come to this position? One method is to recognize the "economic value added"[2] (EVA) to an investment because of the actions of the firm's management.

While MVA measures the premium earned on the collected investment in the firm (an investment typically made over many years), EVA provides a measure of the success of the firm in the most recently completed year. This is done by measuring the *economic profit* of a firm rather than simply taking at face value the stated profit from the firm's income statement. The simple formula is:

$$\text{EVA} = (\text{Operating profits after taxes} - \text{Cost of investment}) = [(\text{Sales} - \text{Operating Expenses} - \text{Taxes}) - (\text{Investment} \times \text{Cost of investment})]$$

For example, consider the following financial statements:

Example income statement	
Sales	$600,000
COGS	300,000
	——
Gross profit	300,000
Operating expenses	100,000
	——
Operating Profit	200,000
	——
Taxes	80,000
	——
Net profit	$120,000

Example balance sheet	
Cash	50,000
Accounts receivables	100,000
Inventory	100,000
Property	750,000
Total assets	**1,000,000**
Accounts payable	100,000
Long-term debt	200,000
Owner's equity	700,000
Total equities	**1,000,000**

In the example, the firm had an operating profit after taxes of $120,000. For the purposes of computing the EVA, the cost of all investor supplied *equity* is included.[3] This includes the cost of all debt where a charge for having the debt (interest) applies. Investors also require a return on their investment. For this example, assume that both the debt interest rate and the expected investor return is the same; say 10%.

The EVA then would look like this:

$$\text{EVA} = \$120{,}000 - (\$900{,}000 \times 0.10) = \$120{,}000 - \$90{,}000 = \$30{,}000$$

The EVA reflects the economic profit of the operation. This computation reflects the accounting costs of doing business and also the "cost" of holding on to investors' money. With this methodology investors measure how efficient management has been in managing the enterprise and also how well it manages the balance sheet. This technique may be used on a divisional or even product basis.

An investment is measured by the financial benefit it provides to its owner. This is measured by the return an investment has generated and its anticipated future returns. If investors believe a firm will provide superior EVAs in the future then the market will reward that firm with an ever-higher MVA. Therefore, it holds that a firm's MVA is equal to the sum of its future EVAs.

This is where the past meets the future. Management, by choosing to make certain quality investments in the past and in the future, must manage those investments in an efficient manner. By so doing, the firm should achieve superior profits. Superior results, as compared with alternative investments, should follow.

Therefore, financial management focuses on two significant elements: ***the efficient use of assets*** *and* ***the decisions pertaining to investments***.

Using the firm's assets efficiently

Two ratios are used to gain a sense of how well management is using the funds provided by investors, and the assets it has acquired as a result of those investments. These two **profitability** ratios are **return on equity** (**ROE**) and **return on assets** (**ROA**). ROE measures the return provided to the investors of the firm based on their equity. Using the above financial statements, the firm had total shareholder equity of $700,000. Given its net profit of $120,000, ROE equals $120,000 ÷ $700,000 = 17.1% (ROE = net income ÷ total shareholder equity).

ROE is a benchmark that investors understand and pay particular attention to. By examining investment returns in terms of the benefits as a percentage of investment, investors understand the expected return for any investment opportunity. Another measure of how well management performs is to compute an ROA ratio. This provides a measure of how well management invested the resources it has under its control. In this example, the company's ROA is 12% ($120,000 ÷ $1,000,000 = 12%) (ROA = net income ÷ total assets).

By using the ROA and ROE ratios to measure investment alternatives, investors decide what investments to make and what investments should be avoided. Higher ROE and ROA ratios, translate into better EVA and MVA.

Business-unit or program profitability measurement

A corporation is simply one or more programs operating within its legal entity. It is the collection of programs that make up the company. Management decides what programs to add or to abandon. It is this aggregation of programs which provides the cash flow that investors use to judge the firm's value, as reflected by its stock price.

When considering internal investments (like NPD programs), management often utilizes a ratio similar to the ROA, called the **return on investment** (**ROI**). The amount of investment is the base and the expected cash flow is the benefit. ROI is used for all of types of business decisions from plant and equipment purchases to NPD programs.

Using the financial statements in the example, the ROI would be the same as the ROA, or 12%. The subtle difference for the ROI calculation is that the investment is the amount of money needed to fund the program or the total of the equity side of the balance sheet. This approach focuses attention on the fact that it costs money to secure funding for any program. How much it cost depends on how the business decides to support or fund the program. Using debt or using the proceeds from selling new shares of common stock in differing levels usually means differing costs.

Regardless of how the funding is provided, whatever its cost, existing programs or a contemplated NPD program must provide a return greater than the cost of the provided funding (the cost of capital). Furthermore, the funding cost to a business typically has a premium attached. The rate quoted to a business unit is often called the "hurdle rate." An NPD program should provide an ROI greater than or equal to the hurdle rate.

Where does this elusive hurdle rate come from? In large part the firms existing or targeted EVA rate may drive it. In the example, the EVA rate is 13.3%. What is the difference between the ROI and the EVA? In computing the EVA in this example, non-interest-charging liabilities or accounts payable in this example are not included. The EVA calculation is $120,000 ÷ $900,000 = 13.3%.

The greater the difference between the cost of capital (or its hurdle rate) and the ROI earned, the greater the EVA. Ultimately this will have a positive impact or MVA. And, that's how shareholder wealth is enhanced.

Capital budgeting and the cost of capital

Overview

Capital budgeting is the process of evaluating and investing in new products and processes. For large corporations, funding for NPD programs usually comes from the "home office." Corporate funds provide the money if a program has sufficient merit from a financial perspective. For small businesses, the funding might come from a local bank or the owner's personal savings.

For the purposes of this discussion, it is assumed that the NPD program makes good business sense. The underpinnings are available. The NPD program has potential customers who are expected to buy the product at the right price, it has reliable suppliers that can supply materials at good prices, it has the workforce to make it happen, and it won't violate any laws getting it done.

Given the level of investment required, the principal question is: Is it an investment worth making? It will be if, given all the alternatives, this particular investment will return to the firm an ample level of reward. Will the NPD program provide a sufficient amount of cash flow to make the investment worthwhile?

The answer is derived by comparing the cash flow – in terms of invested capital (the investment) – to develop and implement the NPD program with the incremental cash flow over time generated by the NPD program based on the timing of the cash flow (the return or the reward). The focus is on the incremental cash flows to determine if it is in the best interests of the company to make the investment. The analysis focuses on the difference. In this context, cash flow means the flow of money to the company after all expenses, except the cost of the money invested into the NPD program. The cost of the capital must be exceeded if there is to be a true enhancement to the value of the firm by adding an NPD program.

The cost of capital is the money that it costs to get or invest the money. Therefore, if a firm expects to make a true profit it must more than cover the cost of attracting investment dollars. A firm's capital comes from three primary sources: debt, preferred stock, and common equity. Each source of capital has a unique cost structure.

The cost of capital

The cost of debt

The required rate of return on debt is the return that lenders charge on new borrowings. A lender, when considering a loan to any entity, must consider all alternative investments when determining what interest rate should be charged. Borrowers are in competition with each other when they are sourcing the money. If a firm is looking to borrow money for an NPD program, it is in competition with a number of potential borrowers, from federal government to an individual looking to charge a purchase to a credit card. Clearly, the federal government expects to borrow at a more-favorable interest rate than say a financially strong corporation, just as the corporation expects to borrow at a better interest rate than is available on a typical charge card. Why? Because each presents differing levels of risk when borrowing money. Those risks are:

- Will the loan be repaid?
- When the debt is repaid, will the money be worth as much as it was when it was lent? (Inflation!)
- How much time will pass before the loan is repaid?

Moreover, the lender loses liquidity. If the lender needs the money back before the agreed repayment time, is there some mechanism in place to make that redemption possible. Astute lenders receive compensation for taking on each of these risks.

The equation using conventional terms for the cost of debt is given below.[4]

$$k = k^* + \mathrm{IRP} + \mathrm{DRP} + \mathrm{MP} + \mathrm{LP}$$

(example: $10\% = 5\% + 1\% + 2\% + 1\% + 1\%$)

where:

k = nominal or observed interest rate
k^* = real risk-free rate of interest[a]
IRP = inflation risk premium
DRP = default risk premium
MP = maturity risk premium
LP = liquidity risk premium

For the federal government's borrowings the cost of borrowing would be:

Less than one year:

$k = k^* + \text{IRP}$

(example: $6\% = 5\% + 1\%$)

More than one year:

$k = k^* + \text{IRP} + \text{MP} + \text{LP}$

(example: $7\% = 5\% + 1\% + 0.5\% + 0.5\%$)

For a corporation or an individual, the *stated* cost of borrowing money would be:

$$k = k^* + \text{IRP} + \text{DRP} + \text{MP} + \text{LP}$$

with only the factors associated with each component of the equation changing to reflect the differing level of risk. The difference between large borrowers, say IBM, and an individual using a credit card with an interest rate of 18% might look like this:

$\text{IBM} = 8\% = 5\% + 0.5\% + 0.5\% + 1\% + 1\%$
$\text{Credit card} = 18\% = 5\% + 1\% + 8\% + 2\% + 2\%$

[a] The required rate of interest on a security that has no risk at a time of no inflation. This is usually reflected by the interest rate on short-term US government securities.

Note that the risk-free rate and the inflation premium stay the same. The risk-free rate is the underlying rate. Everyone pays for inflation. For the IBM example, the term used is the stated interest rate. This is *not* the cost of borrowing money for IBM. The reason, assuming that IBM pays income taxes, is that the federal government allows IBM to deduct the cost of debt (interest expense) as a business expense. The cost of that debt to the borrower must be adjusted for taxes. Therefore, the cost of debt to a firm is:

$$\text{Stated or nominal interest rate} \times (1 - \text{Tax rate}) = \text{Cost of debt}$$

In IBM's case, should it have a 30% tax rate, this would result in the following: $8\% \times 0.70 = 5.6\%$ cost of debt.

Preferred stock

Determining the cost of preferred stock is very simple. It is computed as follows:

Cost of preferred stock = Amount of preferred stock dividend ÷ Net proceeds per preferred share

For example, if the dividend is \$5.00 and the net proceeds per preferred share are \$99.00, then the cost of preferred stock is \$5.00 ÷ \$99.00 = 5.05%.

Common equity

Determining the cost of common equity is not very simple. Indeed, the cost of common equity is never known with certainty. Rather, it is simply an estimate averaging the results of several costing formulas. The reliance on an estimate of cost is due to the nature of equity ownership, which makes an exact calculation impossible. Recall that equity in a firm is derived from two sources: purchased-equity and reinvestment of earnings. The only difference in cost between retained earnings and selling stock comes from the fact that the reinvestment carries no issue costs. Stockholders are the residual owners of a firm. This means that their future return is known only after they settle their contractual obligations with creditors and preferred stockholders. Therefore, it is impossible to determine with a high degree of accuracy the cost of common equity since the firm's future retained earnings can only be estimated. Estimating the cost of equity uses two methods: the dividend-growth model and the capital-asset pricing model.

Dividend-growth model

Theoretically, a stock's current price is equal to the present value of all future cash flows generated by that stock. Future cash flow is generated from dividends and the sale of the stock. The estimate of the cost of common equity is obtained by estimating the growth in earnings and, as dividends represent a distribution of earnings, the corresponding growth in dividends as well.

Therefore, the formula representing the cost of common equity for a dividend-paying company would be:

$$K_{\mathrm{cs}} = \frac{D_1}{P_{\mathrm{cs}}} + g$$

where:

K_{cs} = required rate of return on the firm's common equity
D_1 = anticipated annual dividend one year in the future
P_{cs} = today's stock price
g = firm's anticipated annual growth in earnings per share

The beauty of this formula is its simplicity. Its weakness is its simplicity. This measure assumes a constant rate of growth of earnings for ever. This simply does not happen. Yet, over time, a firm has averaged a growth rate (using historical numbers) and its future growth rate, g, is estimated by compiling the expected results of the various ongoing and future (known) programs of the firm. Finally, for those firms that do not pay a dividend, one would use the estimated growth rate in earnings alone.

Capital-asset pricing model (CAPM)

Another method used to *estimate* the cost of common equity is the capital-asset pricing model (CAPM). This model *attempts* to measure the cost of common equity by utilizing the *expected* return from other investments and modifying those returns based on the *historical* risk of the common equity in question. The obvious weakness then is that while it is known that history has repeated itself, it can never be assured that it will do so exactly for this investment. Nonetheless, it does provide some insight about what an investor should expect as an adequate return. The formula for this is:

$$K_{\text{cs}} = K_{\text{rf}} + (K_{\text{m}} - K_{\text{rf}})\beta$$

where:

K_{cs} = required rate of return on the common equity
K_{rf} = current risk-free interest rate (the same as k^*)
K_{m} = expected annual return for the entire stock market
β = the risks associated with the program

K_{rf} is found by computing the cost of debt. By default, many investors simply use the current US Government 6-month Treasury Bill as K_{rf}. K_{m} is found by estimating the expected rate of return for the entire stock market. The expected annual return (appreciation) in a stock index, such as the S&P 500 or the Russell 2000 is used. Who provides this estimate? Each individual investor does. A firm's beta, (β), represents how volatile the firm's stock price has been compared with all other common stock for the past several years. This information is readily available from a number of sources (Yahoo Finance, most brokerage firms, Standard and Poors, etc.). The β value for most firms ranges between 0.5 and 2. The higher the number the greater the volatility has been.

The weighted-average cost of capital (WACC) using an example

Most companies use a mix of funding sources and the result is the firm's capital structure. Find the cost of capital for any firm by computing a single weighted average of each of the funding sources. As the firm does not use any preferred stock, we need only compute the cost for debt and common equity. Let's use our example company and the above methods to estimate its cost of capital.

Example income statement	
Sales	600,000
COGS	300,000
Gross profit	300,000
Operating expenses	90,000
Operating profit	210,000
Interest expense	10,000
Profit before taxes	200,000
Taxes	80,000
Net profit	120,000

Example balance sheet			
Cash	50,000	Account payable	100,000
Account/receivables	100,000	Long term debt	200,000
Inventory	100,000	**Total debt**	**300,000**
Property, plant and Equipment	750,000	Owner's equity	700,000
Total assets	**1,000,000**	**Total equities**	**1,000,000**

Additional information is provided in the table below.

Shares outstanding:	120,000	Loan rate:	5%	% Equity = 70
Current stock price:	$16.00	Tax rate:	40%	% Debt = 30
Expected EPS growth rate:	12% current	Current K_{rf}:	4%	
Dividend:	$0.25 per share	Expected K_m:	14%	
Dividend next year:	$0.27 per share	Firm's β:	1.2	

The equation for determining the WACC is:

$$\begin{aligned}\text{WACC} = {} & (\text{after tax cost of debt} \times \text{proportion of debt financing}) \\ & + (\text{cost of equity} \times \text{proportion of equity financing})\end{aligned}$$

Cost of debt:	$K_d = 0.05(1 - 0.40) = 0.05 \times 0.60 = 0.03$
Cost of common equity:	
Dividend growth rate	$K_{cs} = (\$0.27 \div \$16.00) + 0.12 = 0.017 + 0.12 = 0.137$
CAPM	$K_{cs} = 0.04 + (0.14 - 0.04)1.2 = 0.04 + 0.12 = 0.16$
Average cost of equity	$= (0.137 + 0.16) \div 2 = 0.149$ or **14.9%**
WACC	$(0.03 \times 0.30) + (0.149 \times 0.70) = 0.009 + 0.104 = 0.113$ or **11.3%**

Therefore, given the company's capital structure, its WACC is 11.3%. Notice that by using debt, the firm lowered its cost of capital. While it is true that debt is often the least expensive way to raise capital, should a company borrow excessively, its cost of borrowing tends to rise to the point where the advantage disappears. Although common equity is often regarded as being the most expensive form of capital, it carries no required debt servicing as a loan does. During lean times, a firm may opt to not pay a dividend to conserve cash. If a firm borrows money, the banks may not be so ready to let payments slide. Remember the old adage: ***debt is relentless***.

Program-based financial evaluation

With the firm's WACC computed, an accurate analysis of existing and potential NPD programs is technically possible. Whether as part of a huge corporation receiving funds from "corporate" investors or a small business seeking out its own funding, NPD programs should provide a return greater than the cost of the provided funding. Again, this is referred to as the "hurdle rate." The reason for this is simple; if an NPD program does not return enough to cover the cost of capital it will lose money. In the example, the computed WACC is 11.3%; this then would be the firm's lowest possible hurdle rate. To use any lower number would mean the firm would not be covering its cost of capital. Consider a company contemplating the two NPD programs shown below. Table 6S.1 provides a simple example of the payback for the two programs.

	Alternative projects	
	Program A	Program B
Hurdle rate = 11.3%		
Initial investment	−25,000	−25,000
Year 1 net cash flow	15,000	7,000
Year 2 net cash flow	15,000	5,000
Year 3 net cash flow	5,000	20,000
Year 4 net cash flow	10,000	20,000
Total net return	20,000	27,000

Table 6S.1 *Payback example*

	Alternative programs			
	Program A	Payback for A	Program B	Payback for B
Hurdle rate = 11.3%				
Initial investment	−25,000	−25,000	−25,000	−25,000
Year 1 net cash flow	15,000	−10,000	7,000	−18,000
Year 2 net cash flow	15,000	+5,000	5,000	−13,000
Year 3 net cash flow	5,000		20,000	+7,000
Year 4 net cash flow	10,000		20,000	
Total net return	20,000	Payback = year 2	27,000	Payback = Year 3

Payback

The simplest method for determining the financial viability of an NPD program is to calculate its payback. Using the two NPD programs listed above, Program A would be chosen as it reaches payback in the second year. Program B reaches payback in the third year.

An obvious shortcoming of this method is that cash flows after payback are not considered. Taken to the extreme, using payback, if Program B had cash flows totaling millions of dollars in Year 4 it would not be counted. Given its limitations, the payback method should only be used in minor investment decisions.

Table 6S.2 *Net present value calculation*

	Program A			Program C		
	Cash flow	PV factor	NPV	Cash flow	PV factor	NPV
Hurdle rate = 14%						
Initial investment	−25,000	1.0	−25,000	−25,000	1.0	−25,000
Year 1	15,000	0.8772	13,158	7,000	0.8772	6,140
Year 2	15,000	0.7695	11,543	7,000	0.7695	5,387
Year 3	5,000	0.6750	3,375	10,000	0.6750	6,750
Year 4	10,000	0.5951	5,951	10,000	0.5951	5,951
Total	20,000		NPV = 9,027	9,000		NPV = −772

Discounted-cash-flow methods

Providing information that is far more useful are various discounted-cash-flow (DCF) models. These models take into consideration an NPD program's cash inflows and outflows and the timing of these flows. Recognizing that money today is worth more than money tomorrow, these models provide a time value to the flow of funds of the investment being considered. These methods provide a better understanding of how the cost of capital, and the timing of cash flow, affect an investment's attractiveness. This, therefore, provides a view of a project's success by demonstrating if the program, based upon its anticipated return, will or will not cover the cost of capital necessary to make that investment.

Net present value

A widely used method of DCF is the net present value (NPV) method. This technique computes the present value of all future expected cash flows from the investment using the hurdle rate as the discounting rate. Compute the discount rate on a per period basis by:

$$\text{NPV} = \sum_{t=0}^{n} \frac{\text{Cash flow}}{(1 - \text{HR})^t}$$

where HR equals the hurdle rate and t equals the period to be discounted.

NPV tables also provide the appropriate discounting factor for a given period that is then applied against the investment's future cash flows. After summing up the appropriately discounted cash flows, if the investment provides a positive number it more than covers the "cost" of the discounting or hurdle rate. A negative number means the investment did not cover the "cost" of the hurdle rate and is a weak NPD program from a financial perspective.

For example, at a 14% hurdle rate, NPD Program A provides a positive NPV of \$9,027 and should be funded. NPD Program C, however, shows a negative NPV and would not generate enough return to compensate for the true cost of funding the project (see Table 6S.2).

This methodology is useful when comparing different NPD programs with different cash flows. In the table below, investors are considering two different NPD programs providing differnt cash-flow timings and amounts.

In this example, both programs provide positive NPV so both would be funded. If, however, one had to choose between the programs due to a scarcity of resources, at the stated hurdle rate, Program B would be funded.

	Program A			Program B		
	Cash flow	PV factor	NPV	Cash flow	PV factor	NPV
Hurdle rate = 14%						
Initial investment	−25,000	1.0	−25,000	−25,000	1.0	−25,000
Year 1	15,000	0.8772	13,158	7,000	0.8772	6,140
Year 2	15,000	0.7695	11,543	5,000	0.7695	3,847
Year 3	5,000	0.6750	3,375	20,000	0.6750	13,500
Year 4	10,000	0.5951	5,951	20,000	0.5951	11,902
Total	20,000		NPV = 9,027	27,000		NPV = 10,389

If the hurdle rate is changed to 20%, a different picture emerges. The steeper rate causes later cash flows to be heavily discounted to the point where Program A becomes the favored investment, even though Program B provides more gross revenue.

	Program A			Program B		
	Cash flow	PV factor	NPV	Cash flow	PV factor	NPV
Hurdle rate = 20%						
Initial investment	−25,000	1.0	−25,000	−25,000	1.0	−25,000
Year 1	15,000	0.8333	12,500	7,000	0.8333	5,833
Year 2	15,000	0.6944	10,416	5,000	0.6944	3,472
Year 3	5,000	0.5787	2,894	20,000	0.5787	11,574
Year 4	10,000	0.4823	4,823	20,000	0.4823	9,946
Total	20,000		NPV = 5,633	27,000		NPV = 5,825

The NPV evaluation of an NPD program is clearly linked to the firm's goal of shareholder wealth maximization. If a project shows an NPV of greater than zero then the firm's worth (and hence its stock price) will be enhanced by accepting the project. If the NPV is less than zero then accepting the project will lower the worth of the firm.

Internal rate of return

While the NPV method provides a clear picture of which project to accept, many firms utilize another method, the internal rate of return (IRR), to select projects. Ironically, IRR is simply defined as the discount rate that will cause the net present value of a project to be equal to zero.

$$\text{NPV} = \sum_{t=0}^{n} \frac{\text{Cash flow}}{(1 - \text{IRR})^t} = 0$$

The IRR is expressed as a percentage, which is intuitively easy for a business person to understand. After computing the IRR the firm would compare the results with its cost of capital or hurdle rate. If the IRR exceeds the hurdle rate then the project should be considered; if not it should be abandoned from a financial perspective.

Recall from the NPV table that both projects provided a positive NPV at a 20% discount rate. Therefore, each project has an IRR of greater than 20%. To determine the IRR one must increase the discount rate until the NPV is driven to zero. One method is to guess at a higher rate:

	Program A			Program B		
	Cash flow	PV factor	NPV	Cash flow	PV factor	NPV
Hurdle rate = 20%						
Initial investment	−25,000	1.0	−25,000	−25,000	1.0	−25,000
Year 1	15,000	0.8333	12,500	7,000	0.8333	5,833
Year 2	15,000	0.6944	10,416	5,000	0.6944	3,472
Year 3	5,000	0.5787	2,894	20,000	0.5787	11,574
Year 4	10,000	0.4823	4,823	20,000	0.4823	9,946
Total @20%	20,000		NPV = 5,633	27,000		NPV = 5,825
Discount rate, −29%			NPV = $1,582			NPV = ($30)
			IRR = 33.2%			IRR = 28.9%

At the new discount rate (29%), we have lowered the NPV to the point where Program B has a negative NPV of ($30). The IRR must be just under 29%. The computation reveals an IRR of 28.9% for Program B while Program A has an IRR of 33.2%. The decision remains the same. Program A provides a greater return. However, with the IRR calculation, we have its exact rate of return; most managers seem to prefer this type of presentation.

Final comments

This supplement attempts to provide a mechanism to determine which commercially feasible projects are also the most financially rewarding. A successful firm is one that provides a superior return to its investors. The measurement for that is simple: increased total return to the owners. If that is indeed the aim, then the only way to accomplish this, from a financial standpoint, is to select those NPD programs that provide the greatest level of return on investment. The firm improves the economic value added to the enterprise and, sufficient numbers of such programs underway and in the process of being developed.

Notes

1. Proctor & Gamble, *Proctor & Gamble 2002 Annual Report* (Cincinnati, OH: Proctor & Gamble, 2002).
2. The term has been copyrighted by Stern Stewart & Co., New York.
3. Liabilities or equities are claims on assets just like owners' equities.
4. This is the standard form of the equation.

Part III

Methods and techniques for analysis and decision making

Introduction

Managing new-product development (NPD) includes developing a model or framework, creating an effective NPD process, understanding the organizational implications, and determining and using the methods and techniques for analysis and decision making. Part III provides a schematic presentation and discussion of the essential mechanisms for analyzing the decisions and solutions required for maintaining the flow of the NPD process. The various methods and techniques are divided into the fundamental categories used for developing new products from an internal perspective. The areas include: product/market considerations, marketing strategies and programs, production strategies and programs, and financial applications and implications.

The methods and techniques discussed in Chapters 7 to 10 are typically the more-sophisticated approaches used during the later phases of the NPD process. However, some of the methods and techniques may be applied during the conceptual level as well. As discussed earlier, the applications depend on the type of new product and the complexities involved in the program. The more complex the NPD program, the more likely it is that sophisticated methods will be used during the earlier phases of the NPD process.

These chapters are intended to provide a broad understanding of the methods and techniques so that practitioners understand the fundamentals of their discipline as well as those of their colleagues. It is imperative that the specialists in each of the main disciplines have a working knowledge of the approaches used to make decisions.

Part III is made up of the following chapters:

- **Chapter 7 Product/market considerations, integrated product design, and product architecture**

- **Chapter 8 Marketing strategies and methods: conceptualizing and designing the new-product marketing campaign**
- **Chapter 9 Production strategies and methods: operational and manufacturing implications**
- **Chapter 10 Financial applications and implications**

7 Product/market considerations, integrated product design, and product architecture

Introduction

This chapter discusses product/market considerations, product architecture, and product design. The concepts, methods, and techniques described and assessed provide a foundation for the approaches used to link the product/market conceptual aspects with the elements of product design and development. The discussions focus on the product/market and the technical basis for selecting, analyzing, and implementing product- and market-related techniques.

Given that the techniques for market analysis were covered in Chapter 2 and that Chapters 4 and 5 provided a general overview of the conceptual aspects of the new-product development (NPD) process, this chapter examines how product/market planning and design strategies are essential parts of the NPD process; the aim is to achieve product quality and performance and to minimize potential defects and burdens.

The key to creating outstanding new products is to understand the opportunities and challenges of the business environment, the dynamics of the markets and the external dimensions, and the consequences of the decisions made during the NPD process. Integrating product/market strategies with the selection of the appropriate technological- and product-innovation methodologies provides a linkage between the technical and market-related requirements, and the marketing, production, and financial elements. Design techniques focus on analyzing the product requirements and selecting the best market-based design approaches.

Appropriate design strategies satisfy the social, economic, technical, and functional objectives of the product/market design, and meet the requirements of the design philosophies and the program priorities and realities. The focus is predominantly on product design and architecture, the tools and techniques available for improving the quality of the design(s), and the analytical methods used to make good decisions. Product design involves creating superior solutions for customers and stakeholders.

The chapter includes discussions on quality and value analysis, concurrent engineering, and design aspects; and covers techniques related to total quality management (TQM), design for reliability, and design for the environment. Other techniques covered include quality function deployment (QFD), computer-aided design (CAD), computer-aided manufacturing (CAM), the theory of inventive problem solving (TRIZ), axiomatic design, and failure mode and effects analysis (FMEA).

The supplement at the end of the chapter provides additional details about the relationship between customer needs and requirements, and product characteristics, providing additional insights into the details of QFD. The supplement presents the strategic utilization of QFD, which links the voice of the customer with product design.

Chapter 7 includes the following topics and learning objectives:

- Understanding how TQM, design philosophies, and product architecture are central to design, and development, and for meeting customer expectations.
- Exploring methods for determining product architecture and identifying techniques for creating effective designs.
- Developing a working knowledge of CAD, CAM, TRIZ, axiomatic design, and FMEA.
- Determining how to use the voice of the customer and QFD.

Achieving customer and stakeholder satisfaction through the integration of quality, product design, and product architecture

Design philosophy

Traditional NPD models incorporate structural processes with clearly defined sequential activities. The sequential models used a series of steps as the product was defined, designed, developed, and then transferred to manufacturing, testing, and commercialization. The linear processes allowed designers to focus on one issue at a time. They were able to optimize the design point at hand, but were unable to embrace the complexity of the entire set of requirements, particularly the downstream implications.

Integrated product development (IPD) overcomes the disadvantages of the linear processes by incorporating diverse contributions from every functional aspect into the design discussions and decisions. The emphasis is on information and knowledge about the interactions among the essential design elements, both internal and external. The purpose of design is to transform concepts and product specifications into design elements and reality.

Brilliant product/market concepts, great designs, and excellent marketing do not guarantee success unless they are strategically linked to the overall NPD process and are consistent with the internal and external dimensions. A good design fulfills the expectations of customers, stakeholders, and participants. Considering the intensity of the competitive forces in today's business environment, new-product designs have to balance a multiplicity of competing objectives, and driving forces.

In *The Goal*, Eliyahu Goldratt articulates the straightforward idea that the goal of a business enterprise is to make money.[1] Excellence in design results in making money and providing satisfaction.[2] Customers purchase the products to enjoy the benefits.

Since the attainment of benefits is more difficult to accomplish for customers than the simple buying of products, the linkage between the product and customer satisfaction is complex. Customers want solutions, not products. Indeed, the main ingredient in the complex equation is **trust**. In the NPD situation, the overarching short-term goal is to build trust and to provide sustainable solutions. Generally, customers and society support those products and producers that fulfill their expectations and continue to provide satisfaction over the long term. Gaining the consumer's trust is central to achieving success. The basic design philosophy is to ensure that trust is built into the product during the design process.[3]

Value engineering

Providing features, functions, and benefits that customers find significant and advantageous creates interest in the new product. Customers purchase outcomes that bring them value. Value is defined from both the producer's and customer's perspectives. The new-product developer must generate new value if he or she is to sustain the process. Customers must derive sufficient value for the price and burdens involved. It is value that brings producers and customers together. Each seeks appropriate rewards for his or her participation.

Value is enhanced in many ways. Performance, quality, benefits, and flexibility relative to the cost or price are essential elements of the design decision-making process. Reducing the costs associated with the processes has a powerful effect on improving value, but many other approaches also lead to higher value. To focus only on costs is an inward-looking tactic, which may miss the point altogether. Simple cost cutting may eliminate valuable benefits to customers. Effective cost cutting means eliminating unnecessary or unwanted features and functions that add costs, but nothing else.

Reducing or eliminating burdens also increases value. Burdens are the negative impacts of a product that reduce customer and stakeholder satisfaction or inconvenience the customer or cause them difficulties. For example, the Toyota Prius has a fuel efficiency of approximately 55 m.p.g. (23 km/l); not only does the high fuel efficiency reduce the cost of operating the vehicle, it also cuts the time and effort associated with filling the car with gasoline (a necessary, but otherwise unwanted burden to the owner/user).

Value-driven strategies generally focus on delighting customers. The design objective should be to achieve best delivered value. Value analysis includes many facets of contemporary management thinking, such as:

- Reducing costs by preventing or eliminating quality defects and wastes (six-sigma thinking and also lean business practices).
- Reducing cycle times for product development and delivery (speed to market)
- Improving quality and minimizing the liabilities associated with products (risk reduction or avoidance).

- Using standard designs and parts (cost reduction).
- Incorporating mistake proofing into the design (TQM thinking and liability containment).
- Eliminating unwanted burdens (value enhancement and sustainable development).

The list could continue, but the point is simple. The opportunities for improving the product architecture are numerous and every design decision may have a profound impact on the value and viability of the new product. Value analysis is a method used for improving the design process. It focuses on the activities of the designers and the NPD team to develop a better product. Value engineering is a related method that evaluates the functions and features of the new product as they pertain to customer needs.

Value engineering is an analytical tool using customer input to determine the most beneficial ways of providing the total product package. The objective of value engineering is to identify the essential characteristics and functions and ensure that they are provided in the most cost-effective manner. In simple terms, the goal is to avoid including the "bells and whistles" that serve no function or contribute little to customer benefits.

Value engineering may be used as a precursor step to QFD or it may be used as a more direct means to achieve the same end. This is particularly true when there are extreme time pressures on the NPD process or when the NPD team has a good understanding of the design requirements. Value engineering is most appropriate when the internal and external participants agree on the essential attributes and can eliminate the preliminary steps in the analysis.

Value engineering can be used during the Concept Development and Selection Phase and/or during the Design and Development Phase. Given its simplicity, it fits the requirements of the Concept Development and Selection Phase better than the Design and Development Phase in most cases. The following are the major steps in the generic process:[4]

(1) ***Information gathering***. The team collaborates to determine what the problems or challenges are, why there are problems or challenges, and what can be done about them. It also explores the root causes and collects information pertaining to the situation.
(2) ***Brainstorming or benchmarking***. Potential options for solutions are identified and examined in the light of their possible impacts on the situation and the design. They are compared to the prevailing designs or existing competitive products through benchmarking.
(3) ***Technical analysis***. Each option or potential solution is assessed analyzed to determine its technical feasability and economic viability. The list of potential solutions is narrowed to make subsequent work feasible.
(4) ***Value analysis***. The proposals are expanded to illustrate the implications of the solutions on all of the attributes. The assessment might take the form of a comparative assessment of the essential attributes.
(5) ***Validation***. The selected solution(s) is tested to ensure that it fits the real-world situation. The validation step includes management's review and approval.

(6) ***Documentation***. The decision elements are recorded and communicated to all of the NPD participants to ensure that there is a universal understanding of the solution.
(7) ***Execution***. The solution in the form of the selected attributes is used in the design.

Value engineering is a well-defined methodology for analyzing NPD situations and solutions. It requires time and effort, and is one of many valuable methods for improving the new-product opportunity.

Concurrent engineering

Concurrent engineering practices significantly contribute to improving the time-to-market metric and customer satisfaction for many NPD programs. The concept of concurrent engineering applies to more than just the engineering disciplines; it cuts across all aspects of the NPD process. The Concurrent Engineering Research Center at the University of West Virginia defines the technique as:

> CE (concurrent engineering) is systematic approach to integrated product development that emphasizes response to ***customer expectations*** and embodies team values of cooperation, ***trust***, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all lifecycle perspectives early in the process synchronized only by comparatively brief exchanges to produce consensus.[5]

Concurrent engineering does more than reduce time to market. It provides the organization with a better understanding of customer needs and how to satisfy them, since there is a broader perspective employed for translating needs into benefits. It implies that people from design, process engineering, and testing, work in conjunction with team members from marketing, purchasing, production, finance, and support services to design the product and develop the programs that bring the product to the market. The fundamental concept is to maximize the number of activities performed in parallel.

Concurrent engineering means considering all aspects of the design simultaneously, discovering and curing deficiencies during the Design and Development Phase, or earlier, thus avoiding downstream difficulties. It is an essential part of the "phase and review" mechanism of IPD, because it allows early discovery of critical problems, providing the opportunity to take corrective action, retrace activities or even phases, or to terminate the program without wasting additional time, money, or resources.

IPD emphasizes the importance of collaboration between functional groups within the organization. Concurrent engineering focuses on achieving a superior, well-balanced new product, reflecting the diverse perspectives of the participants. Collaboration, concurrent engineering, and quality are key instruments in rapid product development. Collaboration provides a broader view of the design requirements and downstream implications. Having all of the critical players working on a concurrent basis enriches the discussions, facilitates more-thorough analyses of the efforts, and provides more-effective decision making. Concurrent engineering ensures that downstream activities and outcomes are considered during upstream decision making, and that decisions reflect the requirements of the entire process. The implications of concurrent engineering include having a more-easily produced and a more-marketable product.

Concurrent engineering requires the involvement of the suppliers of the parts and components as early as possible in the NPD process. The extensive use of suppliers as significant contributors in the design process increases the technological sophistication of products and speeds up the development process.[6] A trusted supplier can provide thoughtful insights into new technologies, materials, parts, components, or manufacturing techniques. Suppliers' knowledge about innovations in their fields of expertise can help the organization to avoid producing designs with obsolete technology or approaches. Avoiding such mistakes improves the potential life cycle of the product.

Concurrent-engineering efforts link people together and they link the different phases of the program together as well. Concurrent engineering facilitates upstream and downstream communication, creating a stronger commitment to the NPD process, and bringing about a focus for cross-functional problem solving.[7]

Integrated product/market design

Integrated product/market design involves marrying the technical aspects of the product with the market-related needs and expectations. It includes selecting technologies and the technical functions, and determining the product configuration based on the requirements of the entire enterprise. It examines the elements of the creative activities performed to translate the conceptual aspects into a definitive product/market form.[8] Product design is a holistic process that defines product attributes in terms of customers and stakeholders, links product specifications and engineering selections to marketing and manufacturing, and facilitates the testing and commercialization of the product. The product/market design is refined over time as analyses are performed and more details become available to produce a richer view of the new product and its place in the world. The additions and modifications to the product/market design have to reflect changes in the marketing and production plans, suggesting that the process is integrative and iterative. The development of the design, the marketing, the production, and the financial aspects must be determined on a concurrent basis so that there is consistency and alignment between all of the dimensions.

Good designs embody superior attributes that provide outstanding performance and exceptional customer satisfaction. Quality facilitates superior performance-to-price characteristics and provides flexibility in the marketing, production, and delivery of the product. Quality is an essential element that leads to customer satisfaction and continuous improvement. Fully integrated designs facilitate production and tend to lower the cost of producing the product. The ability to provide high quality lays the foundation for cost-effective designs and enhanced value.

Product architecture

Product architecture involves product characteristics, material selection, packaging options, resource utilization, and market considerations. It requires the determination of features, functions, benefits, and detailed specifications of the product.

The physical product characteristics form the features of the product, which then define the functions of the product. The tangible design elements are the materials, parts, components, and assemblies that become the building blocks of the product. The materials flow into the parts, parts into components, and components into assemblies that become the product.

The architectural structure defines the product and the production requirements. The functions describe how the product is used, converting the features into benefits, designed to respond to customer needs. Product architecture provides the linkages between customer needs and the technical functions of designing the product. The architecture for most products is complex, consisting of hundreds or even thousands of elements. Good designs incorporate all of the required attributes, ensuring that the critical success factors are embedded and become the focus of the product description and the marketing campaign. The challenge is to understand which attributes promote customer satisfaction, and to design them into the solution(s). Such a design philosophy simplifies the downstream activities since the design itself becomes the trigger mechanism for the marketing techniques and the messages for promoting the product. It also establishes the production methods for generating quality, reliability, and manufacturability.

When selecting product attributes, there are many qualitative and quantitative techniques used to identify and analyze the essential few from the many. The techniques also provide the mechanisms to link the external requirements with the internal capabilities. Table 7.1 lists the essential elements that most products have to provide. These techniques provide the means to determine the relationship between the internal and external factors. They also offer ways to understand the interrelationship between the elements.

Product quality related to design and engineering

TQM philosophy

TQM is a widely accepted management system, a subset of the product delivery system or operating system, that incorporates quality-management practices and techniques necessary for meeting customer expectations in terms of quality, reliability, and responsiveness. The basic philosophy of TQM is to build quality into every product and process, and to strive for continuous improvement.

Table 7.1 *Essential elements of features, functions, and benefits*

	Features	Functions	Needs/benefits
External (customer)	Dimensions (size)	Quality/conformance	Applications
	Materials	Compatibility	Ergonomics
	Packaging	Ease of use	Aesthetics (appearance)
	Performance	Reliability	Value creation
	Services	Delivery	Maintainability
	Total cost of ownership	Durability	Serviceability
Internal (company)	Product characteristics	Quality/conformance	Performance versus liability
	Manufacturability	Robustness	Health and safety Protection
	Unit cost	Process selection	Financial resources
	Compliance	Testing	Risk reduction
	Marketability	Communications	Public and customer reach
	Shelf life	Logistics	Life cycle (longevity)

Customers define what quality means. It is their perception of quality that counts. Customers view quality as the integration of the essential product characteristics and benefits to meet or exceed their expectations.

W. Edward Deming, Joseph Juran, Armand Feigenbaum, Kaoru Ishikawa, Philip Crosby, and Genichi Taguchi are some of the principal architects of the quality imperative. These quality-management leaders laid the foundation for TQM and its related practices.

Deming suggested that most quality defects are attributable to the management system. He emphasized that it is management's responsibility to ensure quality and continuous improvement. Deming developed 14 total-quality principles focusing on management commitment and involvement, employee training, and continuous improvement.[9] He was an advocate of process analysis for problem solving and decision making. He promoted the "Plan–Do–Study–Act" (PDSA) cycle, which is one of the best-known TQM tools, providing a simple format for understanding and improving processes.[10] Figure 7.1 depicts the PDSA cycle.

The Deming cycle is a simple model for understanding customer needs, setting priorities, developing quality plans, assuring quality, and improving the quality system and all of the iterations necessary to obtain superior results. This simple model can be applied to the NPD process. Designing a new product is essentially a plan–do–study–act process. It relates perfectly to the iterative aspects of the design process. The "Plan" focuses on defining customer needs and translating them into product characteristics. The "Do" integrates the technical features and functions of the product into a viable design. The "Study" includes analysis and testing that verify the efficacy, reliability, and safety of the design. The "Act" is the incorporation of the design element and the continuation of the process. The intent of the cycle is to provide structure for the design

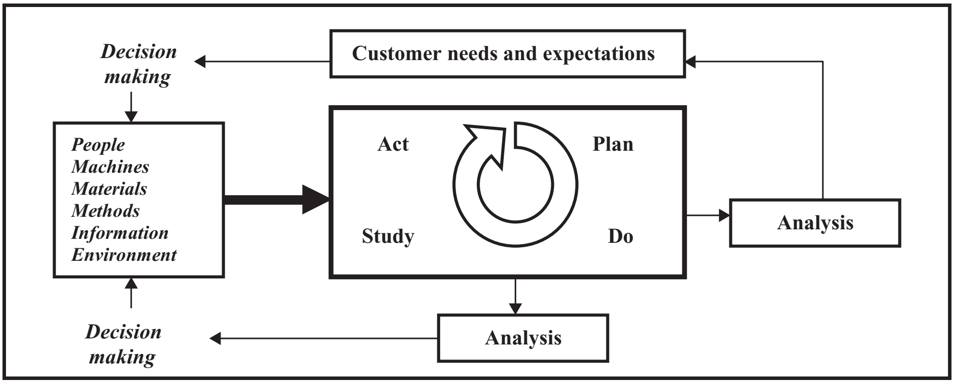

Figure 7.1 The Deming (PDSA) cycle

process, to validate the selection process, and to ensure consistent implementation. In essence, "design for six-sigma" is a Deming cycle.

Juran developed the concept of "fitness for use" as a definition of quality. In this construct, quality depends upon the application of the product or service. Juran suggested a "quality trilogy" that includes quality planning, quality control, and quality improvement.[11] Quality planning is required to ensure that processes are capable of meeting the quality objectives. Quality control evaluates actual performance in terms of the requirements and standards, and focuses on non-conformance and corrective actions. Quality improvement means discovering innovative ways to exceed the standards and to achieve higher-quality results.

Feigenbaum originated the concept of total quality control (TQC).[12] He suggested that TQC is the responsibility of the entire organization, not just the quality professionals. He also argued that higher quality levels could lower costs.

Crosby proposed the goal of "zero defects" for quality. He argues that the goal of the organization should be zero defects and continuous improvement. His focus is on understanding customer needs and requirements, and achieving customer satisfaction.[13]

Taguchi introduced the quality loss function, suggesting that any deviation from the target value of a quality parameter results in a loss to someone. He argues that the smaller the loss, the more beneficial the results. The losses may be borne by the producer, the customer, or society. This argument is very important in the NPD situation, since deviations from the target reduce benefits and add costs and burdens. The overall implications are sub-optimization and reduction in value for customers, producers and stakeholders.

Ishikawa invented the concept of quality-control circles to broaden the reach of the quality programs to the individual worker. He developed the cause-and-effect diagrams, known as "fishbone diagrams," to provide a method for root-cause analysis. Root-cause analysis identifies the reasons why quality defects occur. His work on statistical methods offers the practitioner simple statistical tools to manage quality.[14]

The basic TQM tools include the following:[15]

- ***Cause-and-effect diagram***. A qualitative summary of the potential causes of problems.
- ***Pareto chart***. A tool that organizes data to identify and focus on major problems.
- ***Control chart***. A statistical tool to determine how much variability in a process is inherent and how much is due to unique events.
- ***Flow charts***. A schematic showing the relationship between process steps which helps to illustrate any significant deviations from an ideal process.
- ***Check sheets***. A simple formatting of data into categories.
- ***Histogram***. A tool that displays the distribution of data from a process.
- ***Data collection***. Product and process information used for analysis to answer the basic question pertaining to design issues: Why? What? When? How? Where? How much? How long?

TQM philosophy emphasizes preventing, identifying, and correcting defects. Defects and variations to customer specifications can be viewed as losses and such losses, according to Taguchi, decrease the creation of value. The primary objective of TQM is the elimination of losses and wastes which negatively affect the value equation.

TQM focuses on improving quality during all phases of the NPD process and the product delivery system. Improved competitiveness, continuous process improvements, and innovation result from the organization's drive to increase quality and performance. Crosby assumes that "quality is free" and that poor quality during production, distribution, and marketing carries a high, indirect cost to producers and customers. The benefits of improved quality include reduced rework, improved productivity, lowered unit cost, reduced product liabilities, improved competitive positions, improved profitability, and enhanced corporate reputation.

The business environment has evolved over the last decade to the current situation in which customers and stakeholders expect the maximum value for their money. Moreover, the entire system has to be satisfied. This includes improving employee satisfaction and ensuring that suppliers receive their fair share of the rewards.

J. Persico views the implications of TQM as:

> Customers get high quality at a low price, vendors get predictable long-term sources of business, and investors earn increased profits. Everybody wins. On the other hand, if productivity alone is stressed to achieve competitiveness, quality can be sacrificed, and lower output may actually result. Employee morale will plunge, costs will rise, customers will be unhappy, stockholders will be concerned, and competitive position will decline. Everybody loses.[16]

These views fit nicely into the NPD situation.

TQM methods provide dynamic models that can be used on an enterprise basis (e.g. a systems approach) for assessing the overall health and well-being of the business and the NPD process. TQM approaches are not easy changes that can be unveiled and implemented quickly. Typically, it takes several years before every employee embraces the TQM philosophies, practices, tools, and methods.[17] Several tenets are fundamental if a TQM model is to succeed in a corporation. These are:[18]

(1) "*People want to do a good job*. Believing that people want to do a good job means that often their performance is affected more by the system in which they work rather than by their particular skills, abilities, or motivation."

(2) *"Process (how things are done) is more critical, though not more important, than the results."*

(3) "*Senior management must lead the transformation*. While it is possible for 'grass-roots' efforts to achieve limited successes, organization-wide successes cannot be achieved unless top management leads the TQM transformation in a visible and supportive manner, and commits the necessary time, energy, and resources to the effort."

A commitment by senior management to quality management is essential for building quality into new products. Empowering participants with information and knowledge about quality builds a cohesive organizational structure. Management's willingness to allow participants to share in decision making facilitates a quality perspective in integrating the design and development processes.

Achieving quality through quality measures

The basic objective of the design process is to produce the highest quality product with a high level of reliability at a cost that provides exceptional value for customers. To achieve total customer satisfaction, a product must be delivered on time, without defects or early failures during its service, and with minimal burdens. A high-quality product must have a superior design margin (tolerance) between the requirements of the applications and the capabilities of the product to meet those requirements. Quality is built in during the design process as well as during production and delivery.

Six-sigma quality and "zero-defects" concepts of the 1980s and 1990s have been developed into the philosophy of building quality into the product from the concept phase through to commercialization. Motorola and General Electric's "Design for Six Sigma" are examples of a corporate methodology that is an excellent perspective of an enterprise model for new-product development.[20] The goals are to design and produce products that exactly meet requirements and customer expectations over their entire life cycle. The closer the product is to meeting the exact requirements, the higher the probability that the product will enjoy success in the market.

Good designs have adequate tolerance between the upper value for the parameter and the lower value. The difference between the upper parameter and the lower parameter is the tolerance based on the specifications. It is important that tolerances are not very tight. However, there are constraints on how large the tolerance can be. The preferred situation is to have the tolerance reasonably large without exceeding the expected physical and aesthetic requirements from a customer's perspective. From a design perspective, acceptable tolerances fall within a defined range depending on the type of product. Generally, the markets set the acceptable ranges. Tolerances become tighter over time as customers demand better-looking and better-performing products, and world-class companies are able to improve their processes to achieve high-quality output with greater precision.

Taguchi's quality-loss function suggests that the smaller the variation between the design requirement and the outcome from production, the lower the losses. The target is the value of the design parameter according to the product specifications. It is the required dimension that should be the mean of a large population of outcomes. It is the expected value. Table 7.2 provides a description of the basic statistics and also provides an example. The best case is to have a small tolerance in the design requirements and a process with a capability to exceed the requirements from a manufacturing perspective. The capability of a production process is defined by its standard deviation of the distribution of outcomes.

The tolerance has to reflect customer requirements and the process capability has to provide results that are acceptable and achievable. The capability index denotes this relationship and is the measure of the capability of a process to meet customer requirements. Capability index, C_p, provides a measure of the ability to produce the design. Customers want appropriate design tolerances and producers want to deliver exceptional outcomes by having outstanding process capability. It is clear from the formula that capability index is simply a ratio expressing the requirements based on what is feasible. If the capability index exceeds 1, it indicates a feasible solution.

The relationship between product design and process selection has a direct impact on C_p.

$$C_p = \frac{\text{Design tolerance}}{\text{Process capability}} = \frac{\text{USL} - \text{LSL}}{\pm 3\sigma}$$

where USL and LSL are the upper and lower specification limit, respectively.

The design can be improved by increasing the allowable variation of the design tolerance or by improving the capability of the process. If the tolerance is large in relation to process capability, then the products, components, or parts are acceptable.

A C_p index of 1 or greater indicates that the process is capable of meeting expectations. If the number is 1, then the process is just capable; a value of 2 indicates that the process is twice as capable of meeting expectations.[21] The link between design tolerance and process capability is powerful evidence that the design of a new product and the manufacturing processes used to produce the product must be linked. It confirms the notion that integrated product development is a necessity, not an option.

Table 7.2 *Example of capability index*

Basic statistics – capability index	Example
Target is the design value of a parameter	10 cm
μ Mu is a measure of central tendency and is the average of the values in the population. $\bar{x}$ is the mean of a sample.	10 cm
σ Sigma is a measure of variability. It is the standard deviation of the population. As the magnitude of σ gets smaller, the values in the population are closer to the mean.	0.01 cm
USL is the upper specification limit of the design parameter. For an acceptable product, the value of the parameter (say, length) must not exceed the USL.	10.05 cm
LSL is the lower specification limit of the design parameter. For an acceptable product, the value of the parameter (length) must not be less than the LSL.	9.95 cm
Design tolerance is the difference between the USL and the LSL. It is the maximum allowable variation of the design parameter	0.10 cm
C_p is the capability index of a process with two-sided specification limits. **The greater the C_p, the smaller the probability of creating defects**.	$C_p = \frac{10.05 - 9.95}{3 \times 0.01} = \frac{0.1}{0.03} = 3.33$

Integrated product design

Overview

Design philosophies are critical for the overall success of the new product. For example, in a highly competitive situation, low unit cost may be essential for achieving a suitable market share. Cost structure and product performance may be the most crucial design requirements. Potato chips, for example, are generally viewed to be commodities that are subject to intense competition. It is essential that a new-product offering is able to fit into the cost expectations of customers and exceed their requirements.

An integrated design process starts with acknowledging the needs of customers and the positions of competitors, and examining the external design drivers. The design process includes all of the activities required to develop the construct of the product. These include: applied research and development (R&D); technical design and engineering; market research; marketing; production; distribution; sales and after-market sales and services; finance; and legal, and environmental, health and safety aspects. Figure 7.2 shows the possible linkages between the internal and external dimensions.

The value of integrating the activities may exceed saving time and money. With concurrent development of plans and programs, the organization is able to resolve conflicts and difficulties during the early stages of the design. This minimizes protracted problem solving near product launch or worse still, after commercialization. This lesson

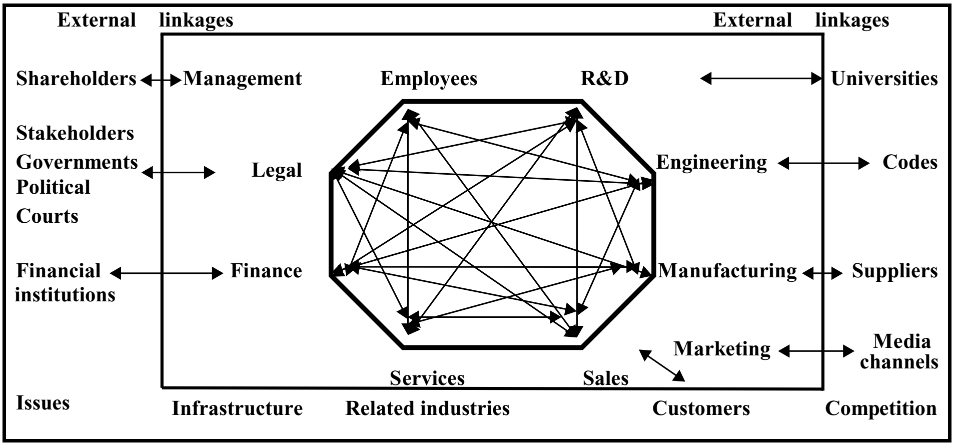

Figure 7.2 Integrated design relationships

Figure 7.3 Integrated product design methodologies

was learned by Boeing Aircraft before it began the Boeing 777 program. It reviewed the design processes used for the Boeing 767 and discovered that the sequential approach for the product-development program created many downstream difficulties and problems. Indeed, many of the original design decisions had to be modified to correct problems discovered during production. Certain engineering and technical selections were not feasible from a manufacturing perspective. What was initially viewed as a good design proved to be defective because the other internal requirements had not been considered.

Integrated design ensures that all required functional characteristics of the product are developed simultaneously during product design. Figure 7.3 provides a summary of the essential elements of integrated product design. Product design addresses all of the functional requirements. R&D and/or engineering select design parameters that satisfy the customer's needs. They must design a product that is robust and can be manufactured at high quality levels and low cost. Product engineering creates the detailed technical specifications of the product. These include the drawings, bill of material, protocols, and related details. Process engineering specifies how to produce the product – including the methods, equipment, processes, practices, and procedures.

Design for manufacture (or manufacturability) facilitates the requirements of the production processes by improving the means and mechanisms for producing a cost-effective product. Marketing and supply-network decisions are made during the design activities to highlight the most profound benefits of the product and to determine the most effective channels for delivering the product to customers. Marketing considerations are discussed in Chapter 8; production and supply networks in Chapter 9, and finance in Chapter 10.

Product engineering

Product engineering involves the creative activities of defining the product in the light of all of the internal dimensions and external forces of the business environment. It translates the product architecture into design characteristics that give specificity to the product. The details are in the form of specifications, flow diagrams, bills of materials, protocols, and spreadsheets that are used during the manufacturing and marketing of the product.

The identification of customer needs is the starting point for the product design. It builds on the knowledge gleaned during the Concept Development and Selection Phase. It may appear that examining customer needs again during the design phase is redundant and involves extra time and money. However, in most cases, the effort expands on the previous efforts and attempts to ensure that all avenues of analysis have been thoroughly explored. This approach is especially important for NPD processes that minimize these efforts during the up-front phases. Often, additional methods are employed to ensure that customer needs are fully understood and translated into design criteria. During the Concept Development and Selection Phase, the principal concerns are value creation, feasibility, and financial viability. During the conceptual level less-sophisticated methods, such as simple surveys, may be used to ascertain customer needs. During the Design and Development Phase, the NPD team may apply more-definitive techniques, such as quality function deployment, to evaluate the potential of the product in terms of market requirements and competitive implications. Product engineering turns the concepts into operational forms that can be built, tested, and marketed.

A design has to meet many requirements. Product positioning of the new product helps to define what is required and how to establish criteria for design decision making. The objective is to create a product that represents the best solution based on all of the competing parameters. Some parameters are in direct opposition to each other. As the designer improves one of these parameters, the other parameter becomes sub-optimized. For example, in the automobile industry, adding weight to accommodate the larger vehicle size of a sport utility vehicle, and a more-powerful engine, reduces fuel efficiency, which itself is an important consideration from economic and environmental perspectives. The balance point may be difficult to determine.

Conjoint analysis is a data analysis technique that uses respondents to rank the importance of various product attributes, according to their preferences for the combinations of the attributes. The analysis provides designers with customer input that allows them to determine the right combination of attributes However, in this book the focus is on creating value without compromising the expectations of external entities. Indeed, the basic philosophy is to maximize the benefits and minimize the negatives. The goal is to create the best solution; it is not to find the best compromise for the situation!

Design for quality using QFD[21]

QFD is a sophisticated technique used to identify, prioritize, and translate customer needs into design characteristics and manufacturing requirements, and build them into the product.[23] According to Dr. Yoji Akao, QFD means translating customer expectations into quality characteristics and developing a quality plan for the finished product by systematically deploying the relationships between customer demand and product characteristics.[24]

QFD starts with understanding customer needs. Customer input is critical to the process of determining product characteristics, and requires time-consuming effort. As discussed in Chapter 4, there are various methods for obtaining information pertaining to customer needs, including surveys, questionnaires, and focus groups.

The needs and expectations of customers are called the "voice of the customer" (VOC). QFD is one of the more-sophisticated techniques for ensuring that the VOC is considered during the design of a product. QFD is often simply referred to as the "house of quality" (HOQ), although technically speaking, traditional QFD makes use of a series of four "houses" and it is only the first house that is called the "house of quality." The rectangular-shaped planning matrix used in QFD has an upper portion resembling a house roof, thus the name "house of quality."

The objectives of QFD are to improve quality and customer satisfaction, reduce time to market and design problems, lower costs during design and manufacture, and to enhance performance and reliability. While QFD offers significant advantages, there are several limitations. QFD focuses on quality and design characteristics, and specifies the actual levels that should be achieved. However, other important considerations such as environmental concerns may be left out. Quality is a baseline, not the ultimate objective. The biggest challenge in deploying QFD is understanding the scope and validity of the voice of the customer. There are many customer requirements, particularly the intangible aspects that cannot be precisely specified. This limits the value of the input side of the equation.

Timing is another concern for QFD. It can be deployed during the conceptual level, providing the detail necessary to make good decisions about the viability of the new product opportunity. However, QFD takes time and effort that may not be available if there are numerous new-product concepts to develop and screen. It depends on the situation whether QFD is used during the Concept Development and Selection Phase or the Design and Development Phase, in some combination, or not used at all. The use and timing is a judgement that the NPD team has to make.

QFD was developed at Mitsubishi's shipyard in Kobe, Japan in 1972. Toyota subsequently refined and used the QFD philosophy. The concept slowly spread to the United States, but John Hauser and Don Clausing, in a 1988 *Harvard Business Review* article, made many more US businesses interested in QFD.[25] Ford's initial analysis for the Taurus used QFD to examine 429 design parameters. QFD has also been used successfully by General Motors (1992 Cadillac), Mazda, Motorola, Xerox, Kodak, IBM, Proctor & Gamble, Hewlett-Packard, and AT&T.[26] In Japan, QFD is considered a key element of "company-wide quality control" (CWQC) and is valued as a means to *deploy* customer needs throughout an organization, thereby producing products at a lower cost and higher quality.

QFD provides a structured method for translating customer requirements into the engineering specifications. It attempts to push quality issues as far upstream as possible, thereby bringing together participants in marketing, design, manufacturing, engineering, production, quality, and other critical functional areas early in the product design process. In fact, it is because of this feature that QFD is a commonly used concurrent-engineering tool.

The first planning house, or the house of quality, is a matrix that translates customer needs into engineering characteristics. Subsequent houses build on this information ending with the production-planning house, where actual production tasks are specified.

The six basic steps needed to construct a house of quality are outlined below. For a more detailed explanation, see Hauser and Clausing (1988), or Evans and Lindsay (1999).

(1) ***Develop "bundles" of customer attributes (CAs), or customer requirements***. CAs represent what the customers really want in the product or service. It is important to include customers' unique phrases and clichés. This information comes primarily from market research, but also utilizes the expertise and experience of company sales people, field technicians, etc, Also, for each CA, a relative importance weight is added to the house. Weights are often stated in terms of percentages so that a complete list of CAs totals 100%, but they can also be stated in terms of an arbitrary scale, e.g. from 1 to 10, with 10 being most important.

(2) ***Develop engineering characteristics (ECs)***. The QFD team uses brainstorming to determine ECs that address each of the customer attributes. The roof of the house, or correlation matrix, is also developed in this step. The roof represents the relationship between each pair of engineering characteristics. Symbols are used to show the strength of each relationship (e.g. ● for strong positive relationship, ○ for weak positive relationship, etc.).

(3) ***Develop the relationship matrix or body of the house***. Examine each pair combination of CA versus EC and determine how much each EC affects each CA. Again, use symbols to show the strength of these relationships. Absence of symbols indicates that CAs are not being addressed.

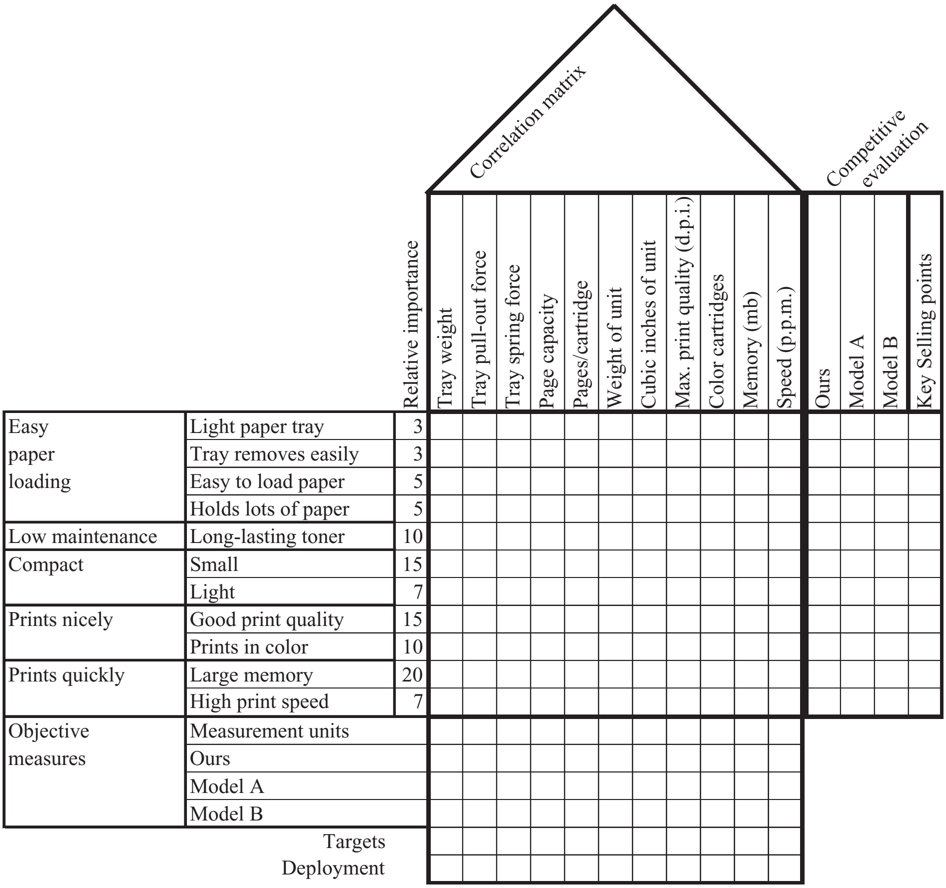

Figure 7.4 A partial house of quality for a computer printer[26]

(4) ***Add competitive evaluation (customer perception) and key selling points for each CA***. Enter this information, based on the customer's perception of competitive products, in a column on the right side of the body of the house.

(5) ***Add objective measures for the ECs and develop targets***. This represents an evaluation of the competition usually accomplished with unbiased laboratory testing. Compare these results with the results of the customer perceptions developed in step 4. If the two measurements are different, a perceived quality problem could exist.

(6) ***Select the ECs to be "deployed" to the next house***. To determine which ECs to carry to the next house, examine the body of the house for ECs with strong relationships to customer attributes. Also look for ECs with poor objective measures (from step 5), or those that are related to CAs with strong selling points.

Rows can also be added at the bottom of the house representing the technical difficulty posed by achieving the targets set in step 5, and the estimated costs to achieve each target. Figure 7.4 represents a partially completed house of quality for a computer printer. There are five CA "bundles" listed on the left side of the house: easy paper loading, low maintenance, compact, prints nicely, and prints quickly.

Carey Curtis and Lynn Ellis reported that companies using QFD had better customer satisfaction, but there was little evidence that it improved financial performance or time to market.[28] QFD is powerful and provides valuable insights into the relationship between customer needs and product characteristics. The standard methodology, described herein and in other books on the topic, can be modified to fit the needs of the specific design situation. It is not an all-or-nothing approach.

The supplement to this chapter includes an article on QFD that provides a detailed explanation of the technique and its application.

Design for reliability

Design for reliability (DFR) focuses on improving product longevity and minimizing failures by increasing component reliability and using redundant parts and components at critical points in the design. Reliability is defined as the probability that the product will perform its specified functions under the anticipated conditions of the design for a specified length of time. It is a simple measure of how long a product performs in accordance with its specifications. There are two main categories of product failures: (1) early failures due to defects; and (2) failures during the product's useful life. Mean time between failures (MTBF) is the average time between failures of a product; it is a measure of reliability. Table 7.3 provides a definition of the terms and an example of the calculations.

Reliability is an important aspect for designing and producing sustainable products. Many products fail prematurely because of a single defect that causes the entire product to become worthless. Finding and the causes of defects and problems, and then rectifying them, enhances the useful life of the product. Improving reliability enhances value and avoids waste.

Design for manufacture and assembly

Design for manufacture and assembly (DFMA) is an important part of IPD. It is a method for creating a robust product design that achieves a high level of performance in its intended application by reducing variations in design, production, and materials. With concurrent involvement of design, production, and supply-chain participants, the product design process can ensure that the selected design architecture can be expected to be produced efficiently and effectively at the highest level of quality, with

Table 7.3 *Measures of reliability*

Measures	Example calculations (light bulbs)
MTBF = Total time of use ÷ Total number of failures A simple mean = $\sum x/n$	Sample of five light bulbs fail at 700, 760, 800, 810, and 930 hours; five failures MTBF = (700 + 760 + 800 + 810 + 930)/5 = approx. 800 hours
Failure rate: lambda, λ, is the inverse of MTBF	Lambda, $\lambda = 1/800 = 0.001{,}25$ failures per hour
Reliability = $1 - e^{-\lambda t}$ where t is the specified point in time; e is the base of the natural logarithms	Reliability at 800 hours = $1 - e^{-1} = 1 - 0.37 = 0.63$

an appropriate cost structure, and on a timely basis. DFMA ties the design and production together. It determines design options and methods that facilitate fabrication and assembly, and simplify production processes. It is a subset of integrated design that focuses on the production aspects.

The fundamental DFMA methods include:

- ***Standardization*** – using industry or company standard parts, components, or modules improves process capability and reduces the variability. Standard items improve cost structures because higher quantities of a few items have a significantly lower unit cost. Standard items have usually achieved the minimum point on the cost-to-volume curve. They also improve reliability because the standard items have a longer history of successful applications.
- ***Simplification*** – reducing the complexity of the design and the related process requirements by using fewer items, less-complicated design processes, and foolproof methods. Simplification moves the design closer to the ideal point in terms of cost and complexity.
- ***Systems integration*** – linking quality, testing, and other process steps to ensure that there is collaboration between all of the participants.

DFMA is based on simple philosophies and principles expressed in Table 7.4.[29]

These and other principles are related to design for quality and customer satisfaction. Chapter 9 includes some additional comments on DFM from a production perspective.

Design for the environment

Design for the environment (DFE) is a systematic approach for evaluating the consequences of products and processes, and their impact on human health and the natural environment. DFE is a compelling environmental-management construct based on cradle-to-grave assessments of products and production processes. It examines all of the inputs and outputs in qualitative and quantitative terms, and links products and

Table 7.4 *DFM philosophies*

Principle	Comments
Manufacturability is an integral part of the design	Integration provides all of the inputs necessary to make good design decisions for all of the participants.
Design decisions should relate to simple and economical production	Simplicity contributes to quality and timeliness. It also provides for low-cost production.
High quality is dependent on the quality of materials and parts	Using high-quality parts reduces defects per unit, improving the quality and reliability.
Product characteristics should be easy to produce and assemble	The design selection process should focus on manufacturability. This includes ease of fabricating and assembling components.
Minimization of the number of parts, components, and subassemblies	Reliability and manufacturability are related to the number of components. The greater the number of components, the higher the probability of failure.
Modular designs facilitate production and testing	Modular designs enhance standardization; reducing the costs, testing, and use of the components. If a module fails it can be replaced easily.
Parts and components for multiple use	Multiple use increases the volume of the part or component, reducing costs and improving quality and reliability.
Design to reduce handling	Handling costs money and increases the probability of a mistake or defect. It adds to complexity.
Employ standard parts and components	The use of standard parts improves costs, quality, reliability, and availability.

processes to all of their precursors and outcomes. The ultimate objective is to design or redesign products and processes, making decisions based on the needs of the entire system. The goals of DFE are to: maintain quality; minimize health and safety risks; eliminate negative impacts, and their consequences, on the natural world; reduce waste streams, residuals, and disposal issues; minimize raw material consumption; and reduce energy consumption.

The DFE process has a very broad scope requiring an assessment of the life-cycle implications of products and processes, beginning with the selection of materials during product design to the final disposal of the materials and the abatement of the emissions, effluents, and waste streams. The concept requires comprehensive and time-consuming analyses to reduce the effects and impacts of the product and the related processes on the environment. It is an important environmental-management tool for holistically analyzing the environmental consequences of products and production processes and operations.

The primary focus is on identifying the materials incorporated in a product and the quantities used, determining their environmental implications and their impacts over the life cycles, and then developing environmentally compatible products and processes.

DFE attempts to avoid or minimize the use of hazardous or toxic materials and to reduce the amount of wastes and by-products.

Design and development strategies for reducing environmental impacts are based on analyses of the product requirements and the selection of the most economic, technical, and environmentally conscious approaches. Appropriate strategies satisfy the economic and functional objectives as well as the environmental, health and safety goals. DFE offers designers and product managers a methodology to understand the positive and negative impacts of their products and processes in economic, environmental, regulatory, and social terms.

The principal technique for implementing DFE strategies is life-cycle assessment. Life-cycle assessment is a systematic method used to analyze and evaluate the resources and outcomes, and the environmental burdens associated with a product: its related processes, distribution requirements, and applications. The analysis is used to identify, quantify, and evaluate the materials and energy used to produce and use the product over its entire life cycle. The approach is a multi-stage input–output model that examines all of the inputs, outputs, and impacts – including materials, products, wastes, and emissions. The model examines an existing situation and explores the possibilities for systematic improvements through product design aspects.

BMW and design for the environment (design for disassembly)

In June 1990, BMW opened its pilot disassembly facility at its Landshut factory in Germany, becoming the first automobile manufacturer to research methods for the disassembly and reuse of materials from old cars. The pilot program specifically targeted parts made of plastic, glass, elastomers, and other non-metallic materials. The main objectives of this comprehensive project were:

- To develop and improve model-specific methods of disassembly.
- To optimize the time and cost of disassembly.
- To develop internal and external logistics for collecting, storing, and transporting parts, assemblies, plastics, glass, etc. for reconditioning or recycling of materials.
- To develop further-reaching waste-management and recycling technologies, in particular for automotive applications.
- To compile and complete BMW's own recycling directives which had then to be implemented within the network of BMW factories;
- To substantially increase each vehicle's recycling potential.
- To compile and apply recycling and ecological standards for suppliers.

BMW has stripped 3-, 5- and 7-Series cars to gain knowledge on how to process its current models. Assemblies and subassemblies were studied to determine the best means for disassembling and recovering components. Specific items such as engines and body panels were sorted for reuse or recycling. Using various recycling technologies, parts and materials were examined for potential reuse.

Special consideration was given to the effect of shredding on the suitability of materials for reuse. Since the properties of certain plastics change during granulation, material data and specifications were studied in a special laboratory to determine how the material could be used to make new products. BMW assessed the profit potential of repairing components, selling exchange parts, and recycling materials. Moreover, the work at Landshut was linked to the efforts of the designers who are developing "design-for-disassembly" concepts.

Designers used knowledge gained from the disassembly of old cars to improve the designs of new models to make them more suitable for recycling. As a direct result of the work at Landshut, recycling requirements have been incorporated into the development phases at BMW. These phases are Definition, Concept Development, Series Development, and Final Development. In the Definition Phase, the environmental capability of the overall vehicle level is defined. In addition, the desired recycling rate is determined. In the Concept Development Phase, environmental capability is reviewed at the component level. During this phase BMW conducts a dissassembly analysis and determines dissassembly rates. Recycling requirements are also defined, and a life-cycle analysis and energy balance is compiled. In the Series Development Phase, the environmental capability of the vehicle is reviewed holistically. The actual recycling rate achieved is compared with the target level. If the actual recycling rate is below the target rate, this rate will be addressed during the Final Development Phase. BMW has incorporated recycling requirements in the definition stage and two-fold development phases, which ensures that products are optimized for subsequent recycling.

Source
BMW, *BMW Environmental Report 1998/1999* (Munich, Germany: BMW, 1999)

Design and creativity

The design process is essential for the success of the NPD process, requiring knowledge and creativity to achieve the desired results. Knowledge should be part of a well-defined and documented system that is available to the participants of the process. However, in some cases, knowledge has not been captured by the system and remains in the hands of only a few practitioners. While the company may own the knowledge, creativity takes the form of empowerment rather than ownership.

Creativity is the aspect of new product development that is difficult to define and manage. Theresa Amabile stated the following in a *Harvard Business Review* article:[30]

> In business, originality isn't enough. To be creative, an idea must be appropriate – useful and affordable. It must somehow influence the way business gets done – by improving a product for instance, or by opening up a new way to approach a process . . . what managerial practices affect creativity? They fall into six general categories: challenge, freedom, resources, work-group form, supervisory encouragement, and organizational support.

Amabile suggests that while knowledge is important, freedom to explore and solve problems or create new ways of achieving results by wandering in intellectual space is an important part of innovation.

A generalized construct for selecting an appropriate design strategy

Determining the design strategy based on the business environment

One of the most difficult questions facing management when it is considering innovation involves selecting the right design strategies (programs) for managing the implications of change. The options are multifaceted and depend on the business conditions and trends. Generally, product innovation is the choice if the business environment is stable. Small changes in business conditions and trends mandate incremental changes in products and processes. The general concept is to respond in kind.

The general theory suggest that if the existing products are successful and generally fit the business environment, then significant changes to product positions and attributes or dramatic changes to process capabilities are unnecessary. For instance, Toyota has enjoyed great success over the last decade because of its outstanding portfolio of successful products. The question is why would it seek revolutionary change when the prevailing situation is so favorable.

Technological innovation is the focus of attention if the business environment becomes less stable[31] – referred to as fluid[32] – and even more so if it becomes turbulent. In such situations, product innovation may be less effective, and in some cases, it may be risky. Indeed if the underlying technologies used in the current products become obsolete, then creating more products using the obsolete technologies may simply be a waste of time and money. Such strategic moves may make the organization vulnerable in the future, if resources are overly committed to the old technology(s) and products and the organization is not positioned in the new ones.

The construct of assessing the business environment using the terms “stable,” “fluid,” or “turbulent” is based on a relative view of the conditions and trends rather than any absolute sense. The determination of what each category means is dependent on the industry structure and its maturity. While it may be impossible to codify in absolute terms, participants within an industry usually have a sense of what the conditions are and how their company fits into the overall structure. The following is a general description of the categories. (Note: these are broad generalizations that have to be fine-tuned for specific situations; not all of the factors have to be present.)

- ***Stable***. Markets are cyclical, or growing or declining at relatively low rates (±10%); demand is predictable; dominant technologies form the basis for most products and there are relatively few alternatives; economic and political underpinnings are well understood and are stable; industry structure and participants are known and there are predictable patterns of behaviors. (Example: the automobile industry.)
- ***Fluid***. Markets are growing or declining at significant rates (±20 to 100%); demand is less predictable; new market segments are being created; dominant technologies are being challenged by new technologies competing for share; there are often several technologies forming the basis for products with many alternatives; economic and

Table 7.5 *The relationship between the driving forces in the business environment and the commensurate strategic action in terms of leading change*

Business environment	Product delivery system	Strategic-business-unit level	Enterprise-management level	Driving change/ innovation
Turbulent	Disruptive technologies	Radical innovation	***Business (model) innovation***	**Radical**
Fluid	New-generation products	***Technological innovation***	Breakthrough technologies	**Quantum**
Stable	***Product/process innovation***	Technology integration	Technology linkages (enterprise)	**Incremental**

political underpinnings are changing and are in a state of flux; industry structure and participants are changing and there are less-predictable patterns of behaviors. (Example: telecommunication.)

- ***Turbulent***. Markets are growing or declining at significant rates (±100%); demand is unpredictable; new markets are being created, old ones being replaced; dominant technologies are being replaced by new technologies that offer significant advantages; old technologies are fighting to maintain their positions; many options; economic and political underpinnings are changing dramatically and are in a state of complete flux; industry structure is dissolving and new structures are being created; patterns of behaviors are developing, but are unpredictable. (Example: Internet.)

Table 7.5 suggests appropriate strategic actions based on the change mechanisms in the business environment. A stable business environment is conducive for product/process innovation and incremental change. A fluid business environment suggests technological innovation and quantum change should be examined. A turbulent business environment suggests that the business model has to be evaluated and radical change may be necessary.

The relationships mapped out in Table 7.5 provide a sense of direction, given the business environment. The matrix indicates a suggested approach. However, it is not a prescriptive approach. The design strategy should be determined based on the full analysis of the business environment and the capabilities of the organization. The selection of appropriate strategies relies heavily on analysis. While the basic construct suggests a potential solution, the actual solution depends on the long-term implications of the driving forces. The following provides a description of the three categories of change:

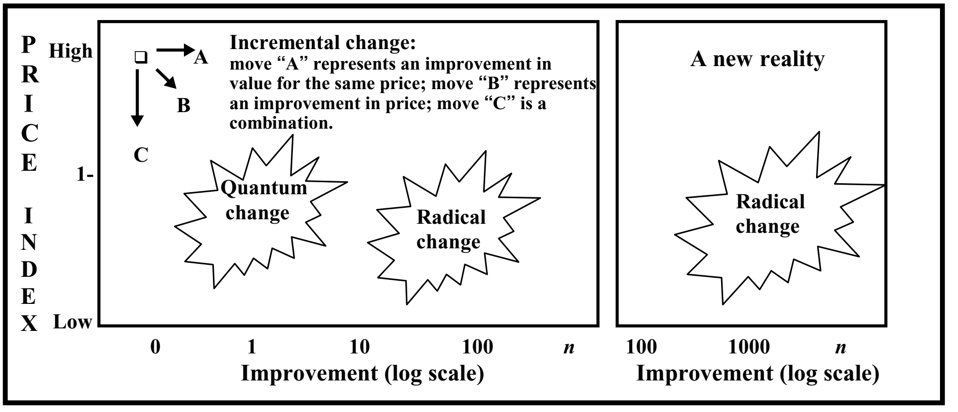

Figure 7.5 A graphical view of incremental, quantum, and radical change

- ***Incremental change***. Incremental change focuses on proportional improvements in products and technologies, typically measured in terms of 5 to 20% improvement. (Example: improving the fuel efficiency of an automobile by 15%, as in the case of Toyota's lean-burn technology.)
- ***Quantum change***. Quantum change represents stepwise improvements that have significant consequences on the value equation, typically measured in terms of several factors (a factor of 2 or greater) of improvement. (Example: wireless telecommunications eliminate the need for telephone wires and poles and enhance mobility.)
- ***Radical change***. Radical change focuses on creating a new reality. It is difficult to articulate the implications precisely, but often the results lead to 10- to 100-fold improvements, or even more. It also includes eliminating significant barriers or burdens associated with the prevailing technologies. (Example: automobiles using fuel cells are expected to produce zero emissions and a hydrogen-based fuel-cell car could eliminate gasoline, a particularly dangerous product.)

While these categories appear to have definitive characteristics, the construct is not precise, nor is it intended to be so. The construct is based on relative aspects between the three categories. Figure 7.5 provides a graphical view of the strategies and the distinctions between the three.

A new product using existing technologies is, in most cases, incremental change. A quantum change involves a new-generation technology, or a breakthrough of new-to-the-world technology. Radical change evokes the notion of disruptive technology(s). Radical change can create incredible opportunities as well as producing enormous challenges. However, the opportunities or threats do not always materialize.

The above construct also suggests that as the solution set moves toward the radical-change approach, the level of uncertainty increases dramatically. While most product-innovation types are based on known market conditions and known technologies, radical

Table 7.6 *Given a stable business environment, the external and internal perspectives of the management system*

	Product delivery system	Strategic-business-unit level	Enterprise-management level	Essential factors
	Product/process innovation	Technology integration	Technology linkages	Incremental change
External perspective	• Customer needs • Satisfaction • Competition • Dominant product	• Market demand • Value creation • Core technologies • Strategic alliances	• Globalization • Business environment • Change/time	**Market conditions and trends**
Internal perspective	• Product focus • Core capabilities • Quality and cost • Supply networks • Leadership	• Core competencies • Financial position • Business integration • Management system • Mission	• Reputation • Knowledge • Sourcing • Life cycles • Vision	**Capabilities** **Resources** **Product portfolio**

change requires the concurrent development of the market factors and the technological parameters. The choice may be based on what the organization understands and selects as its preferred method for managing innovation. Each of the major categories is examined below.

Stable business environment

A stable business environment typically evokes the notion of continuous improvement using incremental innovation. The focus is on known market conditions and trends, and customer requirements. Product and process innovations deal with customer needs, expected competitive responses, and core capabilities. The prime objective is to create dominant product positions and to sustain those positions using the value network.

From a strategic-business-unit perspective, the management construct centers on technology integration. The goal is to create value for customers and stakeholders that is superior to that of the competition. Integration means linking strategic partners and internal resources into a holistic system that outperforms all other choices. The enterprise perspective focuses on managing technology linkages across all business units and strategic alliances; across the entire enterprise. The goal is to build relationships that create knowledge and capabilities for the future. It bases decisions on a global perspective of the business environment. The essential outcome is the enhancement of reputation and image.

Table 7.6 depicts the salient aspects of managing a stable business environment using incremental change.

Fluid business environment

A fluid business environment typically suggests a high level of uncertainty. Great care has to be taken to ensure that investments into products and technologies are at the right level. Incremental changes to prevailing products may be insufficient to achieve competitive advantage. In a fluid environment, significant improvements or changes are often necessary to sustain an acceptable position in the light of market expectations and changing conditions. Opportunities and threats have to be identified and assessed. New discoveries are often the essential ingredients for success. Prevailing products, practices, and perspectives have to be examined and often replaced. New markets or changing market conditions become the focus for creating new capabilities. Inventing new technologies is the prime strategic action for managing in a fluid situation. Technological innovation, rather than product innovation, becomes the strategic methodology. Technology development becomes the necessary management construct for discovering breakthrough technologies leading to new-to-the-world products and applications. Given a high degree of uncertainty, there are often vulnerabilities to both existing positions and new ones. With significant changes in the business environment, products may become obsolete rendering resources, assets, and capabilities worthless. Finding the right opportunities for investments is essential for future success. The key management perspective for selecting the right strategies is the ability to analyze current and future business conditions and trends.

The enterprise perspective focuses on managing technological innovation across all business units and the entire enterprise. To some extent, the fluid category is the most difficult because the solution(s) is not obvious. While a quantum change may be a good solution in general, it is not always the right answer. There may not always be compelling evidence to warrant a change from the current situation. Table 7.7 depicts the salient aspects of managing a fluid business environment using quantum change.

Turbulent business environment

A turbulent business environment indicates that a radical response is needed to position for the future. Radical change may be the right response for turbulent conditions as well as for achieving a significant strategic advantage based on creating new-to-the-world technologies. Such technologies are referred to as disruptive if they have the potential to significantly change the essence of competition, markets, and industry structure. Disruptive technologies, as characterized by Clayton Christensen, have the potential to change everything, destroying the prevailing situation and creating a new one.[33] In a turbulent environment, radical innovations are necessary to stay ahead of the demands of the future. Radical change converts opportunities into powerful positions for the future. Moreover, the change mechanisms relate to the business construct itself. New business models may be created in the process. Indeed, radical change means changing the products, the technologies, and the business model.

Table 7.8 depicts the salient aspects of managing turbulent business environments using radical change.

Table 7.7 *Given a fluid business environment, the external and internal perspectives of the management system*

	Product delivery system	Strategic-business-unit level	Enterprise-management level	Essential factors
	New-generation products	Technological innovation	Breakthrough technologies	Quantum change
External perspective	• Market analysis • Market acceptance • New markets • New Competitors	• New Opportunities • Potential threats • Rapid changes in business environment • Fragmented markets	• Uncertainty • Vulnerabilities • Risks • Rapid changes • Social/political	**Opportunity** **Threat** **Discoveries**
Internal perspective	• Technologies • R&D capabilities • Technical skills • Marketing • Entrepreneurship	• Technology Development • Sourcing technology • Investment portfolio • Strategic focus	• Partnership • Ventures • Funding • Rewards • Global view	**Creativity** **Capacity** **Research** **Learning**

Table 7.8 *Given a turbulent business environment, the external and internal perspectives of the management system*

	Product delivery system	Strategic-business-unit level	Enterprise-management level	Essential factors
	Disruptive technologies	Radical innovation	Business (model) innovation	Radical change
External perspective	• New-to-the-world markets • New industry structure • Lack of data	• Many opportunities • Many threats • Rapid changes in business environment • Infrastructure issues	• Uncertainty • Vulnerabilities • Risks • Rapid changes • Social/political • Sustainability	**Opportunity** **Challenges** **Discoveries**
Internal perspective	• New technologies • Technology development • Sourcing	• Breakthroughs • Creating relationships • Investment portfolio	• Partnership • Ventures • Funding • Rewards	**Creativity** **Research** **Learning** **Building**

Table 7.9 *Summary of the salient points for each category*

	Turbulent	Fluid	Stable
Strategy	Radical change	Quantum change	Incremental change
Innovation	Radical innovation	Technological innovation	Product innovation
Team construct	Autonomous	Dedicated	Cross-functional
Products	New to the world	Derivative	Improvements
Targets	"Change the world"	Significant benefits	Improvements
Metrics	New reality	$2\times$ to $10\times$ change	% Improvement
Focus	Business environment	New/changed markets	Markets and customers
Implicit assumption	Change is necessary	Change is uncertain	Change is unnecessary

Leading change

Leading change is the proactive means of staying ahead of the competition. The critical question for the twenty-first century is: Why create radical change if the prevailing situation is advantageous? Again, it is the question! With a myriad of successful products based on its lean-burn technology, Toyota would be hard pressed to justify radical change!

Managing radical change is significantly different from managing incremental change. The methods that work under the well-known and established conditions may not be useful if radical change is expected. Many senior managers assume that traditional approaches and practices are appropriate in a radical-change situation. However, radical change necessitates an entrepreneurial spirit. The management system has to be open-ended, allowing for creativity and "out-of-the-box" thinking.

The strategic question is how to lead change; i.e. incremental, quantum, or radical change. Each has its own set of requirements, and advantages and disadvantages. The question is difficult; the answer is based on a complex set of variables. However, the dynamics of the business environment plays a significant role. Moreover, the vision of the organization provides insights for the answer as well. Vision is the overarching attitude about the future that lays the foundation for developing business strategies and objectives. The vision provides an articulation of the future for the organization. It provides the people of the organization with answers to the why and what questions.

The strategic choice is not whether to change. The decision is whether to be in concert with the drivers in the business environment – whether the conditions and trends are stable, fluid, or turbulent – and how to adopt a change strategy (incremental, quantum, or radical) that is in line with the driving forces. If the business environment is stable, the traditional strategy would be incremental change, using product innovation. A more-aggressive strategy would be to induce quantum change using technological innovation. The strategy of radical change suggests a fundamental departure from conventional solutions and discovering new ways to disrupt the competitive picture by obtaining overwhelming advantages.

Table 7.10 *Advantages and disadvantages of radical change*

	Inside industry	Outside industry	General
Advantages	• Has the ability to track industry data on an ongoing basis to determine opportunities and threats on a real-time basis. • Has a basic understanding of the industry. • Is part of the information flow of the industry.	• Does not have vested interest in prevailing technologies. • Acquiring new resources is easier if there are not any resources to be disposed of. • Find opportunity to participate, especially if there is a definite structure.	• Gain a significant competitive advantage, distinction, and an improved image, if successful. • Create new value proposition, establishing a win–win situation for customers, suppliers, and the entire enterprise.
Disadvantages	• Change may be disruptive, destroying valuable assets (plant, products, processes, etc.). • People may be unwilling to adapt new behaviors, learn new skills and knowledge.	• Lack of industry knowledge. • Lack of connections. • Lack of awareness and acceptance.	• Have to build acceptance and new learning. • High level of uncertainty and risk. • High probability of failure. • Long development cycle. • Radical change requires a different mindset.

The decision is not a prescribed solution, but an analytical one. It is based on an understanding of the business environment. Table 7.9 provides an overview of the linkages between the prevailing business environment and the strategic actions. The implications of Table 7.9 do not suggest that quantum or radical changes are always better or more aggressive. It does make several pivotal points that are critical for decision making.

- The selection of a change mechanism (radical, quantum, and incremental) is a crucial strategic decision.
- Such selections have to be based on strategic analysis of both the business environment and the core capabilities of the organization.
- The choice of change mechanism has a significant influence on the appropriate methods and practices used to achieve the end game. In essence, this means that if radical change is selected the construct of radical innovations must be used and not that of product innovation. Likewise for the other choices.
- Leading change is not an option; it is essential. The choice is selecting the mechanism and the degree of change.
- Selecting a mechanism is not an all-or-nothing proposition. Depending on the business environment, an enterprise might have some of its units selecting radical change while others are selecting quantum or incremental change.

Radical change is the most complex. If it is based on disruptive technologies, the situation analysis and forecasting methods have to be uniquely crafted to the understand the business opportunities (markets, customers, stakeholders) and determine appropriate directions. For example, existing customers may lack insight into the new technology; therefore, other means have to be used to determine the potential. In many cases, it is impossible to obtain a true perspective of the potential. Who could have predicted the growth of personal computers or the Internet?

Radical change means different things to each organization. An analysis of the situation should be based on whether the radical innovation is appropriate. Table 7.10 provides a simple overview of some of the advantages and disadvantages of radical change, depending on whether the organization is part of the industry structure or not. In some cases, insiders of an industry have an advantage; in other cases outsiders have the advantage. In both cases, acceptance is the crucial factor!

Radical change requires a different management mindset. The people have to be aggressive and management has to tolerate failures as well as encouraging success. The people involved have to conceive, discover, and analyze opportunities and turn them into realities through technological means. The essential skills are determining why the opportunity is important; analyzing the advantages and disadvantages pertaining to the opportunity; developing the means to exploit it; designing and developing the technologies, products and processes; determining how to measure success; validating outcomes; and implementing programs.

Managing change and technology at Toyota

Why does Toyota want to be the number one environmental car maker in the world? Is it due to competitive pressures from others pursuing similar initiatives, namely Honda, Ford, and Daimler-Chrysler? Is it the result of an altruistic leadership vision? While such factors could be at play, three drivers seem most important: the influence of regulatory directives, opportunities in developing countries, and a business strategy for developed countries. Toyota's technology-development program focuses on four critical areas:

(1) Taking every action to reduce CO_2 and other exhaust gases.
(2) Searching for new technologies to further enhance fuel efficiency to make better use of dwindling resources.
(3) Developing alternative power sources.
(4) Building new and more-efficient traffic control systems to help alleviate environmental problems in urban areas.

The initiatives are complex and involve investments of billions of dollars over time. However, the main environmental drivers are the concerns about global warming, urban air pollution, and resources conservation. Toyota's technology-development program is a multifaceted array of product development initiatives and technological innovations. R&D activities are performed by separate units located in Japan, Europe, and the United

States. Toyota allocates approximately 5% of revenues for R&D spending. The essential challenges for the R&D organization are to link its activities with customer and stakeholder needs and wants, and to integrate the development programs within the entire enterprise.

For existing technologies, the issue is simply. Product innovation focuses on identifying customer needs and developing new products that satisfy those needs. It is an ongoing process as Toyota updates its product lines and incorporates sustainable practices and methods into the new vehicle. Each new product is an opportunity to enhance the corporation's position by improving the impacts of the system.

Alternative-technology vehicles are a more-significant challenge. Customer needs and wants are ill-defined. There is uncertainty about the urgency of developing such technology. It is clear that existing legislation and regulations provide requirements for advanced technologies, but the strategic value of being a leader is unclear and the benefits of the new technologies are open-ended. Hybrid technology combines the existing technology with the new; in Toyota's case, the internal combustion engine with the electric motor. Investing in hybrid technologies is a good example of a transitional step. The uncertainties are somewhat contained by the knowledge of the existing technology and the platform that it provides. The changes are substantial, but the underlying structure has many common features and functions with the conventional designs. The commonality of parts and components, and the familiarity of customers with the characteristics of the vehicle, make the investment into transitional technologies a little easier to justify.

Radical innovations that are significantly different from the prevailing conditions of the industry are the most demanding to embrace. Not only is the technology unproven, but the needs of the market have to be demonstrated. Without the time-tested dominant technology, the risks are high, even when the selected path is on the right track.

Toyota's technology development strategy is a three-pronged approach.

- ***Incremental innovations of existing product technologies*** – improving conventional engine technology using lean-burn methods that increase fuel efficiency while reducing emissions.
- ***Hybrid technological innovation*** – developing vehicle technology that exploits the benefits of electric power with the support of lean-burn conventional technology, bridging the gap between the dominant technology of the internal combustion engine and future technologies.
- ***Radical technological innovation*** – exploiting electric-vehicle technology and developing fuel-cell technology for automobile applications. This includes other new technologies based on new methods and means of delivering power to the vehicle.

The investment into the existing technology, the internal combustion engine, has two principal objectives: keep the current products and models viable in the market place for as long as is economically possible; and establish the true benchmark for what the new technologies have to accomplish. The design parameters for the new technologies should be based on what customers are seeking from the best options offered by the existing technologies. The starting point for developing the automobiles of the future is to identify customer needs and determine stakeholder requirements.

The basic questions about the demand for alternative vehicles are unanswered. The knowledge and insights about customer needs and wants for conventional cars are very sophisticated. The required attributes are mapped out and well understood in the context of designing and producing automobiles. This phenomenon is especially true for Toyota. It has a number of leading products, like the Camry, with fine-tuned features geared to the specifications of its customers. From every perspective its position in the industry is extremely favorable.

Sources
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Toyota Motor Corporation, *Toyota Hybrid System THS II* (Tokyo, Japan: Toyata Motor Corporation, 2003).

Tools and techniques in design

Computer-aided engineering

Computer-aided-engineering (CAE) approaches are computerized tools and techniques used to improve the productivity of the NPD process, especially the design aspects. Generally, computer-aided tools are software programs that facilitate the acquisition and management of data and information. CAE provides enhanced quantitative and qualitative analyses of the design aspects, increasing the speed and accuracy of the engineering functions. The overarching objective is to minimize the processing of design details by using the data and information as effectively as possible. When there are many repetitive functions that rely on existing databases, CAE allows designers to use standardized methods to accomplish tasks using designs from previous programs, or enables them to repeat functions that are used many times. CAE takes standardized data and information into the design system once and then has them available for all other design requirements. Design details, once in the systems can be readily assessed to accommodate changes or can be added to other design requirements whenever necessary. CAE enhances performance, speed, and quality by reducing redundant work and integrating all of the elements into one system. In an interactive system, inconsistencies are pointed out and easily resolved.

There are many fundamental elements of design that can be shared across the entire system. In many product categories and product families, the design elements are similar if not identical. Therefore, identical design aspects from previous NPD programs can be incorporated in the new design saving time and effort. Such practice can result in 20 to 30% reduction in the amount of required design work. For example, the design of the USS Virginia, the US Navy's newest fast-attack submarine, was designed using the "CATIA" computer-aided design system. While it is difficult to stipulate the savings during the "Virginia" design program, it is estimated that the savings would be significant for designing derivatives. CAE improves the design process, facilitates documentation and validation of the results of the design process, and provides a legacy database that could be used to support future design requirements.

In their article, "CAE tools as collaborative support technologies," I. Vessey and A. Sravanapudi suggest that CAE helps engineers create faster, better, and more-efficient designs within a collaborative environment.[34] Productivity and quality are enhanced through the application of best methods that are validated within the system and reused for similar situations. The systems approach integrates the activities to improve quality and responsiveness, reduce cycle time, and enhance performance of the participants. The focus is on collaboration and communication.

Collaborative manufacturing technology speeds new product development

Concurrent engineering using computer-aided design is a design philosophy that enables all stakeholders to contribute simultaneously and early in the design stage of the product. In a further attempt to cut costs and speed new products to market, many companies are using *collaborative manufacturing technology* to facilitate teamwork during product design. Collaborative manufacturing technology is also known as collaborative engineering, product life-cycle management (PLM), product data management (PDM), and collaborative product-definition management (CPDM).

Using collaborative software, stakeholders within the extended enterprise can work together in virtual electronic space prior to the first production run. This enables engineering changes to be analyzed early, before any actual production begins. Specialized collaborative software allows engineers separated by distance to look at the same screen at the same time and then communicate via the software's conferencing capabilities. The use of this technique can reduce the time required to retrieve product information, and process engineering changes.

Saturn used PLM software from Electronic Data System (EDS) Corporation, Dallas, Texas to help shorten its product development cycle from 48 to 24 months. Because of Saturn's somewhat unique relationship with the United Auto Workers (UAW), it includes factory associates in the NPD process. UAW representatives ask shop-floor workers about proposed new designs, facilitating earlier production of tooling, and accelerated new-vehicle development. The reps pass their findings on to three UAW advanced-engineering technicians at a remote design center using the PLM software. The advanced-engineering technicians then collaborate with Saturn engineers using desktop conferencing and other means of communication. The goal is to build a virtual prototype, and identify potential problems with manufacturability and ergonomics. The PLM software is used during later stages of product development as well.

Source

Wright, C. M., They don't make 'em like they used to: collaborative manufacturing ushers in a new era. *APICS – The Performance Advantage*, **12**:3, March (2002).

Computer-aided design and computer-aided manufacturing

Overview

Computer-aided design (CAD) is information technology incorporating software and hardware into a computerized design system that links all of the participants and design elements, and integrates the design and the workflow. CAD has evolved from the simple two-dimensional, computer-aided drawings of the 1970s to three-dimensional, parametric solid models of the twenty-first century. The hardware provides the processing and interactive capabilities along with the data storage and retrieval mechanisms. The software handles the mathematical algorithms, graphical images, and the connectivity between the participants.

Computer-aided manufacturing (CAM) links the design elements to the manufacturing requirements and production processes, eliminating the steps to convert information on drawings into details used for producing prototypes or manufacturing the product.

The combination of CAD and CAM creates a design system that links all of the participants and provides them with real-time information based on the inputs and contributions of the entire team. The combined system is referred to as "CAD/CAM" or "CADCAM." A CAD/CAM system is highly automated using standard elements and a common language that links the upstream and downstream activities and integrates the design work so that anticipated additions and revisions are communicated simultaneously to everyone involved. Moreover, participants do not have to be co-located in order to work together effectively. Since everyone shares a common database, changes are instantaneously communicated and incorporated into thought process. The CAD/CAM can link internal and external participants equally well.

The main advantages of CAD/CAM are:

- ***Enhancing quality and design configurations***. CAD/CAM models provide clear product definition and design visualization. Designs can be displayed in three dimensions allowing for visual testing and verification. Design parameters and tolerances can be incorporated into the system providing the means to examine the parameters and the tolerances interactively to ensure that the design can be produced.
- ***Reducing design and production time***. CAD/CAM reduces the design cycle, minimizes the number of engineering changes, and improves the linkages between design and production engineering. Using pre-existing data and design specifications within the systems reduces the amount of original work that has to be performed. It leverages the information and data from previous designs. CAD/CAM links the design steps with the building of prototypes and their testing.
- ***Improving the value equation***. CAD/CAM improves both the cost estimates and the cost structure by ensuring that all cost elements are included in the equation. Productivity gains and possible reductions in cycle-time provide improvements to the cost structure. Cost estimates are typically more accurate given the database of design information and the linkages with production.

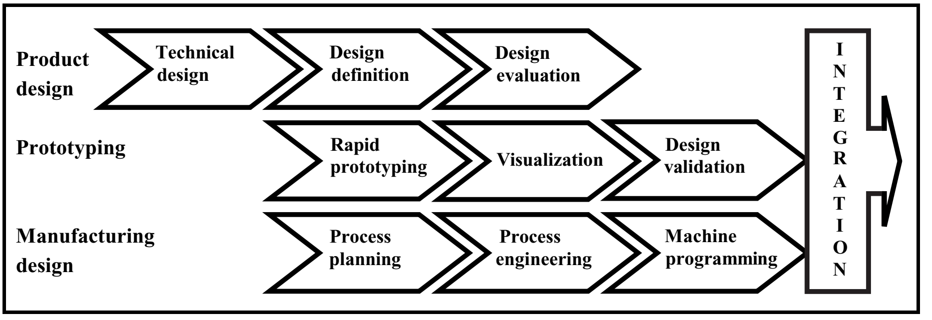

Figure 7.6 CAD/CAM parallel processing

The CAD/CAM development process

CAD/CAM integrates every facet of the design aspects of the NPD process. The principal focus is on engineering, prototyping, and manufacturing according to the requirements of the NPD program. The process elements are developed in parallel with engineering or the technical design as the lead elements. The starting point can have its origins during the concept development steps. Product definition and customer specification, as derived through such techniques as QFD, provide the engineering and technical functions.

The general approach is described below and is depicted in Figure 7.6. There are many variations to the construct, depending on the sophistication of the software and the complexity of the design situation.

Product design

The **technical design** includes the specifications based on the product characteristics and tolerances. The technical design is a three-dimensional graphical display with the geometry defined in a rectangular coordinate system (x, y, and z). The geometry can be shown as a surface or a solid.[34] The solid or the three surfaces of the solid provide satisfactory design details so that the participants can visualize the object and contribute to the enhancement process. Design options can be generated by searching for improved solutions.

Products are actually assemblies of parts, components and modules. CAD/CAM systems allow all the parts to be modeled individually and then combined into a master file. Individual designers can work on their part and then integrate the work into the system. Design work can be created separately or concurrently. Designers have the capability to evaluate the consequences that a design change has on the part or module, and then on the assembly, by incorporating the part into the entire assembly. Assemblies can be checked for interference and the final designs can be verified for accuracy before building prototypes or producing the products. The design model is stored as the master within a central file system. Downstream participants can gain real-time access to the design master as it evolves, providing them with the information they need to perform their tasks or to make comments on the design aspects that affect their functions and responsibilities.

Design definition is achieved through having a master file of design details and drawings. Dimensions, tolerances, and cross-sectional views are integrated into the master file, depicting the product design model. Participants work closely with the software specialists to ensure the validity of the design and that the file is not corrupted in any way. Designers collaborate with participants from manufacturing to ensure that the parts can be manufactured and that the required geometries are feasible. In a three-dimensional CAD/CAM system, the program creates the parametric solid model that can be used for prototyping. This enhances the full integration of the design efforts since parallel processing is maximized.

CAD/CAM models provide the means for **design evaluation**. The models can be used to generate finite elements of the design. Simulated loads can be added to the design models to analyze the stress on the designs. The analysis is used to determine the strength of the elements and to ascertain the breaking point or failure modes. Parametric analysis can be used to identify deflections and stresses associated with the weak points in the design. Vibration, heat transfer, and kinematics analyses can also be performed. The parameters can be varied, so that the model provides information about variability.

Prototyping

Rapid prototyping is the means of testing the design through a simulation of the virtual design in the CAD/CAM system or through the development of an actual model of the product. Rapid prototyping has made significant gains over the last decade as the prototyping effort was linked through the system to create a working model with the minimum time and effort. Rapid prototyping links the design file to the process equipment used for producing the prototype. It allows the generation of a working model that can be tested and validated. See the supplement at the end of Chapter 12 for additional details about prototyping.

Visualization provides the designer with a near-perfect representation of the product and its components. Very sophisticated CAD/CAM systems, like the CATIA system, allow the designer to examine visually every part of the design. Large assemblies that have many subassemblies, such as automobiles consisting of thousands of parts, can be displayed using "facet files."[35] The approach allows designers to show the method of assembly and simulate testing of the design.

Design validation is usually embedded within the prototyping sequences. There are many variations to the methods, including eliminating the Validation Phase because the design was validated during the Design and Development Phase. Such "virtual testing" is gaining acceptance. It offers a significant opportunity for saving time and money. During the design of the USS Virginia, Electric Boat (the designer) was able to use virtual testing to check for interferences and to verify design decisions on an almost-continuous basis. Virtual testing provided a means of correcting difficulties early in the design sequence, thus eliminating problems that were more complicated. Virtual testing with simulated prototypes can be used in place of expensive physical mock-ups. Moreover, as shown on television advertising of the Dodge Intrepid, potential customers can assess the design details using the graphical models from the CAD/CAM system.

Manufacturing design

Design definition provides manufacturing with the design details that it needs to start **process planning**. Process planning deals with the requirements for producing the parts, components, and assemblies, and obtaining the raw material and purchased parts. Process planning determines how the product is going to be manufactured. Rapid prototyping also provides input on what is required to manufacture the parts, components, and assemblies.[36]

Process engineering using information directly from the CAD/CAM system creates the production tooling, fixtures, and methods. Custom fixtures are often required to produce a part. The master models can be used to manufacture the fixtures and to provide the information necessary for instructing the automated machines.

Machine programming provides instructions on how to program the process equipment used to produce the parts, components, and assemblies. A total integrated system uses automated machinery having numerical-controlled (NC) programming. NC machines generate tool paths directly from the master model. This allows the direct input of design information, CAD, into the manufacturing processes, CAM. Once the graphical NC program exists, it can be used in a simulation program or in an actual production process. For instance, these programs show a virtual part being machined.

CAD/CAM provides the means for inspection of all of the parts, interfaces, and relationships; discrepancies are easily identified. CAD/CAM allows suppliers and customers to be linked to the system, closing the loop on communications and coordination. With direct input to and from the system, downstream participants are integrated with the designers and have the capability to interface as direct contributors.

Chapter 9 provides additional details about the linkages between design and manufacturing.

CAD/CAM integration

If CAD/CAM is an inherent part of the NPD process, participants need a champion or interface with the CAD/CAM professionals to ensure effective utilization of the software. The NPD program needs proponents for developing a CAD/CAM system if it does not exist. Systems integration is necessary for database information to be available across the software platforms to link product design, process planning, and the financial systems. The use of a CAD/CAM system does not automatically guarantee improved quality, decreased lead times, and reduced costs. It takes a concerted effort on the part of the NPD team to ensure such results. The implementation of a CAD/CAM system within a NPD situation works well, if participants are trained and they understand the implications of its use. Senior management must set CAD/CAM policy and direction, and provide a work environment that promotes success.

Insights about CAD/CAM

CAD/CAM systems are very complicated and are in the realm of information technology. It is not the purpose of this book to cover the details pertaining to the hardware and software aspects of CAD/CAM. Rather, the focus is on the power of the tools that are available to the NPD participants. The proper applications of CAD/CAM require professionals in computer-science disciplines who can determine the best practices for creating and using CAD/CAM models. Such professionals set standards for content for systems integration. Software applications automate the creation of the design and process definitions and provide the interfaces within the system to link designs and people.

The NPD team is an integrated group of professionals from design, drafting, analysis, process planning, NC programming, inspection, tool design, and others. This provides the mechanisms to share product design throughout the NPD process.

Product-data management

Product-data management (PDM) is an effective tool for organizing and controlling product data and managing the engineering changes. During the Design and Development Phase, engineering selections and changes are made as the design is refined. Numerous iterations may be necessary as inputs from various sources and analyses have an impact on design decision, making. Input from all of the internal and external participants requires an efficient and effective means of capturing and maintaining the flow of information and data.

PDM software enables the design team to organize design information, manage design revisions, keep track of the design details, and retrieve archival information. On the process side, the PDM software helps with design activities, such as reviews and formal approvals, and is a mechanism for checking on performance.

PDM evolved from the CAD/CAM systems used to develop a graphical representation of the design data. Originally, PDM provided an electronic storage and retrieval system for CAD/CAM data. It was a storage vault with password protection and secured back-up; it was like a bank vault. As the needs became more sophisticated, interactive features were added to the functionality providing integrated data management.

New generations of PDM software provide designers with the means to collaborate concurrently on a design and to view the results of the work instantaneously.[37] The new functionality allows collaboration among participants who are not co-located. This feature has become more important as outsourcing continues to increase the use of suppliers.

Table 7.11 *Levels of inventiveness (TRIZ)*

Level	Degree of inventiveness	% of solution	Source of knowledge	Approximate no. of solutions to consider
1	Apparent solution	32%	Personal	10
2	Minor improvement	45%	Within company	100
3	Major improvement	18%	Within industry	1000
4	New concept	4%	Outside industry	100,000
5	Discovery	1	All that is knowable	1,000,000

The theory of inventive problem solving (TRIZ)

TRIZ is a relative new design technique for improving products and their benefits. TRIZ uses analogous situations and design principles for discovering solutions that focus on eliminating conflicts within a design envelope rather than developing compromises. It attempts to avoid the middle-ground solution by mitigating the negative effects.

Genrich S. Altshuller founded the TRIZ construct during his work as a design expert in the Soviet Union. He stated that a theory of invention should satisfy the following conditions:[38]

(1) Be a systematic, step-by-step procedure.
(2) Be a guide through a broad solution space to direct the ideal solution.
(3) Be repeatable and reliable and not dependent on psychological tools.
(4) Be able to access a body of inventive knowledge.
(5) Be able to add to the body of inventive knowledge.
(6) Be familiar enough to inventors by following the general approach to problem solving.

The construct includes some of the underpinnings of the scientific method. The most important aspects are finding solutions through analogous problem solving, using the experiences of designers in different technical fields, industries, or scientific disciplines. The construct of ideality is an important contribution. It simply states that a system (product) moves toward the ideal if the sum of the useful effects is increased or the sum of the harmful effects is decreased, or if both are improved. Table 7.11 is a simplified depiction of the levels of inventiveness.[39]

The levels of inventiveness indicate discrete functions, giving a relative sense of the type of innovation and difficulties associated with inventing solutions. Level 1 involves relatively simple changes to one or more functions. Level 5 might involve radical changes to multiple functions or parameters, or even a whole new invention. In reality, the changes are probably continuous improvements given the very large number of new product programs implemented over the years. TRIZ levels provide insights about the degree of uniqueness within each new product arena. Levels 1 to 3 are the domains of product innovation as discussed in this book. Levels 4 and 5 relate to technological innovation. TRIZ is a great tool for improving the value proposition. It focuses on the essential elements of value. See the TRIZ website for more details (www.mazur.net/triz).

Axiomatic design: the domain model of product development

Axiomatic design focuses on dramatically improving the means of achieving a systematic design with the full integration of the enterprise. Professor Nam Suh, chairman of the Mechanical Engineering Department at Massachusetts Institute of Technology, is a champion of axiomatic design principles.[40] Axiomatic design principles seek the best solution.

In the context of the NPD process, axioms are fundamental truths that are embedded in the design process. The underpinnings of axioms are based on scientific thinking pertaining to superior designs. After considerable research, Suh was convinced that there are two main axioms. The first principle was the axiom of independence. The axiom of independence states that in great design, the product characteristics (the hows) are chosen in such a way that the customer needs (the whats) maintain independence.[41]

Larry Smith, in an article in *Six Sigma Forum Magazine*, presents the following example:[42]

> The functional requirements for a water faucet are two: control the flow rate and control water temperature. The faucet that has two water knobs, one for cold and one for hot is a coupled design that when one of the knobs is turned both temperature and flow are affected. The functional requirements are not independent. If a consumer has optimized the flow rate, then turns one of the knobs to optimize the temperature, the flow rate is changed and is no longer optimal. Designs of this type eventually satisfy the customer by iterating between the two design parameters.
>
> Consider the design that has only one handle and the design parameters are to lift the handle to adjust the flow and move the handle from side to side to adjust temperature. In this design, adjusting temperature does not affect flow and conversely. From an axiomatic design point of view, this design is superior because the functional requirements maintain independence.

The second principle suggests that the best designs have the least information content. Such designs have the highest probability of success. This is the simplicity principle. More-complicated designs require more information to make them function correctly. Simplicity suggests that each customer need (called customer attributes) is expressed in terms of a functional requirement that is satisfied through a single design element (design parameter).

Suh developed the “domain model of product development.” Figure 7.7 depicts the critical domains.

The most important design principle involves the linkages between customer attributes and functional requirements. The axiom stipulates that the functional requirements should be independent and that each functional requirement should address one

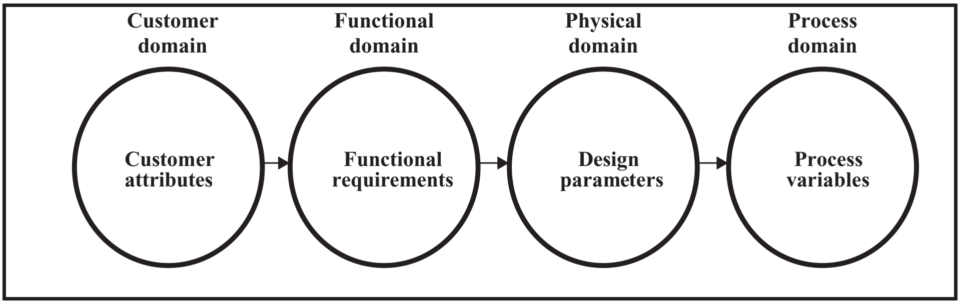

Figure 7.7 Nam Suh's domain model of product development. Source: N. P. Suh, *Axiomatic Design: Advances and Applications* (Oxford: Oxford University Press, 2001)

customer attribute. The best designs are those with a direct link between the customer attribute and the functional requirement.

The design parameters are the physical solutions to the customer needs. The integration of design aspects into a single part minimizes complexity. Standardization through interchangeable parts is consistent with the axioms of independence and simplicity. An ideal design has one design parameter for each functional requirement. Process variables should be linked to design parameters. However, the linkage does not always have to be direct. For more information, read Suh's book!

Failure mode and effects analysis

Failure mode and effects analysis (FMEA) is an analytical tool used to determine the robustness and safety of product and process designs and to understand the underlying risks. FMEA is a quantitative approach used to identify the mechanisms in a product or process that can fail, to determine the severity and the likelihood of the potential problem or failure, and to establish the means of preventing those failures.

There are several types of FMEA:

(1) ***System FMEA*** – examines how the new product or concept fits into the entire management system. It is deployed early in the NPD process to understand the inherent risks associated with the functions and applications of the new product.

(2) ***Design FMEA*** *(DFMEA)* – following the logic of the house of quality, the design FMEA focuses on the components selected during the design process. It is used to analyze the functions of components and to determine potential failure modes and their implications. DFMEA can be used on the entire product.

(3) ***Process FMEA*** – applied to the manufacturing and assembly processes. It focuses on failure to achieve the product specification(s), resulting in a defect. Failure modes may be caused by design or process defects.

DFMEA is an effective tool used during the NPD process for discovering and curing potential defects or risks that affect the viability of the new product from a technical and commercial perspective. The application of this design tool depends on the situation.

In a design situation, DFMEA may be applied to a small set of parts or components that have a history of causing concerns, or to the new elements in the design that have not been proven to be reliable. The analysis of a complicated system, new product concept, or design with many components is simplified by selecting those components with significant concerns or severe implications.

A **failure mode** is the mechanism causing the product or process or any part thereof to fail to meet specifications. Missing or defective parts, undersized parts, or loose components are examples of failure modes. An **effect** is the impact on the downstream process, operation, or customer if the failure mode is not prevented or corrected. The effect of a cracked blade on a jet engine may be the loss of power, resulting in a crash. The **cause** of the failure is the deficiency resulting from the failure mode.

DFMEA methodology determines overall risk by examining each failure mode and determining its potential effects in terms of severity, probability of occurrence, and the potential to detect and prevent the occurrence.

The focus of the method is on **analysis**. The analysis is expressed using the following terms to determine the seriousness of the failure:

(1) ***Severity (S)***. What are the potential effects and how significant are the problems if they occur? (Property losses, injury to customers or workers, death.)

(2) ***Occurrence (O)***. What is the probability of an occurrence? (Likelihood of occurring.)

(3) ***Detection (D)***. What is the possibility of discovering the problem? (The ability to detect the cause or failure mode if it occurs?)

The construct of the analysis is relatively simple. It is a mathematical formula using each of the components (severity, occurrence, and detection) scored on a scale between one and ten (one is the lowest, ten is the worst). For each failure mode, a "risk priority number" (RPN) provides an indicator of the risk potential.

$$\text{RPN} = \text{Severity} \times \text{Occurrence} \times \text{Detection}$$

Higher numbers indicate a greater concern. Ideally, the construct usually provides a significant difference between the problem areas with minimal concerns and those with the greatest potential for difficulties.

The RPN is a way to identify and prioritize items or areas that need additional quality planning and improvement. They represent potential problem areas that could lead to higher cost, excessive defects, poor reliability, inferior performance, and increased liability. They also represent opportunities for improvement. Identifying a high RPN indicates that positive action during the design process could result in the reduction of the consequences of the potential failure mode.

The DFMEA procedure described herein is based on the automotive model of QS 9000 and the Automotive Industry Action Group.[43] Figure 7.8 provides the general template for implementing DFMEA.[44]

Potential failure mode and effects analysis (design FMEA)

—System
—Subsystem
—Component________________________

Design responsibility ______________________

FMEA number ________________

Page_______of__________

Prepared by_____________________________

Model year(s)/Vehicle(s)__________________

Key date ________________________________

FMEA date (Orig.)________(Rev.)_________

Core team ____

Item function	Potential failure mode	Potential effect(s) of failure	Sev	Potential cause(s)/ mechanism(s) of failure	Occur	Current design controls	Detect	RPN	Recommened action(s)	Responsibility & target completion date	Action results				
											Actions taken	Sev	Occ	Det	RPN

Steps	1	2	3 & 4	5 & 6	7 & 8	9	10

Figure 7.8 DFMEA template

Table 7.12 *Design failure mode and effects analysis process*

Description	Explanation	Example
Step 1 Identify and describe functions of product/process. (List all design functions.)	The first step is to identify each of the major functions of the product or process and to describe the function to determine the potential for failure. Potential failures include those that could be expected to occur due to the design (inherent) and those that are not intended to be a part of the product or process (latent/unexpected).	Fuel cells require hydrogen to function, converting hydrogen and oxygen into water and electricity. The fuel system stores the hydrogen and supplies it to the cells. Some of the water may freeze in colder climates.
Step 2 Determine potential failure modes. (List all of the failure modes.)	The second step is to identify and define a subsystem, component, part, process, etc. that could potentially fail to meet specifications. Type-I failures are the ones that are inherent in the function (there is a known probability of occurrence). Type II indicates an unknown or unexpected situation.	The hydrogen storage device could sustain damage, cracking the containment apparatus (type I). The failure mode could cause a secondary failure to occur as well. The water could freeze and cause a malfunction of the system during start-up (type II).
Step 3 Describe the effect of the failure modes.	The third step is to determine what the ultimate effects are expected to be. A failure effect is described in terms of the application, when it would be expected to occur, and its impact.	The crack could allow hydrogen to leak into the vehicle. The hydrogen could cause an explosion in the vehicle if ignited when within the flammability range. Vehicle start-up problems affect customer satisfaction.
Step 4 Determine the severity ranking using Table 7.12A.	The fourth step is to use a severity-ranking table and determine a numerical ranking for the severity of the effect.	An explosion could kill the occupants of the vehicle. The severity ranking for such an effect is 10. The severity of the start-up problem is low in comparison.
Step 5 Identify the potential causes for each failure mode. (List the mechanisms for failures.)	The fifth step is to identify all of the potential causes of the failure mode. The causes are usually related to the design or manufacturing processes. This effort requires root-cause analysis to discover all of the potential defects. For each cause, the probability of occurrence should be established based on historical records and empirical testing.	The failure rate of fuel storage tanks is very low. Assume that records indicate that failure occurs, only at 1 in 100,000. The failure could be due to poor material selection, inadequate production methods, lack of appropriate tolerances, etc.
Step 6 Determine the probability of occurrence using Table 7.12B.	The sixth step is to use an occurrence-ranking table and determine a numerical ranking for the severity of the effect. The occurrence ranking is selected from a table that defines the closest level of occurrence. The criteria are based on the likelihood that the cause will occur.	If the probability of occurrence is 1 in 100,000, Table 7.12B provides a ranking of 3.

Table 7.12 *(cont.)*

Description	Explanation	Example
Step 7 Determine the ability to detect the potential problem.	The seventh step is to determine the ability of the current design configuration or NPD process to detect the potential problem. These include the design validation activities used to prevent the cause, detect failure, and/or reduce impact.	The original design does not have a hydrogen detection device that can sense the leaking gas.
Step 8 Determine the likelihood of detection using Table 7.12C.	The eighth step is to use a likelihood of detection table and determine a numerical ranking for the probability of detection.	The ability to detect a potential problem is very remote. The ranking is 9.
Step 9 Determine the risk priority number (RPN).	The ninth step is to calculate the RPN. RPN = severity × occurrence × detection. In general, a characteristic is considered critical if either the severity is >7 and/or the RPN is > a certain number determined by management.	The hydrogen example has a high RPN = 10 × 3 × 9 = 270.
Step 10 Identify and implement action to mitigate.	The tenth step includes all actions to improve the case and reduce the risks and potential causes of defects and their consequences. This includes improving the possibility of detecting the failure mode. The process includes identifying the responsible individuals and the schedule for completing the actions.	In the example, the primary action was to build in a fail-safe mechanism to insure that hydrogen could not accumulate in or near the vehicle. Assuming the severity was reduced to 1, the new RPN = 1 × 3 × 9 = 27.

Table 7.12A *Severity ranking*

Effect	Rank	Severity of effect
None	1	No effect from a severity perspective.
Very slight	2	Customer not annoyed. Very slight effect on system or performance.
Slight	3	Customer slightly annoyed. Slight effect on system performance.
Minor	4	Customer experiences minor nuisance. Minor effect on system performance.
Moderate	5	Customer experiences some dissatisfaction. Moderate effect on system.
Significant	6	Customer experiences discomfort. Item performance degraded, partial failure.
Major	7	Customer dissatisfied. Performance severely affected, system impaired.
Extreme	8	Customer very dissatisfied. Item/system inoperable but safe.
Serious	9	Potentially hazardous effect. Time-dependent failure.
Hazardous	10	Hazardous effect. Sudden failure, safety related.

Table 7.12B *Occurrence ranking*

Occurrence	Criteria	Rank	Possible failure rate
Remote	Failure unlikely	1	<1 in 1,500,000
		2	1 in 150,000
Very low	Only isolated failures	3	1 in 15,000
Low	Isolated failures associated with similar products	4	1 in 2,000
		5	1 in 400
Moderate	This product or similar product has experienced occasional failures	6	1 in 80
		7	1 in 20
High	This product or a similar product has often failed	8	1 in 8
		9	1 in 3
Very high	Failure is almost inevitable	10	>1 in 2

Table 7.12C *Probability of detection*

Rank	Likelihood of detection by design[45]	Probability of detection
1	Design will detect potential cause and failure mode	Detected prior to engineering prototype
2–3	High chance the design will detect	Detected prior to design release
4–5	Moderate chance the design will detect	Detected prior to production
6–7	Very low chance the design will detect	Detected prior to shipping
8	Remote chance	Detected after shipping but before customer's use
9	Very remote	Detected in field but before failure occurs
10	Absolute uncertainty	Undetectable until failure occurs in the field

DFMEA is a stepwise process that flows horizontally across the page for each functional item and its potential failure modes. The process continues vertically as all of the selected functions are identified, added to the list, and analyzed. The process is articulated in Table 7.12.

Once the critical characteristics are determined, action plans are formulated to lower the risk of the design. This activity entails listing recommended actions, responsibility, and timing. The actions taken are described in quantitative fashion along with the results.

DFMEA is a simple method for detecting potential concerns and determining the means to improve the design. Used in conjunction with risk assessment and quality improvement DFMEA enables the NPD team to produce a more-robust design earlier in the process and to discover potential or hidden defects before they have significant adverse impacts on the cost, quality, and performance of the product.

DFMEA has the potential to improve value by reducing defects and burdens. It is most appropriate where there is a high level of uncertainty or where there are high risks and liabilities. It allows management to compare the relative merits of the new

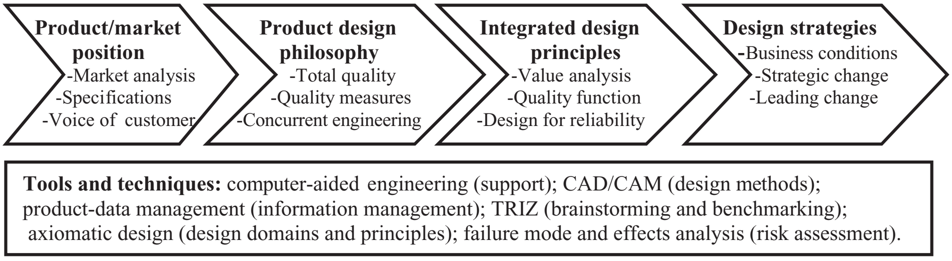

Figure 7.9 The interrelationships between the design-process elements and the tools and techniques

design to previous designs that used a similar construct, and to determine the need for mitigation. DFMEA provides a wealth of information and knowledge to the participants who can not only improve the effected design but also improve their own capabilities and enhance the NPD process. The methodology described herein can be used in conjunction with DFE and product life-cycle assessment to discover various types of defects and burdens.

Summary

The nature of product/market considerations and their implications on product design is dynamic. The external forces of change are multifaceted dimensions driven by social pressures, political realities, economic forces, and technological advancements. Inventing solutions to the complex realities of new product opportunities is the challenge that lies at the heart of product/market planning and product design. Leading change through product design means translating opportunities into meaningful outcomes. It requires creative methods and techniques for understanding design complexities and discovering, developing, and implementing solutions. The basic approach is to create sustainable value streams and design solutions that exceed the economic, market, social, and technological needs of the enterprise.

The front-end of the design sequence is driven by design philosophies that provide guidelines for design and decision making. The tools and techniques provide the mechanisms to analyze the customer and stakeholder requirements and to translate those into actionable activities and design solutions.

Solutions have to be holistic. The basic construct presented in this chapter follows a logical flow from positions, philosophies, principles, and strategies. The tools and techniques are embedded within the design process and are used for analysis and implementation. Figure 7.9 depicts the general view.

The chapter provides the essential product/market elements that can be used to facilitate analysis and decision making during the Concept Development and Selection Phase or during the Design and Development Phase. Because most of the methods and techniques in the chapter are fairly sophisticated, it is more likely that they would be used during the operational level than during the conceptual level. The discussions are therefore linked to the related areas in Chapter 11.

Notes

1. E. Goldratt and J. Cox, *The Goal: Excellence in Manufacturing*, 2nd edn (Great Barrington, NY: North River Press, 1992).
2. For a more balanced perspective on goals, read: R. Kaplan and D. Norton, *The Strategy Focused Organization: How Balanced Scorecard Companies Thrive in the New Business Environment* (Boston, MA: Harvard Business School Press, 2001). The authors in their several books argue that making money is just one of many objectives of a business enterprise. They contend that successful companies have a balanced approach to setting goals.
3. This postulate is the underpinning of every product and service. Imagine buying a ticket for a flight on a new airplane that had a history of crashes. The first commercial jet airplane, the DeHavilland Comet, is an example of being first, but not achieving success because of design problems. The Firestone-tire problem on the Ford Explorer is an excellent example of the implications of the loss of trust in a product. The first and foremost goal is to have a philosophy that trust is essential for success.
4. There are many similar constructs. The process is stated as generic because it contains the common elements of the standard methods. A refined approach might include benchmarking or similar methods.
5. K. J. Cleetus, *The Definition of Concurrent Engineering*, CERC-TR-RN-92-003, Concurrent Engineering Research Center, West Virginia University, 1992.
6. C. Karlsson and P. Ahlstrom, The difficult path to lean product development. *Journal of Innovation Management*, **13**:4, July (1996), 284.
7. *Ibid.*
8. The aim of this section is to discuss the protocol for designing products and the related NPD program elements. It is not the aim to discuss the engineering aspects of product design. The engineering or technical design aspects are engineering-related subject matter.
9. K. T. Delavigne and J. D. Robertson, *Deming's Profound Changes* (Englewood Cliffs, NJ: PTR Prentice Hall, 1994, pp. 265–268). Deming's 14 points are:
   (1) Create constancy of purpose for the improvement of products and service.
   (2) Learn the new philosophy; teach it to employees, customers, and suppliers; put it into practice.
   (3) Cease dependence on mass inspection and testing; much better to improve the process in the first place so you don't produce so many defective items, or none at all.
   (4) End the practice of awarding business on the basis of the price tag alone; instead minimize total cost in the long run.
   (5) Improve constantly every process whether planning, production, or service.
   (6) Introduce training for skills, taking into account the differences among people in the way they learn.

(7) Adopt and institute principles for the management of people, for recognition of different abilities, capabilities, and aspirations.
(8) Drive out fear and build trust.
(9) Break down barriers between staff areas – in other words build a system in which everyone wins.
(10) Eliminate slogans, exhortations, and targets – asking for zero defects and new levels of productivity.
(11) Eliminate numerical goals and quotas for everybody.
(12) Remove barriers that rob people of the joy in their work.
(13) Institute a vigorous program of education and self-improvement.
(14) Accomplish the transformation and continue to study the new philosophy; develop a critical mass in your organization that will bring about the transformation.

10. *Ibid*., p. 54. The Shewhart PDSA Cycle was developed in the 1930s by Deming's mentor, Walter Shewhart. It was Deming who made this construct popular in Japan and later in the United States. PDSA is also known as The Deming cycle. See also: J. Persico, *The TQM Transformation: A Model for Organizational Change* (White Plans, NY: Quality Resources, 1992, p. xii).
11. J. M. Juran, The quality trilogy. *Quality Progress*, August (1986), 19–24. J. M. Juran, *Juran on Quality by Design* (New York: Free Press, 1992, pp. 14–26).
12. A. V. Feigenbaum, *Total Quality Control*, 3rd edn (New York: McGraw-Hill, 1983, p. 11).
13. P. Crosby, *Completeness: Quality for the 21st Century* (New York: Penguin Books, 1992, p. xi).
14. K. Ishikawa, *What is Total Quality Control: The Japanese Way* (Englewood Cliffs, NJ: Prentice Hall, 1985). Ishikawa's elemental statistical methods include pareto analysis, cause-and-effect diagrams, check sheets, scatter diagrams, histograms, and process-control charts.
15. *Ibid*., pp. 9–15.
16. J. Persico, *The TQM Transformation*, p. vii.
17. *Ibid.*, p. xxv.
18. *Ibid.*, p. xi–xii.
19. An example of Design for Six Sigma was discussed in Chapter 3.
20. Capability index is conceptually easy to understand, but it is complicated in application. It involves sophisticated statistical analysis to determine the exact capability of a process. It is very complicated when more than one part or component are analyzed to determine the overall capability of the product. See: G. Bounds, *Cases in Quality* (Homewood, IL: Irwin, 1996). In particular: Case 13, Understanding and reducing variation through statistical process control; and Case 16, The Motorola quality process: six sigma.
21. This section was written by Dr. Edward Arnheiter.
22. B. Prasad, Review of QFD and related deployment techniques. *Journal of Manufacturing Systems*, **17**:3, 1998, 221–234.
23. Y. A. Akao, *Quality Function Deployment: Integrating Customer Requirements into Product Design* (Cambridge, MA: Productivity Press, 1990). QFD is more than three decades old. It was developed in Japan by Akao in 1967 and deployed by Mitsubishi Heavy Industries in 1972. It took about 15 years before QFD was adopted in the United States.

24. J. R. Hauser and D. Clausing, The house of quality. *Harvard Business Review*, **66**:3, May–June (1988), 63.
25. J. R. Evans and W. M. Lindsay, *The Management and Control of Quality*, 4th edn (Cincinnati, OH: South-Western College Publishing, 1999, pp. 405–414).
26. Construct prepared by Dr. Edward Arnheiter.
27. C. Curtis and L. Ellis, Satisfying customers while speeding R&D and staying profitable. *Research Technology Management*, September–October (1998), 23–27.
28. Again, there are many variations to the general concept of design for manufacture. Table 7.4 lists the essential philosophies and approaches. There are many other concepts that apply.
29. T. Amabile, How to kill creativity. *Harvard Business Review*, September–October (1998), 77.
30. H. I. Ansoff, *Implanting Strategic Management* (Englewood Cliffs, NJ: Prentice Hall, 1984, pp. 102–106). Ansoff uses the terms stable technology, fertile technology, and turbulent technology. The construct used is similar to Ansoff with the exception of the use of "fluid" instead of fertile and the notion that the driving forces are in the business environment as well as the technology.
31. J. Utterback, *Mastering the Dynamics of Innovation* (Boston, MA: Harvard Business School Press, 1994, p. 82). Utterback discusses the work that he and William Abernathy completed during the 1970s. They used the term "fluid" to indicate the beginning of the innovation process.
32. C. Christensen, *The Innovator's Dilemma, When New technologies Cause Great Firms to Fail* (Boston, MA: Harvard Business School Press, 1997, pp. 61–76).
33. I. Vessey and A. Sravanapudi, CASE tools as collaborative support technologies. *Communications of the ACM*, **38**:1, January (1995), 83–95.
34. A surfaced model is one in which the faces of an object are defined in the system and take the form of a planar, cylindrical, conical, spherical, toroidal, or freeform surface. Solid modeling provides the full geometric definition of the objects. A solid model can have density so that the weight can be determined.
35. C. McMahon and J. Browne, *CADCAM From Principles to Practice* (Reading, MA: Addison Wesley, 1993, p. 39). Facets are the simplest form of boundary model where a curved surface is approximated using a series of facets. Facet files are approximations of the true geometric model, consisting of many small, triangular faces.
36. V. Balsmeier, Rapid prototyping: state-of-the-art manufacturing. *Industrial Management*, **39**:1, January–February (1997), 1.
37. Some of the main providers of PDM software are Parametric Technology, Dassault Systems (IBM), CoCreate (Hewlett Packard), Unigraphics (EDS), Adaptive Media and NexPrise.
38. Theory of inventive problem solving, www.mazur.net/triz, p. 4.
39. *Ibid*., p. 5.
40. N. P. Suh, *Axiomatic Design: Advances and Applications* (Oxford: Oxford University Press, 2001).
41. L. Smith, Six sigma and the evolution of quality in product development. *Six Sigma Forum Magazine*, **1**:1, November (2001), 5. www.asq.org/pub/sixsigma/evolution.html.
42. *Ibid*.

43. General Motors, Chrysler Corporation, and Ford Motor Corporation, *Potential Failure Mode and Effects Analysis*, 2nd edn, General Motors, Chrysler Corporation, and Ford Motor Company (1995, pp. 3–24).
44. Websites http://egweb.mines.edu/egg491/lecture and Cayman Business Systems16949.com provide similar constructs.
45. General Motors, Chrysler Corporation, and Ford Motor Corporation, *Potential Failure Mode and Effects Analysis*.

Supplement to Chapter 7
The strategic utilization of quality function deployment

By Richard Picard

Introduction

In recent years there has been an increasing focus on better and faster ways of creating new products and making them with the highest quality and lowest cost. More and more manufacturers of consumer goods are rapidly creating new products and derivatives. In addition, product life cycles are becoming greatly condensed. Many corporations, especially those in consumer electronics, understand this. Other companies are failing and desperately try numerous techniques to stay ahead, or more realistically, "even" with the competition. Many of these companies jump from one technique to another due to poor or sluggish results.

Quality function deployment (QFD) is a technique (management construct) used to improve the linkages between customer and stakeholder needs and wants, and the selection of appropriate product characteristics and downstream production requirements. QFD is a new-product development (NPD) technique, which focuses on customer-driven quality and involves every aspect of an organization. If conducted properly it gives a company a competitive advantage over competitors who are without it. It is a proactive development process that utilizes cross-functional empowered teams. QFD is a strategic tool for product innovation.

QFD was originated in Japan during the late 1960s by Dr. Yoji Akao, Industrial Engineering Professor at Tamagawa University in Tokyo. By the early 1970s QFD was used at the Mitsubishi Heavy Industry at the Kobe shipyards. In 1974, Toyota Motor Company applied QFD in Europe to address warranty problems due to rusting of automobile bodies. This process allowed Toyota to reduce costs significantly. In 1983, almost 20 years after its inception, QFD reached the United States.

QFD is a poor translation of the Japanese "**Hin shitsu ki no ten kai**." Even when read in its English translation, QFD doesn't make much sense. The literal translation is given below:

Quality	Features	**Function**	Mechanization	**Deployment**	Diffusion
	Attributes				Development
	Qualities				Evolution

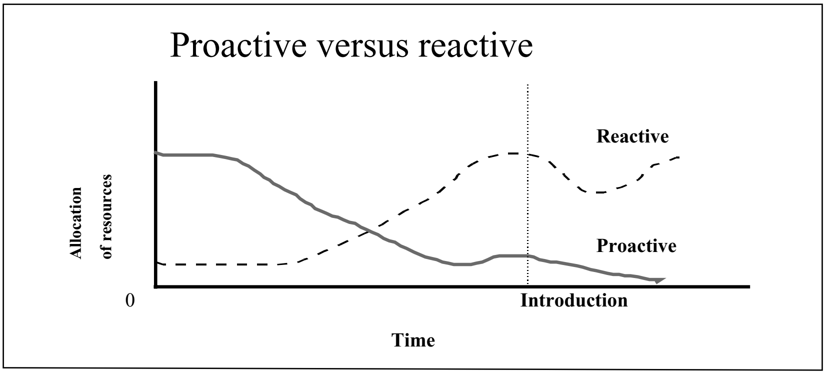

Figure 7S.1 Proactive approach to new-product development

Glenn Mazur of the QFD Institute has articulated a more-practical description based on the Japanese translation. "A group of courageous people working in harmony pursuing the finest detail to unlock the organization and roll out products that the multitudes in the market place will value."[1]

Dr. Akao has also given his own description of the QFD process: "QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demand into design targets and major quality assurance points to be used through the production phase. QFD is a way to assure the design quality while the product is in the design stage."[2] While QFD can be considered to be a quality tool, it is more-accurately considered an NPD tool which involves all aspects of the organization focusing on what is termed "the voice of the customer" (VOC).

Figure 7S.1 illustrates that many more individuals should be involved "up-front" in a proactive NPD process. It allows for customer-driven product design, and lower costs and higher quality.

Another way of looking at the benefits of a proactive approach to product development is through the use of the quality lever. In the very beginning of the NPD process the possibility of designing out problems is great. Using QFD there are built-in checks and balances to ensure that the proper decisions are made early in the process. Such decisions tend to eliminate costly rework due to poor communications, as is found in the traditional sequential approach.

In Figure 7S.2, the quality lever visually depicts the benefits of a proactive process. At the production phase, the leverage ratio to solving problems is only 1:1, yet in the design phase, with the ratio of 100:1, the ability to design out problems is significant. This approach yields a much more robust design. The benefits of a proactive process are easily understood, yet are very often difficult to attain. QFD focuses on discovering problems.

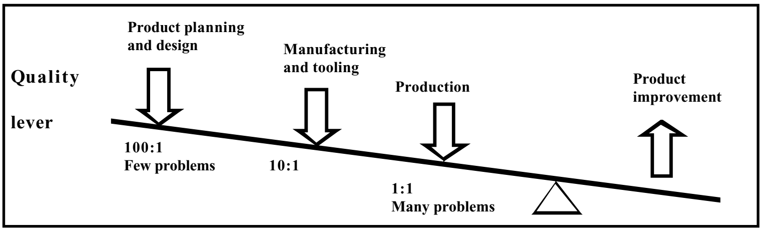

Figure 7S.2 The quality lever

House of quality and QFD

QFD is often referred to as the "**house of quality**" (HOQ). This term is used to describe a system of matrices associated with applying the QFD process. The matrices are mechanisms converting the VOC into measurable outcomes and relationships, which translate into key aspects of new product design and manufacture.

As shown in Figure 7S.4, each part of the house is built individually in phases. Normally there are four phases, with each phase focusing on specific areas. In more complex QFD's one house can be devoted to one specific aspect of the NPD Program, with many teams working on different houses. See Figure 7S.4 which provides an overview of VOC and HOQ.

The four phases of QFD are: I, Product Planning; II, Design Deployment; III, Process Planning; and IV, Production. Successful completion of all phases of the QFD reflects a successful interpretation of the VOC.

The VOC represents the root needs and wants of customers. Gathering these data is considered the pre-planning section of QFD and is handled in a number of ways. Usually research is done by individuals in marketing. In the QFD process it is best to get all of the core cross-functional team members together to perform the on-site visits and interviews with numerous customers. While determining the VOC it is best if all members relate to the customers themselves when necessary throughout the QFD process. The VOC should represent a good sampling of the customer base, not just local customers or the biggest customer.

Figure 7S.3 depicts the flow of the four phases of QFD.

Determining the VOC is not quick and easy. Just because information has been collected doesn't mean that it is in a usable form for the QFD process. The information must be properly translated into root needs and wants, and this takes time and involves a learning curve for teams just starting QFD. An example of properly identifying root needs and wants of the customer can be seen in an example given by Mary Cicala of Proactive Product Development Inc. Her example shows what consumers expect to get out of something as simple as buying a cup of coffee from the local coffee

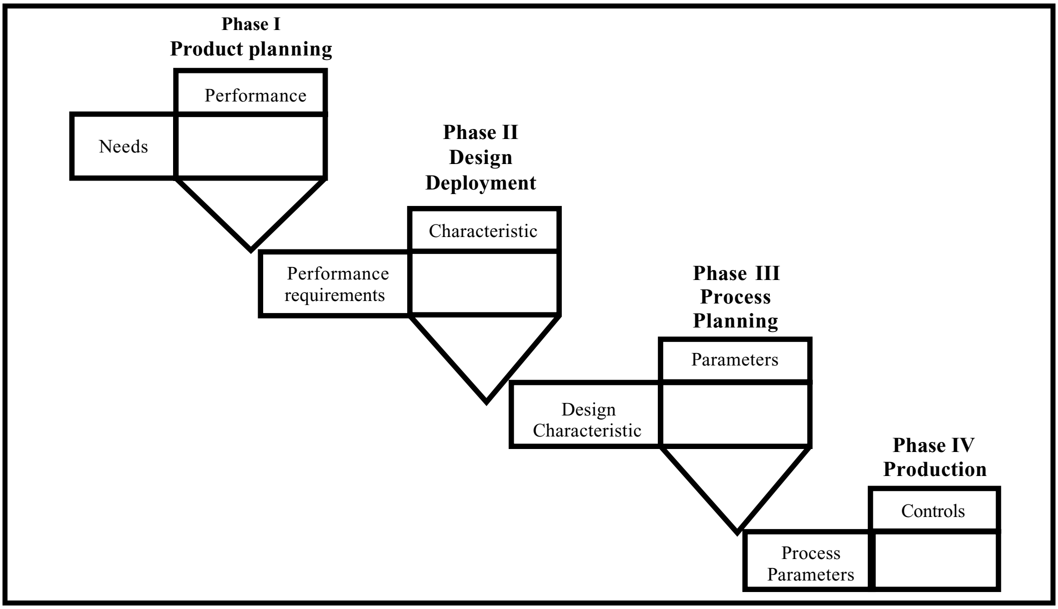

Figure 7S.3 The four phases of QFD

shop. A customer may say that he or she wants a cup with handles. This appears to be a straightforward statement, yet the root need may actually be "I don't want to burn my hands."[3] The coffee shop that doesn't translate the customer desires properly, serves cooler coffee, which in turn may cause customer displeasure. Even though the customer doesn't want to burn his or her hands, it doesn't necessarily mean they want colder coffee. During interviews, customers may have neglected to indicate that hot temperature is a desired attribute. They just considered it to be a "basic quality" of the product that is expected.

There are other qualities that are necessary in order to transform the customer information into a new product or service. These qualities are listed in the **Kano Model of Quality**. The Kano model is discussed in Chapter 4 and it is shown in Figure 4.2.

Kano's model of quality looks at three areas of quality, and how they interrelate with customer satisfaction. The three qualities are threshold, performance, and excitement. The model is also dynamic. It states that as time passes, what was once an excitement quality, such as having a Pentium 4 processor in a computer, eventually becomes expected and commonplace, i.e. a basic quality. When asked, customers will usually identify specific requirements and these fall into the performance categories. Everything else is very often unspoken, but still very important.

All of these customer quality requirements must be incorporated into the product and or services. The company that properly translates the VOC will be able to produce a more desired product than the competitor, resulting in gaining market share. After

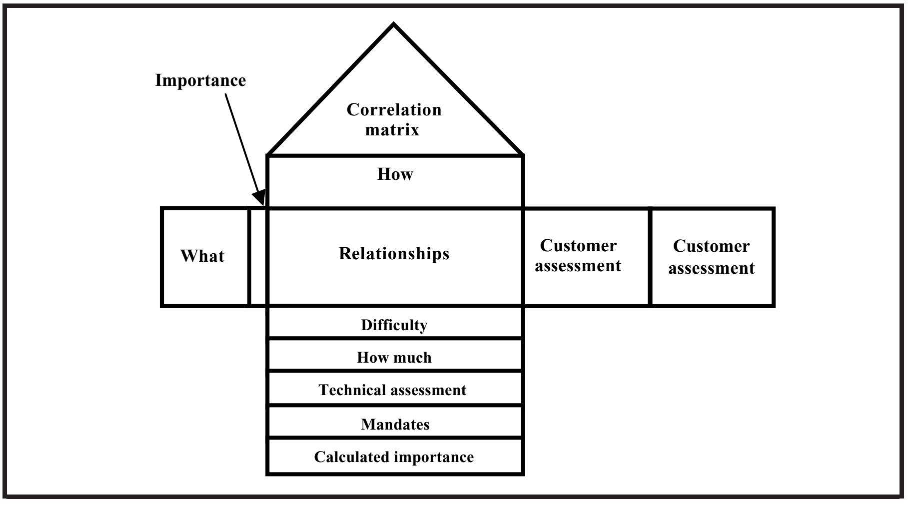

Figure 7S.4 House of quality

gathering and translating the customer inputs and reviewing Kano's model, the QFD process is ready to continue to Phase I, Product Planning.

Phase I: Product Planning

As in all the phases the first step is to determine the "whats" and "hows" of the subject in question. In Phase I, the "whats" are the criteria identified by the customers. The "whats" can also come from mandates, such as manufacturing location requirements, or government regulations, such as meeting safety rules and obtaining permits, licenses, and certification. The "hows" are a list of measurables that describe the product or service performance characteristics without dictating the design. Importance ratings of each area are required, and come from both customers and the organization. How each of these affect the other form a basic matrix called the relationship matrix. The relationships are reported on three levels: strong, moderate, and weak. They are marked with geometric entities: a double circle, a circle, and a triangle, respectively. Figure 7S.4 provides the essential elements of the house.

The relationship matrix is the central portion of the "house of quality." It provides a mechanism to show the fit between the "hows" (characteristics) and the "whats" (needs). There are several other matrices or "rooms" which aid in design optimization and decision making. The "whats" and "hows", and the "how much" measurements help determine values necessary to satisfy the performance measureables. For example, the "how much" specifies the exact requirement for a basic parameter such as a coffee temperature of 200 °F, or a Pentium 4 processor operating at 2.8 GHz. Once the relationship matrix is completed, conflicts between the "hows" must be identified. This section of the house is the correlation matrix, and is more commonly called the "roof" because of its shape. Actions may be required to resolve conflicts. These decisions require the organization to determine whether to develop the technology on their own and shelve the NPD program, or terminate it. Sometimes the "how" that is causing the conflict with another may be removed if the company feels that it is not an important performance measure. Knowing how customer satisfaction will be impacted is important to the decision-making process. The correlation between the customer needs and the product characteristics can be either positive or negative, and the negative ones offer the best chance of nipping potential problems in the bud. The roof of the HOQ offers the best perspective from which to view strategic moves regarding technology.

There are several other sections of the "house" used during the first phase. The most important are the technical and customer assessments of the organization's product(s) or service(s) as compared to those of competitors. This is a form of *benchmarking.* Information, such as the number of complaints and service repairs, can help prioritize these assessments for the team. An important aspect of these matrices is that they can give the organization insights concerning areas where the competition is ahead or behind. This information can help the team to plan for areas to attack. If an organization or its competitors are weak in a specific area, this graphic information identifies the area to develop. This can lead to a competitive advantage for the company. The technical assessment is done by the organization establishing how it perceives its product compared to others in the market. If the company considers itself weak, but the customers indicate a strength is required, this information identifies that this area has to be improved. It may also indicate that the company is not as well linked to the VOC as it thinks.

With this information the QFD team has everything it needs on one sheet. This is one of the nice features of building the "house of quality." Everything that is truly important to the customer is right in front of the team. The goal, however, is not to generate the matrices, they are simply a mechanism for organizing the data. The basics outlined above on the formulation of the "house of quality" can be modified and customized for each organization. There are software packages available to help in the database of information and development of the matrices.

At this point Phase I is complete. What remains is only to decide what specific items of Phase I are to be passed on to the next phase: Design Deployment. This is done by looking at all the information together and identifying areas that the team feels they should pursue. These may include areas where the organization is ranked poorly or areas where all competitors are equal, yielding an opportunity to "blaze ahead of the pack." This information is then traced back to the "how" category to identify the exact area which will become the "what" of Phase II. The "what's" related to the "how" category directly link back to the customer wants. All other areas where the organization is doing well at satisfying the customer are left alone, and are dealt with as they have been in the past, outside of the formal QFD.

Phase II: Design Deployment

In Phase II the design/part characteristics are formed into the "how's". The system works in the same manner as the process outlined for Phase I. The relationships between the "whats and hows" are made, as well as any correlation. The "how much" characteristics are the actual values that define the part characteristics. With this information the design can take place. The core members of the QFD team who are product designers/engineers use this information to develop a plethora of concepts or design options. Detailed designs should be limited as concepts only are required at this point. Selection of the concepts can be done in a number of ways, one being the **Pugh Concept Selection**. Once a concept is selected, then details can be worked out. The Pugh Concept Selection was developed by Stuart Pugh of England as a method of comparison. It can be used to quickly reduce the number of alternatives. Here is an example of how it works. If the QFD designers have developed six new concepts for a new product, the six concepts are presented in the same manner, i.e. blueprints, prototypes, etc. These concepts can be represented across the top of a matrix. The "what's" of Phase II are listed in the right-hand column. One concept, possibly the existing product that the company may wish to replace, is used as a baseline for a comparison. It doesn't matter which concept is used as long as there is a baseline established. Next the team goes through the list of "whats" and evaluates each concept with reference to the baseline. If the concept is better than the datum, the matrix is marked with a "+," if worse a "−," if the same an "s." This methodology works well because it allows the team to compare individual attributes of a concept rather than the entire concept as a whole. In the end each column is added up to total the positives and negatives. The concept(s) which deserve the most attention are those with the most positives and least negatives. This becomes the new starting point. The winning concept at this point should not necessarily be the final one chosen. Another benefit of the Pugh Concept Selection is that it creates an easy way to evolve designs. Concepts/options can be combined with others using the positives from each individual area. This allows for the inclusion of the best ideas into one or two designs that address the customer wants and desires in Phase I. Customers are actually pulling the product and the value directly from the organization. For more complicated designs, evaluation can be done using "value engineering" which breaks down the concepts into the basic components and defines them by function and cost. Several designs, including competitors' designs, can be evaluated this way, identifying the most economical and most functional designs. Whatever method is used, a final design is selected.

At this point a confirmation of the VOC is recommended. Using prototypes, team members should take several trips out into the field. This is a small investment to ensure that the organization is on the right track and is accurately translating the VOC. After this is done, the design is completed and fully detailed. This is done by listing all components that will comprise the completed design. Each component of this “bill of material” will have physical attributes associated with it, noted such as “length,” and “weight.” These attributes of the individual parts become the “how’s” of the Phase II matrices. By completing the relationship matrix the QFD team is able to determine what impact they make on the performance characteristics. If a blank column is found, then the part characteristic is not important and can be removed from the matrix. If a blank row is discovered, then part characteristics should be redefined. This is because the performance requirements were identified as important to customer satisfaction and were the reason it was deployed from Phase I. The finite values for the part characteristics are the “how much” inputs. These can be determined by testing and experiments. When these values are determined, importance and manufacturability ratings can be assigned. Once this is done the part-characteristic values, which are the most important to performance and most difficult to manufacture, can be passed on to the “whats” of Phase III. Parts that are important, yet easy to make do not require any further QFD, and focus should be on other more-complicated or problematic aspects.

Phase III: Process Planning

Phase III happens simultaneously with Phase II because the design and the process are best developed together. With cross-functional teams working on the NPD program, those in manufacturing may criticize the design with respect to manufacturing and production. Phase III is very much like Phase II, because a process is being designed. The important issues from Phase II are the part characteristics and they are part of the “whats” category. These are considered in the light of any internal constraints, such as existing lines or equipment that is to be utilized. In many cases the processes used are familiar ones that the organization has used. New products and new processes are rarely developed together due to the inherent risk. If a new process is a possibility then alternatives can be evaluated using the Pugh Concept Selection as outlined in the second phase. Measurables used to make decisions are focused around C_{pk} values or similar evaluations of manufacturing processes. (See Chapter 7 for details.)

Once a process has been selected, the QFD team must identify the “how’s” in order to use the Phase III matrix. These are identified through an understanding of problem areas within the process by developing a flow chart that outlines each step of the production process. Each step can be identified for process parameters that must be properly controlled in order to produce a part. These parameters must be quantifiable and easily measured – in terms such as temperature, force, pressure, time, and location. At this point the expertise of certain team members is key. Prior knowledge concerning the effects of certain measurables on product quality is a necessity. Other resources and tools can also be used to identify the process parameters, and the team is not limited to the flow chart. Brainstorming and process failure mode and effects analysis (PFMEA) are other good methods to accomplish this. For unknown conditions of new processes, Taguchi's Design of Experiments (DOE) can further aid the QFD process.

Relationships between the part characteristic and its values (the "whats"), and the process parameters (the "hows"), can now be made. Again, like all other phases of the QFD, relationships can be strong, moderate, or weak. An example of such a relationship can be seen by considering cut dimensional lumber marketed to the construction industry. A characteristic of a square cut can be related strongly (to within one-half of a degree) to saw position, and moderately to saw sharpness. After the relationship matrix is completed, an analysis for blank columns and rows is necessary. A blank column indicates that the process parameter is not significant to the part characteristic, therefore it can be removed. A blank row on the other hand is not good. It indicates that the process does not influence the part characteristic and may possibly be replaced with one that will. To complete the Phase III analysis, importance ratings and C_{pk} values (if known/applicable) must be calculated with the process parameters (hows). These values will aid in the determination of the process parameter values or the "how much" values. In the sawing example, the saw's position needs to be controlled to a value of plus or minus one-half of a degree from center in order for the squareness of the cut to be good. In areas where there is a questionable or a low C_{pk} value, (lower than 1.33) experiments can be used to establish target values.

Deployment of the critical process parameters will complete Phase III. The critical parameters are identified as those with unknown or low C_{pk} values, or new processes that the organization is not familiar with. The part characteristics are directly related to the VOC and customer satisfaction. Therefore, this is an important step. Each process parameter that may affect this satisfaction must be passed on to the final phase for its control. In this case all process parameters can be passed on to Phase IV to ensure ultimate customer satisfaction and proper production-floor control.

Phase IV: Production

In production, value is added to the raw material that is transformed into a final product. In the previous phases, QFD matrices were used to aid the entire process. In Phase IV the matrix is an identifier of areas in which to implement action plans for production control, training, and improvements. This phase is the most customizable of the phases, because most production processes are not identical from one company to the next, especially in different industries. Each organization must develop the fourth phase on their own to best suit their own needs and those of their customers.

A simple relationship matrix can be used in the beginning of Phase IV. The process parameters from Phase III become the "whats." The associated values of the process parameters are placed in a separate column. Importance and C_{pk} values are noted in their own columns as well. In this phase of the QFD it is important to identify potential failures that could occur. This is best done with PFMEA. A risk assessment in the areas of severity, frequency, and detectability is encouraged. Numerical values on each level are attached to each risk. A total risk value can also be generated by adding all values of the importance, C_{pk}, and risk assessments, and weighing them appropriately. Then all values can be referred to in one number describing the risk factor in obtaining customer satisfaction.

The "hows" of the relationship matrix must represent improvement plans for all the process parameters. Depending on the industry, these plans can vary greatly. Equipment-operator training and total preventive maintenance (TPM) are plans to address machine variability and operator errors, etc. In other cases, process sheets and statistical process control (SPC) charts are necessary. Instruction sheets and standard work operating procedures are other methods of controlling certain process parameters. Quality control and inspection also come into play with this process. Even though the QFD will have implemented the most robust design and process, it is necessary to detect variability or defects (manually or automatically). The relationship matrix will link these action plans to the specific process parameters.

True teamwork can be realized at this point, with those who operate the shop equipment. If they can understand and identify areas that influence customer satisfaction, the QFD will have been successful. With a robust process and controls in place, the operator's job will become easier to do. Everything that happens to the part in the shop should add value that reaches the end user. Thus, the use of continuous improvement methods such as Kaizen activities will allow the process to get better and better.

QFD at Chrysler Corporation

The big three automobile manufacturers in the United States have been using QFD for a number of years. The US automobile industry was the first major industry to start using QFD as a response to Japanese imports dominating the US market with low-cost and high-quality products. Chrysler Corporation is one company that needed help on the domestic front. After the success of its "K" platform, Chrysler went about reinventing itself. The fruits of this endeavor were realized as Chrysler created many exciting products during the early 1990s. One such vehicle was the Dodge Neon. QFD had been used in specific areas of vehicle development in the past, but the Neon represents the first product developed completely using the QFD process. The case, which is cited in the *Transactions from the Sixth Symposium on QFD*,[4] focuses on one aspect of the QFD process. The interesting focus was on the desired quality of making the Neon "fun to drive." This, like most responses from the VOC, is rather subjective. Regardless of this fact, the QFD team was able to identify quantifiable properties that could be associated with the customer desire.

Steering and suspension characteristics were translated from the customer desire for a “fun-to-drive” quality. This was done via interactive clinics with consumers benchmarking many vehicles in the Neon’s class. Once criteria were set in terms of measurable values the team started the design. Concurrently, a testing apparatus for vehicle chassis and suspension systems was developed. This apparatus allowed the team to test the designs in the real world and understand what engineering specifics were needed in order to fulfill the “fun-to-drive” request in the physical sense.

When the team completed their process, a robust manufacturing plan emerged using PFMEA and Poke Yoke (mistake proofing) devices. The rear knuckle of the suspension was identified as being particularly important to satisfying the “fun-to-drive” customer desire. The VOC was also considered on the shop floor and resulted in a very specific location for a punched hole in the knuckle. Chrysler stated that the real benefit of the project was how “it changed cultural awareness” by showing the importance of utilizing team behavior and how the critical location of a hole could be directly linked to the customer quality request of “fun to drive.”[5] The efforts of the QFD team at Chrysler were appreciated by consumers and testers alike. “More than anything else, the Neon is a real kick to drive. Let’s be stronger: it’s more fun to drive than anything in its class. The Neon’s handling is better than good. It’s quick, it’s lively.”[6] (From, *Detroit Free Press*, January 1994.) It is apparent from this statement that Chrysler had a winner. The lesson learned is how important it is to identify the desires of the customer. Translating subjective information into engineering specifics takes practice. The confirmation step built into the second phase of the QFD process helps companies to make sure that they got it right. Other Chrysler products prove that this approach is working. Innovations in design, such as the driver-side sliding door pioneered by Chrysler on its mini-vans, is one of many examples.

QFD at Puritan Bennett

Puritan Bennett (PB) is a completely different story. In its first use of QFD, the company “bet the farm” on the new process in order to stay in business after a terrible blow by a competitor. This company’s products, spirometers, are made utilizing QFD similar to the Chrysler story. A spirometer is a medical device used to measure lung capacity. This is done asking the patient to inhale/exhale into a tube. Some spirometers are disposable and have a ball in them which measures capacity. Others are electronic and receive data, compare it with standards, and provide recommendations. Spirometry is used for identifying certain diseases.

PB had a large share of the spirometer market. Then, its largest competitor introduced a version of the device for half the cost and eroded the market share that PB had enjoyed. In order to stay afloat PB had to cut costs on their unit by 60%. PB was determined that this was untenable and that a new product would be needed to stay competitive. QFD was selected as the best bet for the company and the target market was identified. PB sales were lacking in the General Practitioner segment, where their competitor had focused. In this market segment "bells and whistles" are not desired, and the primary operator of the equipment is the head nurse. With this information the VOC was researched. The cross-functional QFD team identified numerous desired attributes from low cost and portability, to multi-functionality and re-useability. With this information the team completed the first "house of quality" and had this to say about its benefits.

Once completed, the House of Quality became a vehicle for communication. The House of Quality did not automate PB's design. But it did ensure that the technical tradeoffs reflected the needs and desires of the customer, and that the customer-contact people understood the technical tradeoffs. Throughout the development process the House of Quality provided an organizational history, and framework for making decisions. It suggested areas of investigation and provided a means to evaluate potential solutions. It provided a common language (the customers) to discuss and resolve alternative approaches. It made sure that the right information got to the people who needed it, at the time they needed it. In short, it enhanced communication and focused the design process on the customer.[7]

In the end the design that was chosen was vastly superior to anything in the market and the product was available at a cost of more than $400.00 less than that of its competitors. The design was modular and allowed customization via software enhancements. PB regained and increased its market share and the QFD process allowed PB to develop the product smoothly and quickly. The use of QFD definitely saved PB, and allowed the company to switch places with its major competitor. The use of QFD gave PB a strategic and competitive advantage over all of its competitors.

QFD at The Wiremold Company

The Wiremold Company is the leading manufacturer of wire-management products. The business was founded in 1900. Its products were made from stamped and roll-formed steel. During the 1980s, plastic/non-metallic products and the telecommunications industry were the prime areas for the growth of the company. During the late 1980s the organization made a dramatic improvement in the way it did business. The organization focused on improvements using Kaizen techniques. Moreover, the company began the use of QFD "as the core competency for new-product development."[8]

At the time that Wiremold made these dramatic changes, corporate missions and goals were redefined. One challenge that necessitated the use of QFD was the goal to develop 16 to 18 new products a year instead of just 2 to 3 per year.[9] Prior to the implementation of QFD, Wiremold functioned like many organizations using the "throw it over the wall" development process. At that time, product development cycle time was 24 to 30 months. It has been reduced to 6 to 9 months, with a 3-month goal.[10]

Wiremold's products are not very "high tech." The strategy for keeping competitors at bay was to use better manufacturing through Kaizen and introducing many new products. QFD provided the balance that would complement the Wiremold "just-in-time-production" system.

Since Wiremold first used QFD, it has had many successes. It broke the six-month mark in new-product development for its new line of full-capacity radiused fittings for fiber optic and category-five communication wiring for its 4000 series dual-channel raceway. During the development of the 4000 series raceway system, Wiremold first conducted QFD. The 4000 series project was a product enhancement, not a totally new product. This is a good way to start. QFD, at first, was cumbersome, so starting with a smaller-sized NPD program is recommended.

The G4000 was a gray-surface, metal dual-channel raceway. It was divided to incorporate power and data wiring. Numerous receptacles and fittings were available to suit a variety of customer needs. It had been in the market for about 15 years and was starting to lose market share to aluminum and plastic raceway systems available from competitors.[11]

Wiremold needed to focus on getting the true VOC. Many individuals on the cross-functional team were unfamiliar with getting inputs from customers. In this case, end users were not the only people Wiremold needed to consider as customers. Architects for industrial, commercial, and institutional construction projects were important participants to listen to and develop good working relationships with, especially if Wiremold was to expand into new areas such as residential construction. Wiremold, like most companies just starting QFD, experienced many pitfalls at first. "The team was often bogged down in the process."[12] They had failed to translate the wants of the customer and had a difficult time generating engineering measureables from their data. They also followed the system religiously and got buried under a "massive pile of paper."[13] They went to a QFD symposium and discovered they were not alone. One saving grace was that they had utilized a QFD consultant to help them with their first QFD endeavor. This is another highly recommended step that many organizations have discovered. "QFD is a process, a guide and aid, not the Ten Commandments."[14] Many companies abandon QFD, failing to understand this point.

With the aid of their consultant the QFD team was able to understand how to listen to the VOC and determine customers' true needs. A request for a "raceway in many colors" was found to have a root want of not having to paint over the existing gray color for a more commonly requested off-white color.[15] Using this information, the company introduced the V4000 raceway, a durable ivory-color version of the product. The new enhancements to the 4000 series also included features that resulted in labor savings at installation. Pre-cut covers in common sizes, along with special field tools were developed to address this need. New sleek plastic device plates that hid the seams of joined covers were also developed. This new enhancement addressed customer concerns about certain aesthetics. All enhancements were made in both ivory and gray.

Through the use of QFD, Wiremold was able to transform its old product into a very appealing package for numerous customers. Wiremold also supplies the figures to support its success:

- Total system sales have increased 66%.
- New-device-plate sales are up 100% while old-version sales have declined.
- V4000 ivory-colored raceway sales are up 150% from 1993.
- Installation time reduced by over 70% (a big plus for contractors).

Wiremold continues with its success with QFD and cites a 75% reduction in NPD cycle time. This allows them to meet its corporate goals of releasing 16 to 18 new products a year. Through its devotion to Kaizen and QFD over the past several years Wiremold has been able to achieve this with no increase in headcount, showing a tremendous productivity improvement. Since it started with QFD, Wiremold has doubled in size, from internal growth and acquisitions, and continues to supply high-quality products to the market place.

Other perspectives on QFD

The major disadvantages of the QFD process are added effort and money. Even though the process excels at reducing the time it takes to bring new products to market, it does require more time from the individuals who are on the cross-functional team. As a proactive approach to product development, QFD utilizes more resources up-front. Some organizations do not have the necessary resources to devote to a co-located and cross-functional team. In that case it is best to develop the resources first. Certain members may not be able to devote the necessary time to the team in order to make the process work. Team members must be relieved of previous responsibilities, have proper time for learning QFD and must represent as many areas of the company as necessary. Often management is unable to "let go" of certain personnel for a specific time period, even though much of the up-front work of the QFD is planning.

Organizations who use QFD benefit from a change in corporate culture and members often wonder how things were ever accomplished without QFD. The company must be willing to change, and upper management must truly believe in the QFD process. QFD, like many new methods introduced to companies, must have "buy-in" from upper management. If upper management is the champion of such change, it will aid in the success in the implementation of the QFD process.

Another common disadvantage of QFD is the complexity of completing a useful "house of quality." This is the step many teams get bogged down on, and the team can benefit from consultants or facilitators. Many teams fail to understand the VOC and create a long list of customer wants. However, "house" is a matrix and can become quite large. Usually many customer "wants" can be combined into a more general category which will work. The focus should be only on those customer inputs that are truly important. There may be a customer "want" that is very insignificant and the team should eliminate it from the analysis. If teams focus only on creating the matrices of QFD, then that is all they will accomplish; making a pretty picture. QFD facilitators at Ford Motor Company recommend considering only around five customer wants at first, on a relatively manageable product enhancement, in order to see the benefit of QFD.[16] Considering too many customer wants can frustrate the team and cause the organization to abandon QFD entirely. These are not the only disadvantages to the QFD process. There are others that are due to the organization's culture and disfunctionality. QFD will evolve quite well in companies that already understand the value of cross-functional teams and already have them in place. The fact is that an organization must be ready to invest what is necessary to make QFD work.

QFD as a strategic tool

When the basics of the QFD process have been explained, the strategic properties of the process can be understood. Two immediate benefits include the continuous improvement process and returning to the VOC. In the first phase the correlation matrix may have revealed several areas where there was conflict and required the organization to make adjustments. These adjustments may have been required because of undeveloped technology, yet the customer "wants" reflect the need for the technology to be developed. The company may decide to go on without that certain attribute in its product. At the end of the QFD, the team can return to this area and consider developing the technology required to satisfy the customers. The QFD process easily identifies those areas of technology that the organization should be focusing on.

The QFD process also has other strategic benefits, and one obviously is the competitive advantage over others in the same market. Typically QFD results in better products and a reduced development time. Costs are also reduced while producing a superior product that consumers want. One reason is that changes in designs/processes are worked out during the first phases of the QFD. For example, if the team determines that the product must be easily recyclable half-way through the QFD process it may indicate that the true VOC was not determined. Once the VOC is properly translated issues of this sort are very rare, while in traditional organizations that do not have QFD, this is the norm. This traditional way is much more costly in terms of time to market and the development cycle. Because companies who use QFD can avoid costly mistakes such as retooling and engineering changes, superior products are developed quickly and cheaply allowing companies to price the products below the competition and maintain profits. This is a tremendously good position to be in. Therefore, choosing the QFD process for an organization is a choice with a strategic intent, which in time can help bring the company to the head of its industry and allow it to tower over its competitors.

Conclusions

QFD is more than a tool that can improve the product development cycle and product quality. If properly learned and administered, QFD is an important methodology which organizations rely on as a strategic advantage! It is an advantage that provides tremendous improvements in customer satisfaction and improvements in the company itself. It is a powerful agent of change in the corporate culture. In an effort to become more competitive, companies turn to QFD as a solution. Whether companies are truly successful depends on implementation. QFD, as seen in several cases in this chapter, can work. There are problems and solutions, but both depend on patience and the desire for the organization to change. The first requirement is straightforward the second is not. Individuals in an organization may change, but success is achieved only when the entire organization is ready for a cultural change. The culture of QFD does not leave the company after NPD programs are completed. It dominates the organization, helping it to make the best choices, and to achieve better alignment with customers and with technology development. It also allows the organization to be better prepared for the rapid changes that affect global markets and industry.

Notes

1. The Wiremold Company, *The Wiremold Company QFD Handbook*. West Hartford, CT: The Wiremold Company, p. 6.
2. *Ibid*.
3. Proactive Product Development, Inc., *A 3-Day Workshop on QFD, A Proactive Development Methodology*, 1995, pp. 2–6.
4. QFD Institute, Making the Neon Fun to Drive. *Transactions from the Sixth Symposium on Quality Function Deployment*, June 13–14, 1994, 497.
5. QFD Institute, *Ibid.*, p. 507.
6. Id.
7. QFD Institute, *Transactions from the Fourth Symposium on Quality Function Deployment*, June 15–16, 1992, 133.
8. QFD Institute, We design it with our ears. *Transactions from the Sixth Symposium on Quality Function Deployment*, June 13–14, 1994, 456.
9. *Ibid.*, p. 455.
10. *Ibid.*, p. 456.
11. *Ibid.*, p. 457.

12. *Ibid.*
13. *Ibid.*
14. *Ibid.*
15. *Ibid.*
16. QFD Institute, Strategic management of standard QFD. *Transactions from the Fifth Symposium on Quality Function Deployment*, June 21–22, 1993, 360.

8 Marketing strategies and methods: conceptualizing and designing the new-product marketing campaign

Introduction

This chapter examines the strategic marketing aspects related to new-product development (NPD); discusses marketing strategies and plans; and explores pricing, promotion and communications, and distribution techniques. From an NPD perspective, the marketing objectives, strategies, and programs must fit the realities of the business environment and the expectations of the selected market segment(s). The formulation and implementation of the marketing strategies and action plans have to be in alignment with the entire NPD program. The approach is to create a marketing plan that is tailored to the specific requirements of the NPD program and that will lead to a sustainable position.

The marketing plan is not only dependent on the business situation but on the capabilities and resources of the organization. Marketing of new products requires nuances that are different from the marketing of established products. The process for determining the marketing requirements involves the same cognitive considerations as the creative process for conceptualizing, designing, and developing the product itself. Marketing requirements for a new product are fraught with challenges and uncertainties, especially for new-to-the-world products. The market requirements and the appropriate marketing methods may be substantially different from those used for existing products where well-established techniques have been tried and proven in the market. For new products, using standard marketing mechanisms may represent a shotgun approach toward reaching potential customers, risking high expenditures and low penetration rates.

The precursor step to establishing the marketing plan is the identification and articulation of the needs of the target market, and the determination of how the overall market and NPD program objectives can be achieved. The identification includes reviewing the product/market opportunities and the value proposition, and expressing a clear understanding of the customers' perspectives concerning the benefits of the new product. The value proposition and the expression of customer benefits set the stage for generating suitable marketing messages that will resonate with potential customers.

The overarching message focuses on how the product meets customer needs, and provides the value and benefits derived. The value proposition translates the product positioning strategy into relatively simple communication mechanisms that convey the essence of the product in language that potential customers can readily understand. For example, Michelin's focus on safety and reliability sets the stage for its entire marketing campaign, centered on the thoughts about family and security. The clearer the value proposition and message, the easier it is to generate an effective marketing campaign.

Chapter 8 includes the following topics and learning objectives:

- Understanding the strategic marketing requirements and implications.
- Examining the marketing strategies, especially those pertaining to pricing.
- Exploring methods for selecting the pricing strategies.
- Determining the methods for the marketing communication and promotion programs.
- Selecting methods for distribution.

Strategic marketing aspects related to new-product development

Strategic marketing and the market perspective

Strategic marketing for new products requires careful thought about the driving forces impacting on the business and market environments, and the goals and objectives of the NPD program. Integrated product development (IPD) infers that the marketing program is developed concurrently with the development of the concept and product. It requires a convergence of NPD principles and practices with marketing approaches. The fundamental goals of strategic marketing are to identify, select, and develop the best combination of product/market attributes that can be communicated to the market at a reasonable investment and in a timely manner.

Strategic marketing places customers at the center of the attention and concentrates the organization's marketing programs and resources on gaining customer awareness, interest, and acceptance of the new product. Great care has to be taken not to think just in terms of the traditional marketing mix (product, price, promotion, and place) and the selection of standard marketing methods to cover the situation. For example, TV advertising is often very effective for mature, high-volume, consumer products that have a national audience and broad acceptance. Such advertising tends to be cost effective because there are an adequate number of customers in the population to justify the high cost of TV advertising. Conversely, for a new product with a limited base, a focused approach tends to be more effective during the early stages after product launch.

Strategic marketing is the critical starting point in the process of developing appropriate marketing programs for the new product. It includes examining the product/market requirements and the external forces influencing the situation. The external view of the

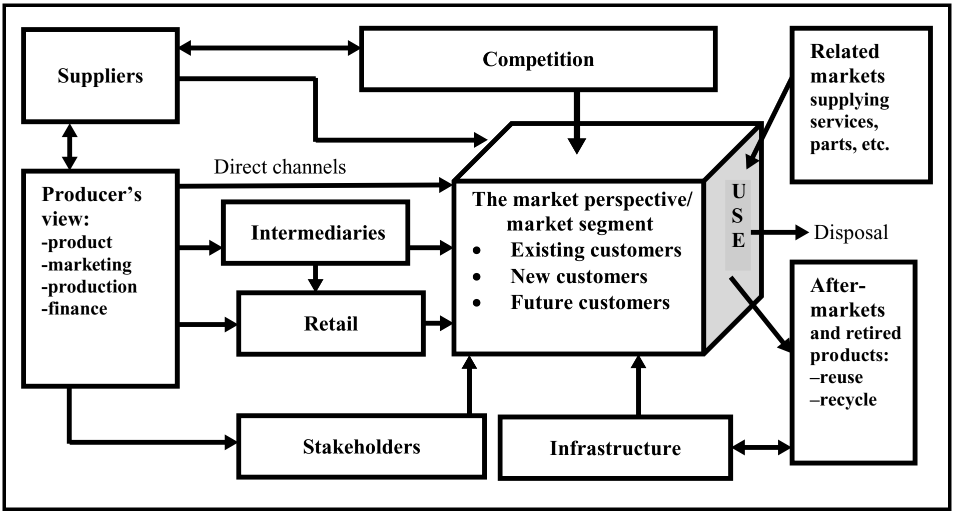

Figure 8.1 The market (customer) perspective of the new product

essential elements of the process explores the economic, market, technical, social, and competitive aspects of the existing conditions and trends.

The purpose of strategic marketing is to describe and analyze the key elements required to characterize the product design and marketing program selection in sufficient detail so that management can be assured that nothing has been overlooked and that the best choices are made. It includes selecting the methods used to conceptualize, design, and develop the product and the marketing programs in the most effective manner; maximizing the positive product features, functions, and benefits, and minimizing the negative aspects.

Strategic alignment, as discussed in Chapter 2, provides an integrated perspective for developing and marketing new products in a wide array of business situations. The focus is on: (1) market opportunities, customer needs and wants, product attributes, product and process specifications, marketing requirements, and technology issues; (2) the interrelated effects of customers, consumers, stakeholders, regulatory agencies, and competitors; and (3) the use of product life-cycle assessment as a tool for making sound business decisions.

The strategic framework includes the primary elements of the product delivery system and examines both the primary side of product creation, production, marketing, and the application side of product use and its afterlife. It includes an analysis of the business environment, based on the market and with customers as a central part of the system. Figure 8.1 provides a broad view of the market taken from the customers' perspective.

Figure 8.1 is essentially a modified version of the enterprise-management model (EMM) and its dimensions as discussed in Chapter 2. The previous version of the

EMM was viewed from a producer's perspective where the internal product and process aspects are at the center. The external perspective is a derivative that includes the same dimensions (markets, supply networks, stakeholders, the infrastructure, related industries or markets, competitors, and the new product producer), except that the center of focus is the customer and/or the market.[1]

The market perspective is important for the development of the marketing programs, because it provides an understanding of the linkages that exist from the customers' point of view. The raw materials flow from upstream suppliers to the new-product developer who produces products and provides services. The new product is delivered to customers through the distribution channels or directly through the resources of the producer. The selling channels include direct sale to customers or distribution channels and through one or more intermediaries and retailers (for consumer products). Customers use the new product for one or more applications during its useful life. At the end of its life, the product is retired and has to be disposed of. Disposal includes all of the downstream mechanisms of managing the retirement of the product, including open-loop approaches such as incineration or landfilling and closed-loop methodologies such as reuse and recycling.

Stakeholders are the supporting, challenging, confronting, regulating, or controlling entities that play a role during the life cycle of a product. Stakeholders include the local community, consumers in general, environmental groups, political parties, regulatory agencies, and the international community as discussed in previous chapters.

The infrastructure supports the flow of the product to the customer, the use of the product during its lifetime, and the elimination of the residuals after the product is retired. The infrastructure also facilitates the flow of information, the transportation of goods or the product, and related activities.

Other elements include competitors, and the related industries. They provide customers with related products and services, alternatives, and additional capabilities. The entire system creates value for customers and, in some cases, if one element is missing there may be insufficient critical mass to achieve success.

Moreover, in some cases, related products are required to complete the product package. For example, Microsoft Office products require virus scan software to function properly. Strategic integration links marketing strategies with product, pricing, promotion, and distribution to create value streams and to achieve a sustainable competitive advantage. Such strategies and programs must be carefully devised and developed to provide value that delights customers and establishes a solid foundation for a long-term capability to satisfy customers.

Market segmentation

Market segmentation was introduced in Chapter 5. It is the categorization of the market into definitive segments that exhibit homogeneous characteristics. Market segmentation is used to target a group of customers having common needs that are identifiable and clustered by behavioristic, geographic, demographic, psychographic, or other patterns.

Behavioral segmentation is based on purchasing patterns or buyer behavior. Some customers tend to seek the same benefits or buy on the same occasions, such as a particular holiday. Greeting cards are typically sold using this segmentation approach. Gift-giving falls into this category. Indeed, there are new product types that are specifically designed and introduced as gifts. Often such new products are classified by the pricing strategy. For example, there are \$20 gifts, \$40 gifts, etc.

Geographic segmentation is a simple and easy way to identify segments. City, county, state and/or regional targets are selected for launching the new product, and all resources are concentrated on the given foci until success is realized. After achieving the appropriate level of success, another area is selected, and the campaign is replicated repeatedly. The logic used to select the target includes identifying the nearest to home base, choosing the largest target or the one with the most potential, focusing on the area with the best fit, and other similar or related considerations.

Demographic segmentation is the broadest and most frequently employed of the established approaches. It considers variables such as gender, age, race, income, etc. It is often easy to determine into which category the ideal customer fits and it provides the means to develop a marketing campaign that is consistent with the needs of the target market. Demographic segmentation, with the broad number of subcategories available, provides the ability to subdivide the market at a level necessary to match the organization's resources with the potential of the market segment. It also allows the NPD team to identify and focus on the best candidates for a new product. Some demographic groups may be easier to penetrate than others. For example, most innovations in the automobile industry are launched in the high-disposable-income (luxury) segment (Cadillac, Lincoln, Mercedes, BMW, Lexus, etc.). Demographic data are usually readily available and are linked directly with market information.

Psychographic segmentation focuses on variables based on personality traits, lifestyle, and motive. Related data may be more difficult to obtain, but may be directly linked to the propensity to buy. Benefit segmentation examines the specific benefits sought by the customer. For example, people may buy a product for the status that it provides.

Effective segmentation of the market allows the organization to focus its attention on the essential requirements of the marketing program. It provides the means of communicating a clear message to potential customers about the new product and its benefits in precise terms related to the identified needs. The marketing program can be fine-tuned to the segment to maximize customer acceptance and satisfaction. Essentially, the methodology is to subdivide the market potential into segments and use a rifle approach instead of a shotgun.

Marketing model – strategies and action plans

New products are difficult to market and sell in many cases because there are limited databases pertaining to the successes and failures of various marketing methods. If the new product is closely aligned with existing products in the portfolio, the task is easier. However, if the product is a new-to-the-world type, a new platform, or a derivative with significant changes, formulating the marketing approach may be a serious challenge requiring insights and creative thinking. A key to success is translating the strategic perspective into a marketing model that all participants can understand. The purposes of the marketing model are to identify and understand the forces at play, to determine the relationships between the organization, its customers, and the competition, and to map out a game plan for the implementation of the marketing program. It describes how the marketing program provides customer satisfaction and shows the linkages between its important elements.

Every NPD program has unique aspects that require careful consideration during its formulation and implementation. It is important to remember that a generic approach may not exist or that it may not work in every situation. Creating a marketing model requires an understanding of the fundamentals. They include the target market segment, the needs of customers, the product positioning in the market segment, the capabilities of existing and potential competitors in the segment, and the marketing-program elements that are required to have a favorable influence on outcomes.

The target market segment provides definition of customer expectations and market potential. The customer expectations are the wants/needs discussed in previous chapters. The market potential depends on the value created and provided. As the potential increases due to enhanced value, generally the market size increases as well. The market potential may be defined as the market-segment size based on the product characteristics and the benefits provided to customers at a given price or value point. The market potential is also dependent on the business conditions and trends, the technical qualities of the product, the stakeholder considerations, and outcomes derived by customers. It is not a given, but in fact a variable relying on the organization's resources and capabilities to aggressively market the product. The more value that can be created in the process of developing a new product, the greater is the growth potential of the product/market.

The company's ability to reach the market potential is dependent on the price that it charges for the product, and indirectly on the cost structure of the product. The pricing strategy is often related to the cost, the technical characteristics and quality of the product, the marketing campaign used to build awareness and acceptance of the product, the production capabilities of the enterprise, and the prevailing market conditions. The latent potential for a new product may be very high, but if the selected pricing is too high then the market dynamics transform the market conditions and the market size into a less-advantageous situation. For example, the prices for personal computers were very high during the pre-Pentium days, keeping the quantities sold relatively low compared with the low-cost Pentium models of the mid to late 1990s.

Customer acceptance of the new product is determined by the customer's view of the benefits and the perceived risks associated with the product, its reliability, ease of use, and long-term value (cost and benefits of ownership). Most potential customers perceive risks when contemplating purchasing a new product. There is uncertainty due to the lack of knowledge about all of the new product's features, functions, benefits, and long-term viability. Hidden defects in design and manufacture may cause customers to invest additional time, money, and effort to resolve the questions or problems. In some situations, the product becomes worthless. If the company goes out of business, customers may not find new sources for the ongoing support services or repair parts. Many of the suppliers of personal computers failed, leaving customers to fend for themselves. Customers may find that there are hidden costs to complete the package or bundle of attributes necessary to use the product beneficially. Moreover, the cost of ownership, including training and maintenance, may become extremely high. For example, a novice buying a personal computer starts a chain of new needs and requirements that include additional software, training sessions, and peripheral equipment.

The marketing program has a powerful influence on the viability of the new product. There is generally a strong relationship between the growth of the market potential for the new product and the money spent on marketing.[2] The critical factors include building awareness and communicating the salient facts about the new product. The marketing program in its various forms provides the mechanisms to reach out to potential customers and bring them the good news about the new product. The marketing program is the link with the market dimension, providing information about the tangible aspects of the product, the definition of the attributes, the information flow through promotion and advertising, and the pathways through the distribution channels.

The marketing model identifies the interfaces between the new-product developer and the potential customers and the market place. The interfaces include: the physical form in the case of the product, or the contacts in the case of a service; the information in the form of pricing and promotion; and the linkages and communications between producer and customer. The marketing model as described in this section portrays the flow of the elements beginning during the Concept Development and Selection Phase and/or Design and Development Phase and continuing through the remaining phases to commercialization and beyond.

The product/market elements are based on the contributions from participants in the conceptualization and design activities and on the insights gained from the customers and stakeholders. These inputs and actions provide details to define the necessary marketing elements.

The marketing model shown in Figure 8.2 suggests a fundamental approach for developing the essential elements of the marketing program. It is not intended to be comprehensive or to indicate that there is no flexibility in the implementation of the

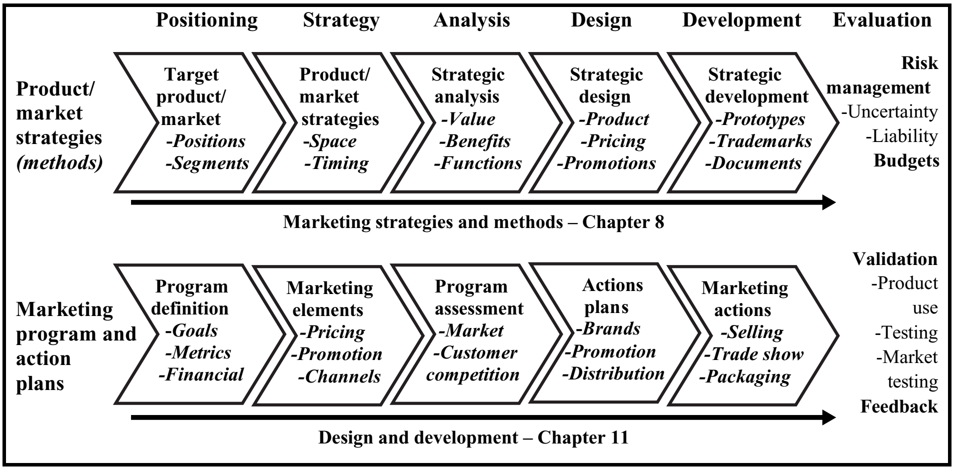

Figure 8.2 The marketing model (fundamental)

marketing program. In some cases, the majority of the work is accomplished during the Design and Development Phase so that the marketing elements can be validated using the various testing mechanisms. In other cases, especially when the program has a more sequential path, as in the pharmaceutical industry, the development of marketing action plans is completed during the later phases of the NPD program because the marketing program is dependent on the finalization and approval of the design of the product.

The framework for the marketing model follows the flow used during the Concept Development and Selection Phase. The starting point is the **positioning** of the program, the product, and the marketing elements. This includes: defining the program in terms of goals, metrics, and budgets; positioning of the product in terms of the target market segment; and selecting the appropriate marketing philosophy for the new product program. The second step, which runs in parallel with the first, is the selection or reaffirmation of the **strategies** for the product/market, the program, and marketing action plans. The third step is a detailed **analysis** of the product/market and business situation. Again, this step may be a reaffirmation of existing information and data; it ensures that the foundation on which the NPD program is built is complete and up to date. The fourth step includes the essential details for the formulation and implementation of the **design** of the marketing campaign. The strategic design examines the external forces, partners, stakeholders, infrastructure, and related markets, to ascertain how they fit into the marketing program and what the action plans for those elements should be. The final step is the full **development** of all of the necessary materials, information, documents, copy, etc. to launch the new product. The development step provides the details necessary for the execution of the program. This typically takes place during the Pre-Commercialization Phase. The evaluation step is normally part of the Validation

Phase, but in some cases selected action plans may precede or supercede the formal validation process. The elements are discussed further in the next sections and in Chapter 11.

Marketing strategies

Product/market strategies

Formulating the correct product/market strategies for the new product is one of the most critical and difficult facets of the NPD process. An excellent product might fail if the decisions pertaining to the marketing strategies are faulty. The most critical point is to convey a clear message to the right **target market segment** about the product and to influence buyer knowledge and behavior. The essential questions are how to select the right target market segment and how to convey the message effectively. The market selection is usually based on a segmentation scheme that provides the best fit for the new product during the introductory stage of its life cycle.

The product/market strategy defines the product's position in the market space; the product's potential life cycle; the expected buyer behavior; economic conditions; and price, promotion, distribution, customer service, and packaging requirements. A **product/market strategy** has two equal parts: the product dimension and the market dimension. The product attributes and characteristics are typically determined by the joint efforts of the designers and the market researchers in conjunction with potential customers. The market dimension is an external factor that is an independent variable. However, the company can make choices about its focus on the market space. It can select the most advantageous segment to concentrate its efforts. The selected marketing approach has to be consistent with the realities of the market during the NPD phases and subsequent stages of market development after commercialization. It must be consistent with the capabilities of the organization to build product awareness and acceptance and to expand market potential and success.

Obviously, the marketing strategies depend on the type of new product. Selecting marketing strategies requires determining the best combination of the marketing resources and programs for positioning the product in the market space and for exploiting its potential over time. The program also requires decision making pertaining to the pricing strategies, the promotional campaigns, and the methods of distribution. The strategies are linked to the objectives. The objectives include: penetrating markets and achieving market share; developing a sustainable, high-quality product, and its attributes; and sustaining the product/market and financial viability.

If the product is a reformulation or a replacement of an existing product, the market structure is usually established and the product must fit into that structure. This means that the options are determined by the market situation. In situations where the organization has products serving existing markets, the strategic alternatives are often constrained by the accepted practices of the organization, by the competitors, and by the prevailing market conditions. For example, if there are existing pricing levels the pricing choices for the product may be limited. In those cases, the product life cycles for such new product types are often in the mature or declining stages. However, if the new product is unfamiliar to the existing markets or it is intended for new markets, the choices are more open-ended.

Strategies are formulated to accommodate the market, product, and financial objectives of the NPD program. In most cases for innovative products, the product life-cycle stages are typically closer to the introductory stage, or possibly the early growth stage. The market conditions are more flexible and there is a broader range of market strategies. There are pluses and minuses to such situations. On the plus side, there are many ways to differentiate the marketing programs from those of the competition. With more options, creativity plays a more-significant role. Given that there is not a prescribed approach, an innovative strategy may lead to a competitive advantage that is difficult for others to duplicate in the short term. For instance, pre-emptive mechanisms to establish a presence in the key distribution channels may make it more difficult for competitors to follow the strategy in those cases where the channel limits the number of competing products carried. There may be a small number of distributors in a region and the first few companies with the new product type may secure the available distributors. On the minus side, the risks and uncertainties are higher. The markets and customers may not be familiar with the new product. Potential customers or stakeholders may not accept the product. There may be unforeseen barriers to overcome. The leader has to blaze a trail that others can inexpensively follow in the future. In such cases, the value-creation process may be captured by the industry participants and not the prime mover. Care has to be exhibited by the leader to ensure that the benefits of the investments in the marketing campaign are sustained for the organization.

Table 8.1 provides some guidance on how to perceive the marketing options depending on the product/market categories. It suggests a general perspective, not a definitive one. “Highly structured” means that the prevailing situation is well defined and that there is not much latitude in determining the marketing elements. Conversely, “loosely structured” suggests that there are many options available when selecting the marketing elements. Likewise, “flexible” means that prevailing conditions are more open-ended. “Uncertain” suggests that considerable thought and effort has to be invested in determining appropriate marketing-program elements, since there is not a preferred or conventional pathway to success.

The product life-cycle stage is a critical factor in deciding how to market the new product. During the introductory stage, building widespread awareness is a critical requirement. The strategy deployment focuses on reaching potential customers and attracting their attention. Awareness building is critical for inducing trial and repeat purchases of the product. Market penetration is an essential mechanism for building the sales volume to the level necessary for reaching the breakeven point and moving

Table 8.1 *Market strategy categories – selecting marketing-program elements*

	Existing products	New products
Existing markets	**Highly structured** • Replacements • Improvements • Cost reductions • New features or benefits	**Loosely structured** • Product line extensions • New-to-the-world • New generations • Derivatives
New markets	**Flexible** • Repositioning (new segments) • Derivatives	**Uncertain** • New-to-the-world • New generations

to a sustainable market share. If the new product is for a mature market, then standard marketing methods often apply.

Product strategy

From a marketing perspective, the critical decisions relating to product strategy pertain to brand equity. Brand equity establishes a tie between the company and the new product. For instance, Proctor & Gamble (P&G) always use a brand name for its products, because P&G wants to capture the full benefits of its marketing campaign for itself and not for the generic product form. It is easy for competitors to benefit from a company's marketing campaign, if there is not a strong connection to a brand name or the company itself. The product may attract attention, but the company may not benefit from the exposure if customers cannot remember the product name or its producer. This is particularly true when using television or radio advertising to reach customers. Competitors simply feed off the demand for the product and offer customers their version.

Brand names help customers relate to the specific product offering and discern the differences between the competing offerings. They help customers to repeat their purchase of the branded product that they enjoy by providing a quick means of identifying the right product. Brand names like "Coke" and "Pepsi" help leverage the marketing effort from one market segment to next one. The "Krispy Kreme Doughnuts" phenomenon is an example where the name helps draw attention from potential customers even before the company expands its presence into a new region. Word of mouth carries the message forward, facilitating entry into the new market segment. Brand names have enduring characteristics that can last for generations.

Obtaining a trademark is one of the best means of protecting the brand name and the related symbols. The rules for obtaining a trademark vary depending on the country. The process involves registering the name and symbols with the government to obtain exclusive usage. Failure to do so may open the door for competitors to attempt to benefit from the goodwill in the market place. Aspirin, thermos, cellophane, and cornflakes are just four examples of names that originated with the companies that created and launched the first-to-the-market products but failed to protect the name; therefore, the names became generics. Trademarks include the symbols used to denote the company or its products. In some cases, the two are embedded in each other. For example, Ford Motor Company uses an oval symbol with its stylized name in the center. It is a good example of a company trademark that has endured for almost a century. Ford has resisted the pressures to "modernize" its symbol. On the other hand, AT&T, changed its symbol to reflect a more-sophisticated and global position. Moreover, there were disputes about the ownership and use of the older version. Based on its reorganizations and new businesses and products AT&T invested in its current trademark. Often small companies do not have the financial resources for investing in a trademark, thereby saving money in the short term but risking the benefits of its efforts in the long term.

Packaging is also an effective marketing tool for conveying the company's message. The package protects the product during shipping and handling, and serves as a vehicle for transporting it.

Proctor & Gamble: innovation and brand management

With annual sales and net earnings of $43.3 billion and $5.2 billion, respectively, in fiscal year 2003, Procter & Gamble (P&G) is ranked as one of the best-performing and most socially responsive consumer-goods manufacturers in the world. It has a five-year annual growth rate in revenue and profits of 11% and 16%, respectively. P&G is a global corporation with operations in 80 countries, selling approximately 250 brands of consumer products to nearly 5 billion customers in more than 130 countries. US revenues account for 54% of the total.

P&G is an integrated manufacturer and marketer of household consumer products and related institutional equivalents. P&G is world renowned for its marketing campaigns and product innovations. The company's operations are segmented into global business units (GBUs) that include the following product groups:

- ***Global fabric and home care*** – bleach and pre-wash additives; care for special fabrics; dish care; hard-surface cleaners; household cleaners; and laundry products.
- ***Global beauty care*** – cosmetics; deodorants, fragrances; hair care; skin and beauty care.
- ***Global health care*** – water filtration; oral care; pet health and nutrition; prescription drugs.
- ***Global food and beverage*** – beverages; fat substitutes; peanut butter; shortening; snacks.
- ***Global baby, feminine, and family care*** – baby bibs, diapers, and wipes; feminine protection pads and tampons; incontinence pads; paper towels, toilet tissue, and facial tissue.

The width and depth of P&G's product mix are considerable. Sustaining and managing the extensive product groups, brands, and diversified products require a considerable ongoing investment and commitment to new-product development. Product planning is largely the responsibility of the company's strategic planners and brand managers. Longevity is a primary characteristic that typifies many of the products. Some of P&G's best-known brands, with their product launch dates, are depicted in the table below. The sustainability of the products in the markets is a testament to P&G's capabilities to rejuvenate its products over time.

With a strong historical commitment to its products, P&G created an organizational structure that continually tracked products during their life cycle to keep them up-to-date. Conceived in 1931, the brand-management concept was established to provide each brand with the resources and management attention necessary for success.

Selected P&G products and year of introduction

Soaps		**Detergents**		**Cleaners**		**Paper**	
Ivory	1879	Ivory Snow	1930	Comet	1956	Charmin	1957
Camay	1926	Dreft	1933	Mr. Clean	1958	Puffs	1960
Zest	1952	Tide	1946	Top Job	1963		
Safeguard	1963	Joy	1949			**Diapers**	
Coast	1974	Dash	1954	**Toothpaste**		Pampers	1960
		Cascade	1955	Gleem	1952	Luvs	1976
Shampoos		Cheer	1956	Crest	1955		
Head & Shoulders	1961	Bold	1965			**Shortening**	
Pert	1979	Dawn	1972	**Coffees**		Cisco	1911
		Era	1972	Folgers	1963		

The brand-management system also ensured that the communications flowed to the proper levels. By design, the vertical flow of information was excellent but the cross-product line flow was limited. In late 1987, John Smale, the CEO at the time, developed the category-management system. He divided the company into 39 product categories and named 26 category-managers; brand managers reported to the category managers. The category-manager concept was designed to give the incumbent the spending power and decision making authority to respond to fast-changing market conditions. In a fast-paced world, P&G recognizes that change is ever present. With all of its successes and enduring product lines, very few consumers would recognize the name of Proctor & Gamble, but most would know about the "power of Tide." P&G is a great example of a company that has used innovation to keep mature products on the leading edge of competitive advantage.

Source

Proctor & Gamble, *Proctor and Gamble 2003 Annual Report* (Cincinnati, OH: Proctor & Gamble, 2003).

Pricing strategies

Selected pricing strategies for new products

Developing pricing strategies for new products is very arduous. Remember Cory's statement, "The art of pricing is to have the price of the product equate to the value received by the customer." The best pricing approach is to determine what value the product

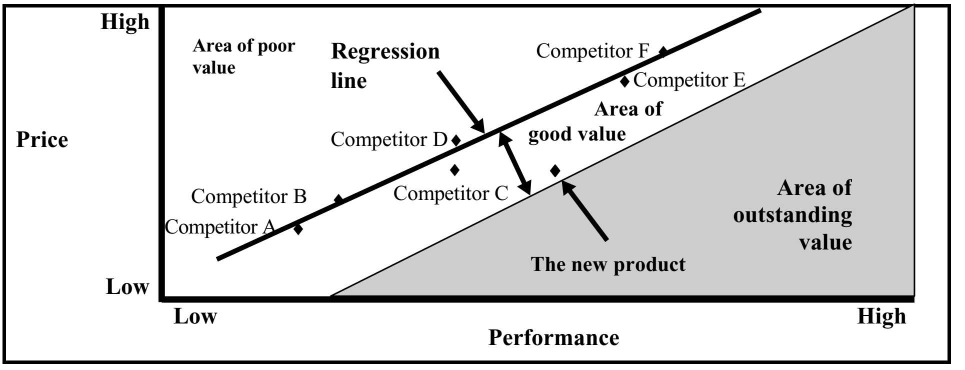

Figure 8.3 Pricing strategy versus competitors in terms of performance-to-price position

offers to customers and price the new product accordingly. This section identifies and discusses various pricing schemes. The choices depend on the market dynamics and the organization's situation.

The **value-driven method** is a relatively new approach. The first step using this method is to assess the competitive products and to determine the performance-to-price position for each of the competitive products. The second step is to calculate the correlation equation of the prices of the competitive products using linear regression. The linear equation represents the fair value line between all of the competitive products. It establishes the parity line. The third step is to determine the performance of the new product relative to the competition. The pricing strategy involves simply selecting a point in or near the outstanding-value area that is superior to any competitor. Figure 8.3 depicts a generic view.

This pricing scheme is an effective way of pricing new products that are superior to existing competitive products in the market. The new product has a price and performance advantage over competitors A to D. It enjoys a price advantage over competitors E and F, even though they have superior performance.

Value-driven pricing may also result in prices higher than the comparable competitors' price. The new product's pricing is based on examining all of the value streams generated by products that enhance customer satisfaction and delight. This means convincing customers that additional value is being provided via additional tangible and intangible benefits. Value-driven pricing examines the value contributions of the entire enterprise and their translation into customer benefits. This requires a sophisticated management system to generate the data and an effective marketing and sales program to convey convincingly the information to customers. For example, customers may perceive greater value from an Internet provider who also provides advice and service. On the product side, customers are often willing to pay more for environmentally friendly products made without hazardous materials.[3]

The **target pricing method** is a more-conventional approach. The marketing function, the NPD team, or senior management sets a target price based on the product cost, sales and marketing expenses, administrative expenses, and the development cost of the NPD program. During the Design and Development Phase or earlier phases, finance determines whether an appropriate profit can be obtained based on the estimates developed by the various departments or the NPD team. If the target price is insufficient to generate the requisite profit, the NPD program is modified or terminated. This approach is often used when market conditions stipulate the price. This is usually the case when the new product is replacing an existing product in a mature market. The same situation is true when there is a price leader who sets the price for a standard or commodity-type product. If there is very little product differentiation and customers are not willing to pay more than the going price it is difficult to successfully set prices that are higher than the prevailing levels.

The two most commonly used pricing strategies for new products are skimming and penetration pricing. The **skimming pricing method** establishes a high initial price during the launch of the product. This mechanism provides customers with a perception of high quality and high value and at the same time provides the means to discount the price of the product through coupons, rebates to consumers, or volume discounts to the distribution channels. Using this strategy, the price can be reduced in the future to meet market conditions. It is based on the theory that it is easier, from a market perspective, to reduce prices than to increase prices.

Skimming is also based on the theory that setting a high price at launch is the best way to recover the investment as quickly as possible and/or to fund a very aggressive marketing program. The strategy is often used by the first-to-the-market competitor with a new-generation or new-to-the-world product. The goal is to maximize per-unit profit and to establish a sense of exclusivity for the customers. This strategy works well when there is a group of customers willing to pay the high prices and there is limited competition. The notion of "lead users" is an important parallel construct for determining who is willing to pay. Using skimming pricing, the marketing program should focus on market segments that are willing and able to pay the high price. Skimming is also appropriate when the production capabilities or the other resources required to produce and deliver the product have limited capacity during the early stages of commercialization. The theoretical view is that it is unwise to stimulate demand aggressively if there are constrains in the management system to meet the customer requirements. It just opens the door for competitors.

Skimming requires excellent competitive intelligence to determine when new competitors may enter the market. High gross margins facilitate entry by competitors since cash flows are normally positive, permitting the market to finance the competitors' position during their launch period. If skimming is used, the price may have to be lowered to meet competitive pressures as competitors become a significant force.

Moreover, skimming may reduce the perceived value of the product for customers. Instead of accepting the new product, they may seek other options that provide better value. Such reluctance on the part of customers may decrease the viability of the product, allowing substitutes or other new products the opportunity to gain a foothold in the market. The most prevalent positive argument for establishing high prices during early commercialization is to convey the image of a superior and high-quality product. This pricing theory is supported by the Kano diagram (Chapter 4), which indicates that customers may be extremely satisfied during the early stages of commercialization if the product delivers exciting attributes. However, this is often only for new-to-the-world products. It may not apply to new products that are simple improvements or are related to the existing product portfolio.

The **penetration pricing method** establishes a relatively low price at launch to stimulate market development and growth. It is used to build market demand quickly and to capture market share. It is often employed when the unit-cost structure exhibits a significant cost-reduction potential based on cumulative volume (the experience-curve phenomenon is discussed in Chapter 10). Penetration strategy is also often used when customers are price sensitive, where economies of scale exist, where there is a strong potential for competitive pressures, when customer awareness is low, or where the market potential is very large. A large market potential suggests that profitability is more of a function of volume rather than price.

Penetration pricing makes entry by new competitors more difficult since there may not be sufficient contribution margin to cover the total cost of the product plus the marketing expense. The first to the market may enjoy a cost advantage until the cumulative volume of another competitor approximates the cost structure of the first to the market, or the volume reaches the asymptotic point. Penetration pricing is also appropriate when the new product is a variation to existing products and there is limited justification for obtaining higher prices.

In either case, Porter's principles on industry analysis as discussed in Chapter 2 pertain. The pricing strategy depends heavily on the power of the buyers and sellers, the ease of entry of competitors, the threat of substitutes, the rivalry among the suppliers, and the capacity of the industry. In some cases, competitors may feel compelled to enter the market regardless of the expense. The Internet is an excellent example of a perceived opportunity that many companies believed they were obligated to address because of its anticipated impact on the future of doing business in their industry.

Figure 8.4 provides a graphical view of the essential differences between skimming and penetration pricing strategies, and Table 8.2 lists the advantages and disadvantages of skimming and penetration pricing strategies.

From a financial perspective, there are other models that are used to calculate the profit-generating pricing. Using the simplified financial equation, total profits are equal to total revenues minus total costs. If the revenue and cost equations can be developed based on the estimated volume, then the profit is obtained by taking the derivative of

Table 8.2 *Perceived advantages/disadvantages of skimming and penetration pricing strategies*

	Advantages/benefits	Disadvantages/concerns
Skimming	High gross profit margins	Stimulates competition due to high margins
	Fosters notion of high quality	Retards market development
	Minimizes negative cash flow	Price sensitivity is an issue
	Reduces production constraints	Delays full market penetration
Penetration	Rapid market development	Requires high capitalization
	High revenues	Longer time to breakeven
	Constrains potential competitors	Low gross margins, requires high volume
	Builds market share	Potential reduction in internal rate of return

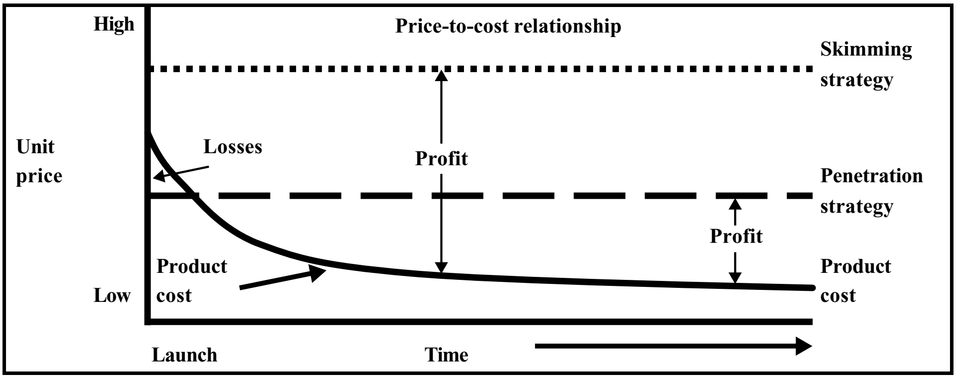

Figure 8.4 Generic view of skimming versus penetration pricing

the equation expressed in terms of profit. This method requires simple calculus. The difficulty is that the equations for price and quantity may not be known in an NPD situation. However, it is a useful technique for pricing if the situation can be quantified.

Another pricing strategy is to establish a targeted gross or contribution margin or net profit objective, and to vary the price of the product as costs decline due to the learning-curve effect, maintaining a constant rate of return on sales. This strategy is easy to understand, but complicated to implement because it requires continuous adjustments in pricing. An acceptable variation to the pricing scheme of establishing/maintaining a constant rate of return is to make periodic reductions rather than continuous ones. This tends to stabilize the pricing structure for a timeframe. The main disadvantage is that if customers realize that prices are going to be reduced, they may wait until the prices are lowered.

The **fixed internal rate of return pricing method** selects the price based on maintaining a given internal rate of return (IRR) or net present value (NPV). (Read the

Supplement to Chapter 6.) The IRR or NPV calculations are worked in reverse to determine the price. The main difficulty is that several iterations may be needed to arrive at the required rate. The time horizon selected for the calculations is also extremely important. A shorter time horizon requires a higher price to maintain a given rate of return. Longer time horizons allow for a lower price, but there is a higher risk that the financial success of the product may be impacted by some other phenomenon in the market, such as other new products, competition, changing customer preferences, etc. There are no simple answers. The analytical techniques help to clarify understanding of the key financial and market factors, but they do not provide foolproof solutions to the pricing dilemma.

A simple example illustrates the method (see Table 8.3). If the original price was \$100.00 per unit and the company had an objective of doubling its investment of \$2 million over four years (2× return) at a 15% hurdle rate, it could set the NPV at the end of four years at \$2 million. Then, it would reverse the NPV calculations of the cash flow to determine what price it has to have for the four-year period to achieve an NPV of 1.0 times the original investment on a discounted-cash-flow basis. In the example, unit costs are \$50 per unit and decline based on a 90% experience curve. Reversing the cash-flow equation gives an answer that the price should be \$90. If the objective was less aggressive, the price would be lower. Conversely, if the NPV objective was higher the price would have to be higher. An objective of 1.5 times the investment requires a price of \$98.65. Several iterations may have to be performed to determine the financial impacts of various pricing strategies.

The price-setting decision process

A systematic method for determining the price follows a strategic process starting with objectives, cost structures, market conditions, and possible competitor reactions as precursors, and then evaluates the pricing options in terms of the best match with internal requirements and external conditions. The goal for most NPD programs is to achieve an appropriate return on the investment, compensated for the risks involved. However, high prices do not always mean high reward. Indeed, high prices may constrain market growth and result in lower profits and returns. High prices and high rewards in the short term may attract competition, affecting both prices and profits in the long term. The most crucial factors in the decision process are market and competitor analyses. Based on the inputs and objectives, making sound pricing decisions depends on a clear understanding of the short-term and long-term effects of those decisions. The key to the process is selecting the pricing model based on the most critical variables. The variables include the time horizon, the window of opportunity, the market demand over the time horizon, unit cost and its relationship to volume, the changes expected in market conditions, the current or expected competitors and their responses, and customer responses to the pricing schemes.

Table 8.3 *Reverse NPV method for determining price*

Profit and loss/cash flow statement – 4-year time horizon				
	2005	2006	2007	2008
Unit selling price ($)	90.05	90.05	90.05	90.05
Sales volume (units)	20,000	40,000	80,000	160,000
Sales revenues	1,801,046	3,602,120	7,204,240	14,408,320
Cost of goods sold	1,000,000	1,800,000	3,240,000	5,760,000
Gross profit	801,046	1,802,120	3,964,240	8,648,320
Operating expenses				
Development cost	100,000	0	0	0
Depreciation	50,000	50,000	50,000	50,000
Advertising	200,000	400,000	800,000	1,000,000
Administration	300,000	400,000	500,000	600,000
Rent, building costs, and other	50,000	50,000	50,000	50,000
Total operating expenses	700,000	900,000	1,400,000	1,700,000
Income from operations	101,046	902,120	2,564,240	6,948,320
Provision for taxes (40%)	40,418	360,848	1,025,696	2,779,328
Net income	**$60,628**	**$541,272**	**$1,538,544**	**$4,168,992**
Cumulative earnings	$60,628	$601,900	$2,140,444	$6,309,436
Profit margin on sales	3.4%	15.0%	21.4%	28.9%
Cash flows	$110,628	$591,272	$1,588,544	$4,218,992
Investment or NPV @ 15%	$2,000,000			$ 2,000,000

The NPD program strategies and the product/market strategies are critical factors in determining the pricing strategy. The objectives for the new product extend beyond financial and market considerations. The purpose of the NPD program may be to solve an existing problem, to satisfy a select group of customers, or to create the perception of being the leader. The new product may be used as a strategic weapon to keep competitors from establishing a foothold in a given market segment. It may be a vehicle to enhance the corporate image or to indicate that the company is being responsive to environmental, health and safety concerns. There are many reasons for introducing and selling a product at a given price. Toyota's pricing for the Prius, as discussed earlier, is an excellent example of an alternative pricing schemes. Toyota is looking to future sales for its profits, realizing that it has to take losses in the short term to develop the "hybrid" market segment.

Product life-cycle considerations are important elements when making pricing decisions. For short-life-cycle products, the window of opportunity is small. In such cases, the philosophy is to exploit the opportunity immediately. Not only is time to market critical, but also the reward has to be realized quickly as well. The pricing strategy has

Table 8.4 *Price-setting decision model*

Step	Process flow	Factors	Comments
1.	Reflect on the objectives and targets of the product and NPD program. Examine the pricing objectives: • Fit • Short term • Long term	Strategic: • Alignment • Resources Market: • Growth • Share Financial: • Profitability • IRR, NPV	The objectives are typically the standard marketing and financial ones. However, there are many other reasons for developing new products. The standard metrics are time, money, performance and risks. These have to be balanced. Social responsibility may be a key factor. Pricing schemes should be aligned with the strategic objectives as well as the financial imperatives. Making money is important but sustaining the outcome is crucial for ongoing success.
2.	Consider the overall business and marketing strategies.	**First to market** **Fast follower** **Strategic delay** **Imitator**	The first to market may have more flexibility in pricing. The follower may have to respond to the prevailing prices. Many new products have to be priced at the going market rate.
3.	Estimate or consider the market demand structure.	**Potential growth and life cycle**	Demand is a variable that depends on price. If the price is lower, the demand may be higher. Measuring the price–demand relationship is critical for understanding the role of pricing in marketing.
4.	Determine the elasticity of demand.	**Elastic** **Inelastic**	The elasticity of demand plays an important role in pricing. If demand/volume does not vary with price, then care has to be taken to determine the right price point. Lowering the price may not increase demand.

5.	Consider costs and their relationship to volume.	**Experience curve**	Unit cost is a powerful variable in the pricing equation. In most cases, unit cost varies with cumulative volume; therefore, if lower prices induce higher volumes, the lower price point may improve sales and profits.
6.	Examine competitors' pricing and costs.	**Existing and potential competitors**	Great care has to be taken during the pricing decision process. High prices encourage new competitors to enter the market. If the price levels hold, high prices provide the resources for competitors.
7.	Review options for pricing using conventional or innovative methods.	**Target** **Penetration** **Skimming** **Fixed return**	The use of the standard methods depends on the situation and the long-term prospects for the new product. Product life-cycle analysis may be an important tool in making the right choice.
8.	Weigh the options and select the most effective method.	**Analytical screening and selection**	Short cycles mean short opportunities. The pricing strategy must fit the situation. There is no generic answer. Remember, there are a myriad of alternatives to the standard models. In many cases, the best solution is a derivative.
9.	Establish prices.	**Set prices**	Prices have to be communicated to the market.
10.	Set game plan for modifying the prices based on changing conditions.	**Adaptation** **Modification** **Flexibility**	Prices are rarely fixed. They exist for a given period and then they have to be changed to accommodate new business conditions. With low inflation, prices are generally lowered, not increased. With the adaptation of a price structure, there should be a game plan for changing the price to stay ahead of changing conditions.

to reflect the need to recover the investment (i.e. breakeven) and gain from the process in a short period. In electronics and computers, the pace of change is extremely fast. The opportunity to generate cash flow and profits is very short. The market life cycle is measured in terms of months, not years. Therefore, the pricing strategy has to be well thought out in advance since there is little time to ponder a solution if the strategy is not correct. In some cases, a high price is the right answer; in other cases, a penetration price may generate volume and profit more quickly.

For long-life-cycle products, there are more options since the timeframe to exploit the opportunity is more open-ended. Nevertheless, the strategic aspects are just as crucial. Penetration pricing may build market share that is difficult for competitors to match in the future. This is particularly advantageous if the higher market share provides the opportunity to build overwhelming strategic assets or positions. AmericaOnline (AOL) was able to build an extensive network as an Internet service provider through creative pricing. Its $20-per-month pricing scheme allowed it to leapfrog competitors.

Setting an appropriate price structure for a new product is both an art and a science. There are many variables influencing the decision-making process, producing a complex situation that requires a systematic methodology to manage it. The price-setting decision model described in Table 8.4 provides a systematic means of formulating, analyzing, and implementing a pricing strategy. It focuses on understanding the goals, the situations, the options, and the implications of the decisions.

Dynamics in pricing

The art of pricing new products is to select the right launch price and manage the pricing strategy over time to maximize the opportunity. As stated in the discussion on the pricing model, the selected pricing strategy is based on the prevailing market/business conditions. As those conditions change, so should the pricing strategy.

Dynamics in pricing refers to proactive pricing strategies, formulated during the design or the earlier phases, that anticipate necessary changes over time and provide a pricing strategy that facilitates the implementation of the changes. Such an approach is generally used when the experience curve provides a significant reduction in the cost of the product as cumulative volume builds. The proactive model either continuously or periodically lowers the price to provide customers with the benefits of economies of scale or other related factors. This is a particularly appropriate strategy when there are strong competitors in the wings who are about to take advantage of the situation.

The reactive model is similar except that the company waits until there are competitive pressures before it makes a move. Using the reactive model, the pricing strategy is maintained until there is evidence that a change has to be made. This approach may improve profitability in the short term, but it runs the risk of providing the means for a competitor to gain a foothold.

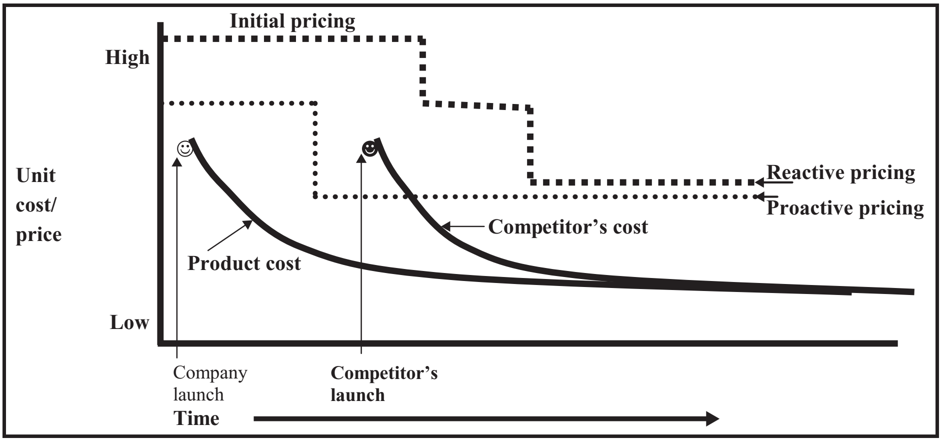

Figure 8.5 Proactive versus reactive pricing models

Figure 8.5 depicts the differences between the proactive pricing model and the reactive models. The pricing of a product or service is always difficult. In most cases, new products are priced following well-established company pricing policies. Such policies provide the directives used by the managers and participants involved with new products. However, there is always a danger that participants who are dependent (their jobs) on the success of the new product may follow their own personal views. The establishment of a committee of unbiased participants or managers to establish the price strategy may overcome the individual biases of marketing or sales personnel or other personnel. The individuals on the committee are theoretically unbiased in the decisions pertaining to pricing. They do not have a personal stake in the new product; therefore, they should use logic rather than feelings when making critical decisions. However, it is rare when there are absolutely no personal views or opinions.

Pricing has a huge impact on the success of the marketing program and the financial performance of the NPD program. Therefore, management involvement in pricing decisions is essential and a fundamental responsibility of the senior management group or the steering committee. The strategic implications of pricing are obvious. Sales, volume, and price are clearly linked to each other, as well as to the probability of success.

Communication and promotion strategies

The communication and promotion factors are simple to identify and define, but the interrelationships between the choices are complex and difficult to ascertain in an NPD situation. The success or failure of a new product often depends on the capability of the communication and promotion programs to reach potential customers and make them aware of the new product and its benefits. For established products, the communication and promotion decisions are based on data and information from the market place, arming marketing decision makers with the knowledge of the viability of the various methods. For new products, especially ones not related to existing products or markets, the best means of communicating with the market are not always apparent. Determining the right mix of communication and promotion methods is also a challenge requiring experience of marketing in general, and insights into the opportunities at hand. The most important perspective is to determine the specific requirements for the new product as opposed to employing the standard array of marketing options. It is a mistake to simply throw some of each option in the marketing mix at the situation.

The communication and promotion mix consists of the following techniques:

- ***Advertising*** – paid messages via the TV, radio, newspapers, magazines, trade journals, Internet, etc. to promote the awareness, trial, and use of the product or service.
- ***Sales promotion*** – methods used to encourage the purchase of the product, including incentives through discounts or coupons, point-of-sales displays, and related materials encouraging the purchase and use of the product.
- ***Public relations*** – any means available, typically through third parties or the media, to influence the market and/or stakeholders about the benefits of the product and the reputation of the company.
- ***Personal selling*** – the mechanisms used to provide information and data about the product directly to potential customers via personal contact or conversation.

In any given situation, the communication and promotion strategies use one or more of these techniques to reach potential customers, convey the messages, and solicit their responses. Within each category, there are a number of options available for meeting the needs of a specific opportunity. The number of combinations is incredibly large making the selection process a significant challenge.

The techniques selected must be in line with the overall marketing program, the market realities, and the resources and commitment of the organization. Moreover, the investment into the communications and promotion programs must reflect the financial implications of the opportunity. If the desired program requires increasing the total investment and lowering the return on investment or internal rate of return, then questions arise about the feasibility of the NPD plan and the suitability of the choices.

When there are many options and the interrelationships between them are complex, the decision-making process is difficult. In an NPD situation, decision makers often simplify the situation by taking an evolutionary approach. The initial NPD program is the combination of the essential tools necessary to build a viable program. Then, based on the lessons learned from the market during the various testing methods or during the launch of the product, the program is modified to reflect the insights and new knowledge. The purpose is to keep the program relatively simple at the beginning, ensuring that the most important or critical tools are used.

Distribution channel strategies

Distribution channels include intermediaries, wholesalers, retailers, value-added resellers who play a role interfacing with the customer, and other mechanisms like the Internet for reaching customers. As discussed in earlier chapters, there is a plethora of options for distributing the new product to customers.

Distribution channels provide the means to reach potential customers. They consist of third-party organizations, which link the product or service with the ultimate customers and provide the flow of information and physical products. The distribution channels may include other entities, which add value by providing specific functions to enhance the benefits received by customers, or they may be narrow connections between the organization and its customers. Distributors often provide a two-way flow of information with the customers and markets. It is the information about the products and their applications that facilitates the proper use of the products and increases the potential for effecting positive solutions. It also includes information about what to do with the residuals after product retirement. Often the channels are the customer's main means of communication about the product and its implications. The customer should know the positive and the negative aspects of the product to enhance the benefits and minimize the negatives.

Historically, marketing methods focused heavily on communicating one side of the value proposition, the positive side. However, the channel entities and the company have a legal duty to provide a full and accurate disclosure of information to customers. This requirement is more complex than it appears because it implies that the channel members have the qualifications to provide the full range of product information for potentially hundreds of applications and situations. It can be a daunting requirement.

Training and education are often critical elements in the overall solution for ensuring safe and effective use of the products. Such services are often provided by specialist organizations, who understand the customer needs and know how to convey the appropriate information. For regulated products, there are often mandates for formal training programs to ensure that practitioners are adequately informed and knowledgeable about proper protocols for achieving acceptable outcomes.

The distribution channel may also provide a link for the flow of used products back to the producers for refurbishment or recycling. In some cases, the channel provides such services for customers or they resell the refurbished products to other customers.

The channel may serve as a conduit for the flow of information about opportunities for handling the afterlife of the products. It may provide the linkages to the support infrastructure of dismantlers, recyclers, and materials handlers who function as intermediaries for effectively moving the residuals to the closed-loop waste-management infrastructure. Table 8.5 illustrates factors that must be assessed when considering the channel's role in logistics and support structures.

Table 8.5 *An overview of selected areas of concerns for the distribution channels*

Dimension	Implications	Assessment
• **Customers**	• Safe and effective use of the product during its life cycle. • Obtaining the maximum benefits and longevity out of the products. • Understanding the best solution for the safe disposal of the product at the end of its useful life. • Taking appropriate and responsible actions to implement the solution.	• What are the best methods for using the product in the most effective manner? • Should a defective component be replaced with a new or used part? Or should the product be retired? • Are its components near the end of their useful life and likely to fail? • Should the product be repaired or retired? • Is there another customer for the used product? • What is the best retirement option?
• **Channel participants (out flow)**	• Understand the responsibilities that are inherent with the handling of the product. • Know what information has to be conveyed to customers for the effective use of the products.	• What are the critical factors that have to be managed to ensure the safe and effective use of the products? • What information is essential for the customers to ensure proper use and applications? • What restrictions must be adequately communicated to customers and stakeholders?
• **Channel participants (reverse flow)**	• Providing the information and potential solutions for product retirements. • Facilitating the flow of materials through the infrastructure to effect the solutions.	• What are the needs for the channel to provide services to customers and users to effect solutions to product-disposal issues? • How can the channel link the service providers to ensure a complete solution? • What are the necessary communications mechanisms?
• **Infrastructure**	• Providing support to create opportunities for reverse logistics. • Eliminating constraints in the flow of materials across the life cycle.	• What are the required improvements or additions to the infrastructure? • What is the cost? Who will pay? • Is it economically feasible to improve the infrastructure?

The list is intended to illustrate the potential contributions that the channel participants can make in effecting improved solutions. The opportunities are multifaceted and the challenges are complex. The BMW example offers insights about how solutions require the inputs and contributions of the original equipment manufacturer, the dealer network, and the support system provided by the scrap handlers and dismantlers.

Methods for marketing communication and promotion

Overview of communications and promotion considerations

The marketing communication and promotion program is the sum of the means to influence the market with a compelling message and to prompt potential customers into action. Advertising and promotion generally focus on building awareness, while public relations and personal selling usually focus on inducing trial and use. It can be argued that personal selling involves the entire process from generating awareness to encouraging trial and purchase.

The process of developing a communication and promotion program is straightforward. While the process elements are easily mapped out, the specifics of the programs and the actions required to achieve success in the market are more complicated. The flow of the elements follows the methods identified during the Program Definition Phase. The flow is based on the goals and objectives of the overall NPD program and the marketing strategies to reach the target market. Table 8.6 indicates the steps in the process.

Designing and developing the communication and promotion program is a significant challenge and an absolute necessity for most NPD programs.

Advertising

Advertising is a powerful means for creating attention in the market segments and building awareness of the product. It is an effective vehicle for reaching a broad array of future customers. It has the ability to reach the primary target, and it can extend deep into the array of individuals often involved in making decisions about new products. For example, the buyer may not be the user, or the decision maker may be tangentially involved as the provider of the funds. Advertising can often influence all of those involved.

The main concern with advertising in a new-product situation is overreaching the intended market. If the new product is to be rolled out geographically, the distribution channels may be too limited to have the product available to all of the customers who become aware of the product through the advertising. Even in those cases where there is a large-scale introduction of the product, the product may not be available to the entire market place. Such overreaching of the market may provide opportunities for competitors to step in and offer their products as a substitute for the new product. The effort simply supports others who can take advantage of the weakness in the channels or elsewhere.

While overreaching the market may be viewed as building for the future, it means that current resources (money) are not being effectively used in the short term. In the case of a new-product failure, the long term may not exist. Indeed, the misapplication

Table 8.6 *Steps in developing the communication and promotion program*

Step	Description	Purpose
1.	**Determine the target audience**	Selected from the target market segment, the target audience is a group of customers or potential customers who are receptive to the program or who may influence others. The target audience is the focus of the program. It might include all potential customers, depending on the resource commitment and scope of the program. It includes the "lead users."
2.	**Identify the primary goals and objectives**	The typical communication problem is that the entity tries to do too much. It is critical to establish the aim and goals of the program. The standard approach is to try to sell the product, rather than building awareness and encouraging trial. The objectives of the program should be as specific as possible and to the point. For example, "the goal is to build awareness." The objectives should focus on the who, why, what, and how.
3.	**Design the content and format of the message and select the means for its delivery**	Based on the objectives, the critical step is the design of the message. The message is embedded in the content of what is conveyed to the audience. The structure provides the fit with the target audience's understanding or perception of the content.
4.	**Determine the resources available to launch the program**	Based on the objectives, financial capability, and the metrics of the program, the next step is to determine a budget for the total communication and promotion program.
5.	**Specify the promotion mix**	Designing the promotion mix is complicated because the questions relate to both the type and level of commitment for the options available. The process includes determining the viable alternatives and understanding their fit in the program.
6.	**Test the viability and measure the effectiveness of each of the elements**	The selection process is a continuum. The selected approaches should be evaluated during the testing protocols and their effectiveness reviewed. If a choice appears to be questionable, the allocation of resources to that mechanism should be reconsidered and changes made if appropriate.
7.	**Manage the process and take corrective actions whenever necessary**	The process requires ongoing attention and evaluation. The effectiveness of the choices has to be monitored to determine their suitability. If one or more are not effective, then changes should be implemented quickly.

of resources may contribute to the failure since those resources might have been needed in other areas.

The main reasons for advertising are:

- ***Building awareness*** quickly and producing an image of quality, capability, stability, and strength. Customers generally know that it takes a lot of money to advertise and may equate the ability to advertise with having the strength to carry out the claims. The Dot.com companies used this as a means to convince customers that they were viable. However, the failures of many of the Dot.coms may have tarnished this perspective.
- ***Reaching unclear targets.*** Advertising is an effective mechanism when the profile of the targeted customer is fuzzy. While advertising may overreach the market, the cost may be low per individual reached if it is not clear who the potential customer is and a shotgun approach is required.

The most important element of the advertising campaign is the **message**. While creating an effective message is an art form, the essence of the message should come from the value proposition and the fundamental perspectives developed during the Concept Development and Selection Phase. The message should be relatively simple, focusing on the primary benefits that are prioritized from a customer's perspective.

Standard advertising vehicles include television, radio, magazines and trade publications, newspapers, the Internet, and direct mail. Each has advantages and disadvantages. Each mechanism has to be carefully analyzed to determine its suitability and effectiveness. There is no simple way to characterize the situation. Advertising requires a significant expenditure of funds to create the copy and the messages. TV advertising involves investments into the commercials, infomercials, etc. The expenditures include the up-front costs of developing the messages and the ongoing costs of delivering the message. Advertising is more effective for an NPD program having an official launch. In such situations, the advertising campaign can be coordinated to reach the targets synchronized with the action plans of the other initiatives, i.e. production, distribution, and the other marketing efforts.

Advertising may not be appropriate for all new-product situations. It may be too costly or may fail to achieve any near-term results. Table 8.7 provides a simple overview of the advantages and disadvantages of the principal advertising mechanisms.

The frequency of advertising is an important issue. It generally requires many repetitions before a message makes a significant impression on the typical customer. The standard rule of thumb is that it takes five to ten repetitions to get a message through. However, for a new product that requires significant awareness building, the actual number may be many times more. This is an important consideration when thinking about response time to sell the product and establish cash flow. If it takes six months to build awareness using advertising, sales volume during the early launch period may be very thin as sales lag behind the placement and appearance of the advertisements.

Table 8.7 *Advantages and disadvantages of various advertising vehicles*

General	Advantages	Disadvantages
Television Most appropriate for building awareness; useful for simple messages; low cost per person reached.	Reaches broad audiences; can be focused on selected segments; builds image as a credible entity, since most people believe that TV ads are expensive and that it takes deep resources; can reach multiple parties involved in more-complex purchase situations.	Overreaches the market; costly in terms of actual penetration; requires many repetitions to get the message across and to have it stick; difficult to explain complicated products, especially for new-to-the-world products; requires a significant investment and commitment; pays dividends in the long term, but may not in the short term.
Radio Directed toward local markets, more focused geographically; useful for reaching commuters.	Greater ability to be selective in the audience from a demographic point of view; different formats reach different audiences, AM versus FM; low cost per person reached providing flexibility in applications; easy to change message.	Limited audiences, especially at certain times of day; more unpredictable in terms of audience make up; programming is not predictable; sports are effective outlets, but the scheduling aspects are difficult to manage.
Magazines–trade publications Highly focused according to subject matter; well established cycles; good statistical analysis.	Reach well-defined, targeted audience; inexpensive per specific prospect; journals usually send cards with information on inquiries; fast response time, journals are published monthly; copy for ads is transferable to other media if necessary; demographic breakdown is often available from publication.	Requires a substantial commitment; lead-times are relatively long, requiring ongoing commitments to ads before results are available from initial periods; requires significant amount of research to determine the right venue; if the audience proves to be inappropriate there are usually limited secondary benefits; advertising in high-circulation magazines has long lead-times; requires many insertions to get definitive results.
Newspapers Local media outlets; broad audience that can be segmented by section of paper.	Effective in reaching higher-end groups, better educated, higher incomes; local content can adapt message to local conditions; provides a good level of flexibility, including the ability to have cut-outs.	Expensive for a long-term, wide-range program, requiring ongoing insertions in many newspapers to achieve necessary coverage; very short duration and impact, one day; difficult to obtain the premium space, easy to get lost in the noise.
Direct mail Local reach; directed to households; ability to target families.	Can target specific households; inexpensive per individual contact; excellent vehicle for standard message and uniform marketing campaign.	Extremely poor response rates, easy to get lost in the clutter of junk mail; may become more expensive as postal rates increase.

Timing is another critical issue. It takes time, effort, and money to produce an effective advertising campaign. The lead-time is based on the cycle to create the copy and other means to produce the advertisements, and the sequencing of the actual delivery of the advertisements to the media. For example, wholesale buyers of children's toys may read the appropriate trade journals just prior to the annual trade shows in February. Missing the placement of an advertisement in the trade journals by a single month may result in missing the buying season for an entire year. Just like the products themselves, advertising tends to be seasonal in many industries.

Advertising budgets are an important subset of the overall marketing budget, which itself is an important subset of the total investment. How much to spend on advertising is a critical question and the answer depends on many factors. The following provide some guidance for decisions about the commitment of resources for advertising:

- Explore the company's databases to determine what has been invested in advertising similar products, examine the successes and the failures, and ascertain the reasons for the outcomes.
- Determine whether there is a correlation between advertising expenditures and the revenues generated for similar products. External sources may be used as well. For example, trade journals may conduct such research and provide the relationship between advertising expenditures and inquiries by potential customers.
- Examine external databases and other sources such as government agencies (Department of Commerce) to discover the relationship between advertising and sales.
- Examine what your competitors spend on advertising when launching similar new products. Such data may be obtained indirectly by reviewing their advertising programs and ascertaining the costs of such programs.

In some cases such as a start-up company, the expenditures for advertising have to be significantly more than for established companies. The advertising campaign has to have the dual role of promoting the products as well as building awareness and trust in the company itself. Deciding on the correct mix can be difficult. Established companies may employ a formula that is used for every new-product situation. For small companies, budget constraints often limit advertising from an affordability basis.

The media mix is a combination of advertising mechanisms. Typically, an advertising campaign includes several of the media outlets in order to reach the market. For example, TV advertisements might be used to stimulate the retail side, while trade journals might be used to communicate with the wholesalers and attract their interests and actions. Often, the media-mix strategy is determined using an experimental approach. The initial mix is based on existing data and analyses of previous cases. The results of the initial selections are carefully monitored during the early stages of commercialization. The ineffective approaches are then eliminated and the scope of the effective ones is expanded.

New-product marketing strategies: Dermabond topical adhesive

In early June 2002, Johnson & Johnson's Ethicon Division began advertising its four-year-old topical adhesive, Dermabond, in major magazines (e.g. *People*) and during daytime cable television shows. Dermabond is a medical-grade adhesive comprised of a chemical called 2-octyl cyanoacrylate. It can be applied in less than three minutes to wounds or incisions. Cyanoacrylate is the primary ingredient of most "super glues," including the market-leading Krazy Glue. Even though off-the-shelf super glue cannot be prescribed for patient use, some dermatologists have been recommending it to their patients for many years.

What makes the Dermabond advertising campaign special is that it directly targets consumers with a product that is "for professional use only." Pharmaceutical companies often advertise their products directly to consumers using a variety of media, and these techniques have brought them increasing criticism from doctors who claim that the companies are trying to make end-runs around them. However, the Dermabond campaign is the first time that a manufacturer has attempted to stock hospital supply shelves by direct advertising to the consumer.

Ethicon owns the marketing and distribution rights to Dermabond, but the product is actually manufactured by Closure Medical Corporation, in Raleigh, North Carolina. Closure uses the same type of adhesive in two other products for oral care and veterinary medicine.

The benefits of Dermabond include fast application, no painful needles, no return office visits, and the material provides a seal that helps prevent infection. Dermabond does not usually sting during application to an injury. The glue simply sloughs off as the wound heals, in seven to ten days. These advantages make Dermabond particularly suitable for use on small children.

Dermabond was introduced in late 1998, after receiving Food and Drug Administration (FDA) approval, and is now seen in about 90% of the emergency rooms in the United States. So far, it is the only topical medical adhesive to receive FDA approval. The adhesive is even used in operating rooms, for procedures such as cesarean sections. It cannot be used on gaping wounds or those that are bleeding profusely. Other areas where Dermabond will not work include the lips, inside the nose, and around the eyes. In addition, use on moving joints is inappropriate, making it sometimes difficult to use on the feet and hands.

Ethicon has also begun to sell an over-the-counter version of Dermabond called Band-Aid Liquid Bandage. Some observers worry that the over-the-counter version could create problems from consumers that are not properly trained in its use. The manufacturer, Closure Medical Corporation, is also testing a thicker variant of Dermabond to be used on more-serious injuries, as well as another version that could be used to close internal wounds.

Sources
Becker, C., Sewing up 'liquid stitches.' *Modern Healthcare*, July 8, 2002, 10.
Pender, K., Small firm expanding line of liquid bandages. *San Francisco Chronicle*, April 18, 2002, B1.

Public relations/publicity

Publicity is the broadest means of marketing communications. Publicity uses third parties to build awareness, gain credibility and visibility, and educate the markets and stakeholders about the new product. Publicity includes news releases to the press, articles, and other positive statements about the product and the company. It represents newsworthy information focusing on building public acceptance and goodwill. Generally, publicity is free of charge, but since it is controlled by third parties, it is difficult to orchestrate. The fact that it is free is the good news. The fact that others control the scope, content, and placement makes it less reliable as a means for achieving market success.

Publicity about new products is a favorite topic for the trade journals. Innovations are newsworthy and are typically special-interest items. Obtaining media attention is the difficult part. A news release requires a special twist to gain notice in crowded industry journals. Special features or benefits like positive environmental impacts may offer a way to overcome the barriers to placement. When writing the copy for press releases and the like, the attention should be on the information provided to the industry or stakeholders and not on trying to sell products. Remember, the hurdle is getting the item placed. Unless the information is credible it will not be used and the opportunity will be lost. The more exciting and fresh the story is, the more likely it will be carried by the media.

Sales promotion

Sales promotion involves very broad categories that include many facets of an effective marketing campaign. The approaches depend on the type of product and the industry conditions and trends. There are four significant goals associated with sales promotion. They are:

- ***Building awareness and credibility***. As with advertising, building awareness is a fundamental goal that triggers downstream actions by customers. First, the potential customer must be made aware of the product and its features and benefits, then there must be a clear message that the product and company are credible and do not represent a significant risk or waste of time and money to the customer.
- ***Communicating product information and marketing-program details***. Promotions provide links with potential customers, who typically require a considerable amount of information to make the favorable decision to buy the product. The product information has to be available to answer questions that arise. Likewise, information has to be conveyed about the marketing program to the distribution channels on how to entice pontential customers.
- ***Positioning the product and the company in a favorable light***. Promotions generally try to link the awareness-building aspects with the actions of the customers.

Promotions should be a sequential process of building the customer confidence in the merits of the new product and soliciting interest on the part of potential customers.

- ***Generating inquiries and incentives for action***. Promotions and marketing communications in particular are geared to not only convey information to prospective customers, but also to get them to initiate action. The desired action depends on the situation. It varies from getting prospective customers to seek additional information to getting them to inquire actively about purchasing the product.

The overall approach is to integrate the four facets of an effective program into a seamless effort. For example, brochures about the salient features, functions, and benefits of the product not only provide the necessary product information, but they also help build acceptance and gain credibility. High-quality brochures portray the company and its products as distinctive and worthy of further examination, which tend to induce the customer to take additional action.

The market categories for promotions include those for consumer products and services, industrial goods, and those geared toward government-related markets. Regardless of the market category, brochures and other forms of printed or electronic communications, trade shows, and promotional materials tend to be used effectively to gain attention by potential customers. Given that there is a vast array of methods, this discussion highlights only those that represent general schemes. Table 8.8 provides an overview of selected methods and the advantages and disadvantages of each. The list is not comprehensive. The advantages and disadvantages identified are a brief summary of some of the salient points.

Each of the above methods must be analyzed in the context of the situation. Some of the methods may be selected based on feasibility criteria. For example, contests require substantial efforts and levels of engagement that small companies may not have the resources to execute effectively. On the other hand, certain methods may be forced on the organization by the distribution channels or even by the customers. Retailers often require point-of-sales displays before they agree to carry the new product. Retailers may believe that special attention has to be given to the new product to draw customers to it. They may also want a commitment on the part of the new-product organization to promote the product before they are willing to invest money into inventory and shelf space. There are many reasons for such requirements, but like end customers, retailers try to reduce their risks with the new product.

The whole notion of promotion and marketing communications is based on the conviction that “products do not sell themselves.” It takes aggressive marketing to achieve success in the market place and every means possible must be used to “pull” the product through the channels.

Personal selling and sales methods

Personal selling represents the “front-line” interface with the markets and/or the channels to encourage customers to actually buy the product. The primary efforts of personal

Table 8.8 *Advantages and disadvantages of selected promotion vehicles*

Vehicle	Advantages	Disadvantages
Industrial		
Brochures	A flexible means to convey product information; cost effective for multi-languages; easy to have various formats, including those providing technical details.	Difficult to change or expand without significant cost; usually produced in large quantities; expensive, especially during the early stages.
Trade shows	Meeting place for a wide variety of potential customers; customers expect to view new products at trade shows and may be willing to take their time to explore the benefits; it is not necessary to know who the potential customers are ahead of time; stakeholders may be positively influenced.	Expensive and time consuming to set up; control of process is in the hands of the show promoter; seasonal; difficult to predict the value of the expenditure; competitors also obtain information on the new products; a lot of distractions, including the new products of competitors; limited time.
Newsletters	Focused approach for getting information to potential customers and for building credibility.	Expensive and time consuming to prepare; recipient may not devote time to reading.
Seminars	Excellent means for communicating a powerful message; good for establishing a dialogue.	Difficult to get the right audience to attend; requires substantial lead-time to get on the agenda of the principals.
Consumer		
Point of sales	Useful techniques for getting prime location in retail outlets; multifaceted approach for displaying product and communicating the message.	Expensive; requires large commitment, since in most cases they have to be produced in quantity; difficult to change the message.
Internet web pages	Flexible; inexpensive; readily available 24 hours a day; easy to change languages and formats.	Difficult for new company to get attention; there is a lot of clutter; information is available to competitors.
Samples	Excellent for getting customers to try the product; builds goodwill with customers by reducing their risk of trying the product; can lead to decisions concerning useful product size for special occasions.	Expensive; difficult to get into the hands of the "right" customer; requires special sizes of the product, consuming production time; usually requires some form of advertising.
Giveaways	Free, usually evokes positive goodwill; more effective if there is personal contact involved; can stimulate interest in company and other products.	Can be expensive, especially if there is a quality item involved; requires substantial information about the market to be effective.
Coupons	Useful for getting attention; good for inducing trial; can be a simple way to temporarily cut the price; good approach for limited time frame.	Discount image; can be costly, especially to prepare and distribute coupons; requires other media approach such as mailings; not effective as a stand-alone.
Contests	Generates interest; can build awareness and excitement quickly; can convey a positive and fun image to the product.	Expensive to orchestrate, needs to be large scale for effectiveness; can be confusing; can have negative consequences by creating too many losers instead of winners.

selling are those of salespeople who communicate directly with the market entities and potential customers.

Sales methods involve a multiplicity of approaches that are as varied as the situations that they address. The key to success for the sales organization and related people is to determine which methods are appropriate given the situation and the resources. As with advertising and promotion, there is not a single answer, but some of the options are:

- Recruit, select and train a dedicated sales force.
- Re-deploy the existing sales force or add the new product to their charter.
- Hire external sales representatives.
- Sell through other organizations or associations.

The major benefits of developing a new sales force to handle the new product are focus and dedication. A sales force that is solely engaged in selling the new product and is not distracted by other opportunities or requirements may provide better results in the short term. The salespeople have a single mission: sell the new product. This approach is most often used for large complex products that require significant amounts of direct involvement with potential customers to articulate technical and commercial information and details. The negative implications include high costs, the long lead-times to find and train the sales force, and the limited opportunities that the sales people may have to engage customers because they only have the new product to sell. From an IPD standpoint, the main advantage is that the sales force can participate fully in the NPD process without other distractions.

For simple additions to the product lines or other uncomplicated modifications to existing products, using the existing sales force is a cost-effective method for selling the product and getting the product introduced to customers. Assuming that the salespeople are adequately trained in sales techniques and have knowledge about the product portfolio, the main hurdle is to train them about the product itself. The more profound obstacle is the normal reluctance of successful salespeople to spend time selling products that require a lot of time to achieve the sale. Because of the lack of awareness and knowledge about the new product(s) on the part of customers, the process of selling new products usually takes more time than selling the existing product offerings. Unless there are incentives for the salespeople, the new product may not get the attention necessary to achieve success during the early stages of the launch.

Hiring an outside sales organization may be a cost-effective solution during the NPD process and launch of the new product, and it tends to minimize the investment for developing the product. By leveraging external resources, the organization can focus its attention on areas that it deems to be critical for achieving success. However, there are several significant concerns associated with using representatives from other organizations. Sales representatives may not wish to be involved during the NPD process, since there is a limited opportunity to make money. Representative organizations are usually good at selling, but may not have the skills necessary or the willingness to contribute to product development. Like an internal sales force, representatives tend to concentrate their efforts on products that are relatively easy to sell; or where commissions are commensurate with the effort. A new product typically requires a significant investment by the sales people before making the sale. Sales representatives, who depend on selling products on an ongoing basis to earn a living, may view the new product as a luxury that they cannot afford. Often they are too busy trying to be successful in the short term to be concerned about the long term. Additionally, sales representatives may have neither training nor interest in the new product. They may convey the wrong perspective about the new product to customers. Representatives are rarely engaged on an exclusive basis, but in most cases, they do not sell the products of competitors. Analysis of the situation is critical when determining whether to use representatives.

Selling through trade associations and similar organizations raises the same issues as when using sales representatives. The main advantage is minimizing the up-front investment. In some cases, it is absolutely necessary because of the nature of the product or the industry structure. For example, laboratory equipment and supplies are typically sold through agencies or supply houses. The main disadvantages are the lack of specific attention given to any product and the fact that competitor products may be sold as well.

Regardless of the organizational form used to sell the product, there are many specific techniques that are used during the selling process. The techniques include direct personal contact, telemarketing, trade shows, testimonials, presentations and networking. Table 8.9 lists some of the common methods, and their advantages and disadvantages.

Methods for distribution-channel selection

The choice of channels to distribute the product is crucial in the strategic marketing plan. The comments pertaining to the selection of advertising and promotion also pertain to the selection of distribution channels. The options have to be carefully weighed and the right mechanism selected. Not everything fits! For example, Dell Computer sells directly to consumers through the Internet and telecommunication methods. When it attempted to establish a distribution channel with retailers, the more-complicated system required many changes to its enterprise that it could not sustain. After failing to achieve its goals using channel means, Dell decided to revert to the direct marketing and sales approach and has achieved tremendous success over the last decade.

The channel may be extensive with many players involved, or it could be quite simple with only one entity between the new-product organization and the end customer. It could be argued that the Internet is a distribution channel with the service provider being the single entity. In other cases, the new-product organization has another company operate its Internet sites and that entity becomes the channel operator.

The choice of the channel structure, and the participants therein, is further discussed in Chapter 11.

Table 8.9 *Selling techniques and their advantages and disadvantages*

Techniques	Advantages	Disadvantages
Direct personal contact	Generates goodwill and personal attention; customers are more inclined to repeat a purchase from an individual who they know and trust; flexible approach for meeting all of the customer's needs; excellent means to convey a broad array of information; easier to make on-the-spot adjustments.	Expensive and time consuming; requires well-trained and dedicated people; a bad salesperson is often worse than none at all; more difficult to control the message and actions.
Telemarketing	Quick way to reach many customers; useful approach for validating customer interest; inexpensive; low cost per contact.	Over-used by many organizations; contacts are too busy to respond; occasional problems with bad information.
Trade shows	Great for getting in personal contact with many potential customers to obtain feedback on what approaches work; good for "show and tell"; good way to obtain contacts.	Expensive; requires large commitment and many salespeople; difficult to determine specific objectives to be achieved.
Testimonials	Excellent for establishing credibility; third-party endorsements reduce the efforts required to convince customers; personal approach is usually compelling.	Difficult to get customers to agree to provide such statements; may be difficult to authenticate the messages; takes time to get such replies.
Presentations	Effective way to get the message across; can standardize the message to be conveyed by entire sales force; can be automated using infomercials and "canned" approaches.	Does not have spontaneity; inflexible; standard approach may not be appropriate for diverse audiences; takes away from the personal touch.
Networking	A simple mechanism for establishing contacts, generally by word of mouth; selling is personal and contacts often provide a testimonial; good for generating leads.	Works well for established products but may not be effective for new-to-the-world products.

Marketing budget

The marketing budget represents an overview and summary of the marketing programs. It provides a means for analyzing the financial implications of the programs and assesses each of the elements with respect to the total budget. It offers insights into the entire marketing picture, and facilitates determination of how the resources have been allocated and how the overall marketing construct fits with respect to the available cash assets.

The marketing budget provides a view of the expected expenditures both in the aggregate and with respect to the elements of the programs. It can also be used for controlling the allocation and application of resources to the overall NPD program.

The marketing budget is typically divided into two categories: one pertaining to the need and use of non-recurring expenses, and the other pertaining to ongoing or periodic expenses. The first category represents the required commitment to each of the specific marketing programs. It includes preparing the copy for advertising, the development of commercials for TV advertisements, etc. without which the actual programs cannot be initiated. The expenditures are for the precursor steps that are necessary to launch the programs. Most of such expenditures are made during the NPD process (before the launch). Without the up-front investments, the ongoing expenditures are usually not possible. Items in the second category have more flexibility. They represent discretionary items that can be expanded or scaled back as the situation demands during the launch process. For example, advertising in a monthly trade journal can be cut back to bimonthly if circumstances dictate change. Funds can be reallocated from one area to another, or they can be shifted altogether.

During the early launch, the investment is funded from cash flow using the resources of the organization. The level of expenditures is prescribed through the budgeting process, and is based generally on a formula for determining the proper level of resources required for achieving success. Assuming that success is achieved in the market place, the cash-flow burden shifts from the organization to the market place. The required funding is obtained through the cash flow from sales.

The budget can be based on calculating the cost of implementing the desired marketing programs using the sales forecast as an indicator. This construct is expanded upon in Chapter 10 in the sections covering forecasting and financial statements. During the early stage of commercialization, marketing expenditures often exceed revenues, making the typical percentage of revenues method for determining marketing expenses impractical. For new products that are related to existing products, the appropriate level of marketing expenses can be determined by using the historical data from the company's previous experiences. Moreover, it can be ascertained from industry or trade organizations that track such data (the relationship between marketing expenses and sales).

Budgeting requires good estimates from the sources of expenditures. It is an iterative process of building information into a comprehensive model. The basis for the initial allocations is an estimate of what is necessary to achieve the expected level of sales. The alternative approach is to spend as much as possible or what might be viewed as all available funds. Over time, the approach shifts to a more-conventional approach such as spending a given percentage of revenues on marketing or allocating the marketing expenses in terms of gross margin. There are many techniques that can be used to rationally determine the proper level or the maximum funding. The relationship between funding for marketing programs and the increase in revenues tends to follow the

"S curve" phenomenon. It takes a significant level of marketing expenditure during the early stages of product introduction to generate a revenue stream. After a certain level of expenditures and market success (i.e. the inflection point has been reached) revenues increase at a higher rate for the next increment of marketing expenditures. Finally as the process matures, additional increments of marketing expenses do not generate significantly higher levels of revenue. The process plateaus as maturation fully blooms. At that point, the relationship between marketing and revenue is well understood and forms the basis for allocating future funds.

The marketing budget provides input to the pro-forma financial statements as discussed in Chapter 10. It is linked to the scheduling of the activities and provides information for the planning and definition aspects discussed in Chapter 6.

Additional insights and concluding comments

Marketing strategies and methods for new products have to be carefully conceived, analyzed, and constructed. Conventional thinking may not lead to success. Innovative thinking is essential for developing creative solutions for obtaining successful outcomes. New products require well-defined marketing approaches that are tailored to the requirements of the market segment(s), the attributes of the product, and the capabilities of the organization. The marketing plan should be developed based on the objectives and goals, and the overall strategies, of the NPD program.

The new-product situation requires careful consideration of the marketing mix. The strategic aspects of market positioning are pivotal in laying the foundation for a comprehensive marketing plan. The foundation depends on the type of new-product situation. Simple improvements can use marketing methods that leverage the ongoing marketing campaigns. The more radical the new product is, the more the marketing effort has to be tailored to the specific needs of the target market segments and the unique advantages of the new product. Great care has to be exercised to ensure that marketing efforts reflect the new-product situation. The most frequent mistake is to use conventional marketing approaches to formulate and implement the marketing program for a new product.

Pricing is one of the most challenging requirements. There is not a single plan that assures success. Pricing strategies have to be thoroughly analyzed and selected based on meeting short-term and long-term objectives. The key to marketing management is to achieve both, or at least obtain a balance between the two. Skimming pricing may provide high gross margins but may retard the growth of the market. Penetration pricing may create rapid demand but it often requires additional investments in the short term to cover early losses. Other pricing schemes such as "return on investment" pricing offer alternatives to the conventional pricing models.

Promotion and communications strategies are essential for building awareness and acceptance. Long-term success depends on building a critical mass of customers who purchase the product and are satisfied with its attributes. Each of the principal methods has advantages and disadvantages in an NPD situation. Advertising reaches large audiences but it is costly and can overreach the target market segment. Promotions are often more targeted but require extensive efforts to reach the entire market potential. Personal selling works well for industrial products. Publicity is inexpensive but difficult to control. Each method has its place in the marketing effort. It is crucial that the marketing professionals think through the options and select the elements of the marketing campaign based on the needs of the new-product situation. There are cases where the new product explodes on the market scene and is an instantaneous success. In most cases, success is achieved through dedication and sustained efforts.

Notes

1. Scholars and new-product professionals might argue that this version should be considered the primary model and not viewed as a derivative. The most compelling reason for suggesting that the producer should be at the center is that the model focuses on the decision making of the organization as its primary purpose.
2. The actual relationships depend on the types of products, markets, and industries. Complex products require a large marketing investment just to create awareness.
3. K. Alston and J. P. Roberts, Partners in new product development: SC Johnson and the Alliance for Environmental Innovation. *Corporate Environmental Strategy*, **6**:2 (1999), 125. A consumer research study performed by Market Facts for SC Johnson indicated that 50% of the respondents "would pay more for a cleaning product with no toxic ingredients." A Roper study in the early 1990s suggested that 25% of consumers were willing to pay more for environmentally conscious products. The argument focuses on value more than other factors.

9 Production strategies and methods: operational and manufacturing implications

By Edward D. Arnheiter

Introduction

Production and supply-chain considerations are essential requirements that must be examined during the conceptual level and turned into definitive approaches during the operational level. The choices are dependent on the new-product development (NPD) situation. While the trend is toward best practices and "world-class manufacturing," the downstream activities of actually producing the product(s) or providing the service have to be determined through inputs from the entire NPD team as the new-product opportunity makes the transition from concept to commercialization. Once the initial design for a new product is complete, manufacturing capability is typically required to bring the product to market. Whether using in-house manufacturing resources, buying the product entirely from a supplier, or using a combination of these two approaches, the enterprise must produce the new product in larger quantities. Frequently, a product previously made only in small quantities in a controlled laboratory environment must be made in large quantities on the more "uncontrolled" factory floor.

This chapter describes important production strategies, methods, and applications; the use of supply networks and outsourcing; and the techniques for improving designs to make products easier to produce, and more appealing to customers. Production and operations strategies for new products combine flexible production with an easy to manufacture and assemble design, resulting in products that consistently meet or exceed customer expectations. By designing and establishing the most efficient and appropriate production system for a given product, manufacturing can be a strategic weapon and a competitive advantage, thus minimizing vulnerabilities to competitors.

Chapter 9 presents an overview of how product and service requirements are translated into production and operations. The topics covered include manufacturing outputs, production-systems characteristics, lean production, process planning, capacity planning, supply-network design, and quality management. The purpose of the discussions is to provide an overview of the practical aspects of analyzing and managing manufacturing and operations issues related to new-product development. The elements covered include principles, philosophies, concepts, techniques, processes, and models that offer practitioners qualitative and quantitative methods and tools used for planning and managing operations.

Chapter 9 includes the following topics and learning objectives:

- Understanding the needs and requirements of the production or operations.
- Exploring standard methods for producing and delivering the product.
- Developing production techniques for creating quality products.

Production-system characteristics

Manufacturing outputs

Production systems convert "inputs" into "outputs" by utilizing machines or other resources to process and add value to raw materials, finished components, or customers (i.e. for service operations), transforming them into finished outputs. In order to maintain a viable, ongoing enterprise, the value of the outputs must be worth more than the total cost of the inputs. Several process-flow structures have been developed and refined over the years to accomplish this transformation from inputs to outputs.

The production system used by an enterprise should address the **manufacturing outputs** desired by the customers. Four well-known outputs, developed from the work by C. Wickham Skinner at the Harvard Business School and Terry Hill at the London Business School, are **cost**, **quality**, **delivery speed**, and **flexibility**, as discussed in previous chapters.

Recently, a suggestion was made to split quality into two separate elements: quality and performance; and to split flexibility into flexibility and innovativeness.[1] Numerous definitions for quality have been proposed over the years. David Garvin's seminal work, published in the *Harvard Business Review* in 1987, provoked renewed thought and interest in the subject. Garvin defined the eight dimensions of quality as:[2]

(1) ***Performance***. The product's primary operating characteristics, e.g. the processing speed of a personal computer.

(2) ***Features***. The availability of options; the "bells and whistles."

(3) ***Reliability***. The probability of a product malfunctioning or failing within a certain time period.

(4) ***Conformance quality***. Conformance to specifications. This is the traditional notion of quality.

(5) ***Durability***. The amount of use the customer gets from the product before it deteriorates.

(6) ***Serviceability***. A measure of the competence, convenience, and ease of repair services.

(7) ***Aesthetics***. A subjective impression of the appearance, feel, or taste of a product.

(8) ***Perceived quality***. Another subjective measure based on the customer's perception of the product's reputation.

Table 9.1 *Manufacturing outputs*

Output	Primary characteristics
Cost	Directly affects the price the customer pays for the item. Manufacturer has to cover cost of material, direct labor and labor overheads, and any other resources used to produce the item. In general, fewer and fewer products are competing solely on price alone, because customers are becoming more demanding, even on low-cost, commodity-type items.
Quality	This can include process quality and product quality, as well as reliability. Numerous definitions of this term have been proposed over the years, the classic one is the extent to which a product conforms to specifications (conformance quality).
Delivery speed	Time between order taking and delivery to customer. How often are orders late, and how late are they when they are late? Includes delivery time and delivery time reliability.
Flexibility	Extent to which volumes of existing products can be increased or decreased to respond quickly to the needs of customers. Can be broadly defined to include coping with changes in demand and new-product introduction speed (sometimes called innovativeness).

Seven of the eight are essentially elements of *design quality*. The *process quality* metric is conformance quality. Traditionally, manufacturers have judged the effectiveness of their production systems by looking at conformance quality, because it is the one element that they directly influence, and because it is usually easy to measure. The other seven dimensions are influenced directly by the quality of the product's design.

By the definition shown in Table 9.1, a clothing manufacturer is *flexible* when it can easily change production mix and production volumes in response to changes in fashion and season. Flexibility will be discussed in more detail in the section on lean production. Innovativeness can be defined as the ability to produce new products or perform design changes to existing products.

Process-flow structures

Deciding the process flow through a manufacturing facility is a critical factor in determining the capacity of the system and the cost structure of the product. While it is advantageous to have an integrated flow to reduce costs and improve quality through repetitive processing, such methods are not always feasible during the early stages of production for a new product because the demand may not be sufficient to justify the expenditures. The typical options are job shops, batch flow, connected or repetitive flow, and continuous flow. They are described below:

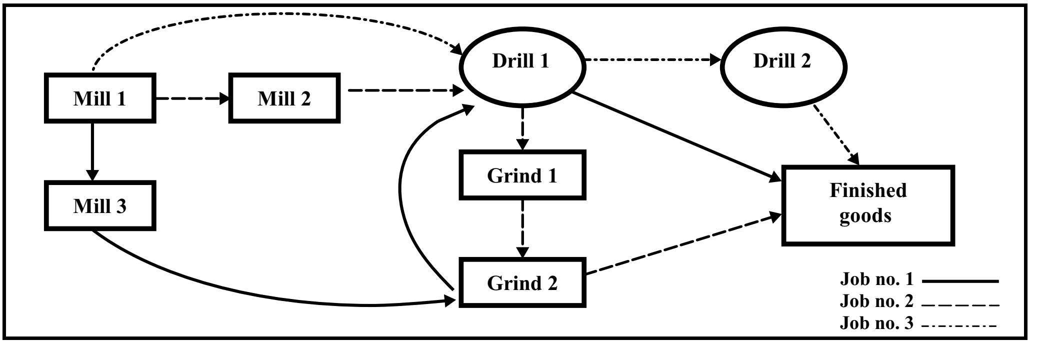

Figure 9.1 Process or job-shop layout: each job has its own routing

Job shops

Job shops are characterized by a jumbled product flow where "*n*" jobs must be processed through "*m*" machines. Not all of these *n* jobs are assumed to require exactly *m* operations, and in fact some jobs may require multiple operations on a single machine. In other words, jobs can have quite different flows and numbers of operations, and therefore may require different sequencing of operations. It is difficult to calculate capacity for a job shop because it depends on the particular mix of orders being produced at a given time. An example of a job shop is shown in Figure 9.1. Notice that all three jobs shown in Figure 9.1 require different routings through the shop. Anyone who has a small home woodworking shop essentially has a job-shop layout. A skilled woodworker is able to construct a wide variety of wooden products in their home shop (so the shop is very *flexible*), but the woodworker would be hard pressed to make these items in quantity.

Batch flow

Batch flow is sometimes called a disconnected flow line process or simply a batch process. The flow is somewhat like a standardized job shop. Product batches are produced on a limited number of identifiable paths or routings through the plant. Each of the *n* jobs, therefore, are processed through the *m* machines in primarily the same order, and each job is processed exactly once on each machine. Batch-flow lines do not make use of any paced materials-handling systems, so inventories generally build up between workstations.

Connected flow lines

There are two types of connected flow lines, the operator-paced flow line and the equipment-paced flow line.[3] Both types of connected flow lines are often referred to as "assembly lines." Operator-paced flow lines generally depend on the operator to move product from one station to the next. In this type of line, cycle times are determined by the bottleneck, or slowest station in the line. For example, workstations can be connected by non-motorized roller conveyors, or even a few long narrow tables (e.g. McDonald's restaurants). Operator-paced flow lines are commonly used to assemble personal computers and computer workstations.

The equipment-paced flow line utilizes a motorized, constantly moving continuous belt to transport material from one workstation to the next. The cycle time of the equipment-paced line is therefore determined solely by the belt speed. A classic example of the equipment-paced flow line is the traditional automotive assembly line made famous by Henry Ford. The assembly line is actually much less common than the batch-flow process, but because many large and important industries such as the automotive industry make use of assembly-line techniques, they have been studied in great detail.

Continuous flow

In this structure, material being processed flows continuously, rather than in discrete units. Similar to connected flow lines, routings are fixed and follow a predetermined sequence of steps. Continuous-flow processes are commonly used to process food, chemicals, oil, roofing materials, paper, beer, and steel, and often make use of highly automated systems which must be operated 24 hours a day to avoid costly start-ups and shutdowns.[4]

A summary of the operating characteristics of the five traditional types of production systems is shown in Table 9.2. For an excellent detailed discussion of these systems, read John Miltenberg's discussion on manufacturing strategy.[5]

Types of production layouts

There are four types of layouts commonly employed in production facilities: (1) fixed-position layouts; (2) product layouts; (3) process layouts; and (4) layouts based on group technology (cellular layouts).

Fixed-position layouts

Certain products, such as planes and ships, are too big to be moved, and must remain fixed in place. The layout is based on the size and shape of the product, where workers and machines move around the product itself. Fixed-position layouts are often thought of as spoke-and-hub arrangements where the hubs represents the product itself and the spokes are supply lines feeding materials and components to assembly points.

Product layouts

In product layouts, machines are arranged to correspond to the sequence of operations needed to produce the products. They are typical of high volume, standardized production. An assembly line is an example of a product layout, because resources are

Table 9.2 *Production-system characteristics*

System	Product mix and volume	Flow	Characteristics
Job shop	Wide variety of products, but make only one or a few of each	Varies considerably	Operators work in a single department but are highly skilled. Equipment and tooling are suitable for general-purpose use.
Batch flow ("batch")	Produce many different products in low to medium quantities	Varies but has prevalent patterns	Basically a standardized job shop. Most items follow the same flow pattern through the plant.
Equipment-paced flow line ("paced assembly line")	Produce large quantities of several different products	Steady and paced by equipment	Suitable for use when product design is stable and volume is high. Equipment is expensive and extremely specialized.
Operator-paced flow line ("flow line")	Several to many products with medium volumes	Mostly steady, but paced by operators	Line is more flexible than the equipment-paced flow line and can be run at different speeds.
Continuous flow	One or a few products with very high volumes	Inflexible and continuous	Similar to the equipment-paced flow line. Produces a standard product at the lowest possible unit cost.

organized according to the sequence of steps required to produce the item. Product layouts work well when flow-type mass production is needed, and in general, flow lines make use of product layouts. There are a few drawbacks to product layouts. They are expensive and inflexible, and can be awkward to deal with when changes in the product flow are needed. In addition, if one part of the line stops, the entire line may have to be halted until the problem is resolved.[6]

Process layouts

Process layouts are comprised of groupings of similar machines, where each grouping has a similar function or capability. The job shop is a classic example of a process layout (see Figure 9.1). Process layouts are frequently used by small-to-medium-volume manufacturers. Process layouts are appropriate when producing a wide variety of products, and when many different flow patterns are required. These layouts tend to minimize idle

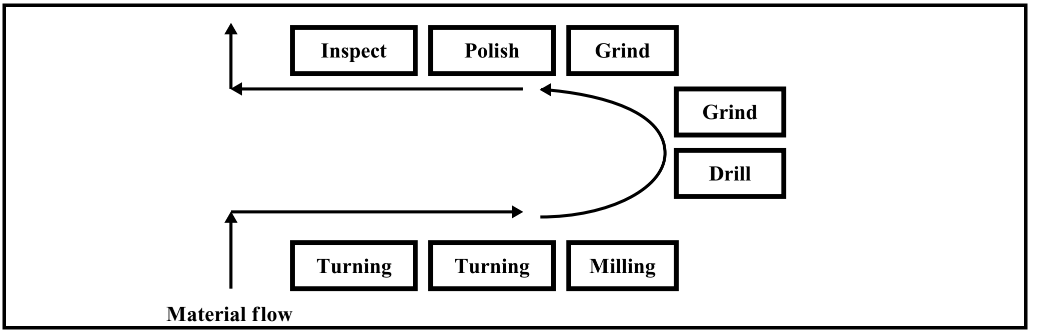

Figure 9.2 Example of a U-shaped manufacturing cell

time because parts from multiple products or jobs queue up at each machine to facilitate high utilization of resources.[7] Process layouts are often used during the early stages after the introduction of a new product because of the flexibility to handle the relatively low volumes and to accommodate the changes that may occur. The advantages include minimizing the investment into plant and equipment until there is compelling evidence about the demand and the specifications, and maintaining flexibility to manage future requirements. The main disadvantage during the early stages is the impact on unit costs. Generally, the cost structure is higher due to the lower capacity and functionality of the process.

The majority of companies utilize either a process or product layout. In addition, many firms have hybrid facilities. For example, a job shop (process layout) might feed parts to an assembly line (product layout).

Layouts based on group technology

Group technology (GT) is the term used for identifying and grouping parts into families based on similarities in function, materials, or manufacturing processes. When grouped correctly, each part in the part family requires similar processing steps. For example, there might be a cubic-parts family containing parts needing drilling and which have a "prismatic" shape (essentially meaning you can draw a box around them), and there might be a rotational-parts family in which all parts can be turned on a lathe. However, grouping of parts into suitable families is not always easy. Identically designed parts might require different processing steps because of material differences, and geometrically dissimilar parts might still require similar machining operations (e.g. surface milling or hole drilling).[8]

A common layout in GT is the U-shaped cell shown in Figure 9.2. The U-shaped manufacturing cell is a basic element of the Toyota production system and is considered an important concept in lean production. Machining centers are usually the central elements of the U-shaped manufacturing cell. There are two types of common machining

Table 9.3 *Production-system groups*

Production classification	Production systems
Craft production	• Job-shop production system • Batch-flow production system
Mass production	• Operator-paced flow line • Equipment-paced flow line • Continuous-flow production systems
Lean production	• JIT production system • FMS production system

centers: one suitable for machining prismatic parts and one for machining rotational parts.

The objective of GT is to schedule parts in order to maximize resource utilization, and thereby gain the benefits of a product layout with job-shop flexibility. Group technology is best suited for large firms that produce a wide variety of parts in moderate to high volumes. Firms that utilize GT might have 10,000 different part numbers, grouped into 50 or so families.[9] It is also possible to form a *virtual* GT cell simply by dedicating certain machines to a particular part family, without actually moving any of the machines around.

Advantages of using group technology include reduced work-in-process (WIP) inventories and material handling, reduced set-up times, better human relations, and improved operator expertise (since work-cell teams turn out finished units). Scheduling is improved, since by isolating part groupings, it is much easier to keep track of the production flow within each cell. In addition, reduction of cycle times and WIP queues results in more reliable due-date schedules.[10] The primary disadvantage of group technology is that it often requires purchasing duplicate machines, since each cell must have the capability to completely process parts for its assigned family. In general, group technology works well in situations where distinct part families exist, and there are several easily movable machines of each type available.[11]

Grouping production systems

A scheme for categorizing production systems, credited to Womack, Jones, and Roos, classified the job-shop and the batch-flow processes as **craft production**, and the connected flow lines and continuous-flow systems as **mass-production** systems.[12] A third classification called **lean production** includes just-in-time (JIT) and flexible manufacturing systems (FMS). This classification scheme is summarized in Table 9.3.

JIT production and its relationship to lean production is discussed in the next section. FMS typically consist of a series of manufacturing cells connected by a common supervisory computer and transport system. The manufacturing cells contain computer numerically controlled (CNC) machines with automatic parts delivery and removal, as well as automatic tool changing. In FMS, the configuration of the material-handling and storage equipment is primarily dependent upon the type of workpiece, i.e. rotational or prismatic. FMS attempt to combine the flexibility of a job shop with the scale efficiencies of a flow system.

Although the application of the JIT and FMS philosophies often includes a mixture of techniques and ideas common to craft and mass-production systems, many aspects of their core elements are unique. For example, by virtue of its design, JIT production forces the elimination of unnecessary, wasteful elements, or "muda" (the Japanese word for waste).

Computer-integrated manufacturing

Computer-integrated manufacturing (CIM) connects the automation technologies of the manufacturing process – such as robotics and computerized numerically controlled (CNC) machine tools – with computerized product and process design, and automated planning and control. In the CIM world, much of the traditional verbal and written communicating is done via the computer. CIM is sometimes called the "factory of the future" or the "lights-out factory" (turn out the lights, go home, come back in the morning and your parts are done, without human interference) because of its reliance on automated processing.

In the CIM environment, technologies are linked using a computer network with a centralized database. In an advanced system, CIM utilizes computer technology to connect design, production, assembly, quality control, and material handling (including product delivery) in a completely integrated arrangement. CIM is not simply a series of computerized linkages, it is really an overall strategy for organizing and controlling the factory.

A drawback to the rigid automation model endorsed by some CIM advocates is that some of the initial automated production systems were not very *flexible*. Flexibility of production is an essential requirement of the modern factory, and any attempt to adopt a CIM model must include the characteristic of flexibility in its operations.

Lean-production systems

A brief history of lean production

The origin of the concept of lean production can be traced to the Toyota production system (TPS), a manufacturing philosophy pioneered by the Japanese engineers Taiichi Ohno and Shigeo Shingo. The Toyota production system is also the birthplace of JIT production methods, a key element of lean production, and for this reason the TPS remains a model of excellence for lean-production advocates.

Scholars have argued that just as the basic tools of total quality management (TQM) were developed and practiced at Western Electric in the 1920s the principles of the TPS were developed at Ford in the early part of the twentieth century. While this neat and simplistic conclusion is not quite correct, it is a fact that in 1926 Henry Ford claimed, “Our finished inventory is all in transit. So is most of our raw material inventory.” He also boasted that Ford Motor Company could take iron ore from a mine and produce an automobile in 81 hours.[13] Ford’s words convey the importance he placed on inventory reduction, short-cycle manufacturing, and in general, the reduction of waste. These are all basic elements of the TPS. It is no wonder that Taiichi Ohno greatly admired Ford and studied his accomplishments.

The term “lean manufacturing” was originally coined by John Krafcik, a key person on the research team for the book *The Machine that Changed the World: The Story of Lean Production*.[14] The book describes the advantages that lean manufacturing techniques, such as those employed by Toyota, have over the more common “batch-and-queue” mass-production methods. Batch-and-queue techniques were very common in the United States at the beginning of the 1990s, and are still prevalent today in many industries and businesses. Batch-and-queue production is characterized by high production volumes, large batch sizes, low product variation, and long product life. Batch-and-queue techniques are developed from economy-of-scale principles, which assume that set-up and changeover penalties make small batch sizes uneconomical. Batch-and-queue methods typically result in lower quality since defects are usually not discovered until subsequent operations or inspection of the finished product. As mentioned earlier, most manufacturing and service businesses still operate batch-and-queue systems.

Key elements of the Toyota production system

Some aspects of the TPS have been distorted. In American literature, for example, authors frequently expound the need to eliminate waste and “drive inventories to zero,” when in fact, the TPS is pragmatic and does allow for buffer inventories. As a practical matter, production-line segments are buffered to ensure that a brief stop in one station does not immediately affect the next. To be sure, the inventory is kept small, but it is still of sufficient size to prevent major line shutdowns most of the time.[15] Another aim of the TPS is to reduce variability at every opportunity. These reductions include demand variability, manufacturing variability, and supplier variability. Variability reduction is today the focus of many quality efforts in the light of the recent interest in “six-sigma” quality programs. The major elements of the TPS are summarized in Table 9.4.[16]

Table 9.4 *Key elements of the Toyota production system (TPS)*

Main elements of TPS	Primary concepts contained within each element
Drive processes to be in control and capable (standardized work and processes that are repeatable, reliable, and stable)	Processes are made capable and kept in control through discipline, which encompasses: • Cleanliness • Worksheets/manuals • Standard operating procedures • SDCA (standardize, do, check, act) • Simplify, mistake-proof, highlight deviations
Problems are natural (good at times) and are opportunities to learn (design the system for learning)	• Most problems arise from not following standards, and every problem has a root cause and countermeasures • Problems must be seen to be solved, so minimize the work-in-process to make them more visible • Stick to the facts, not symptoms, i.e. eliminate blame • Constantly change for the better (use kaizen)
Every activity/task/function must add value (look at the system as a whole, i.e. no sub-optimization)	• Eliminate waste (“muda”) • Single-piece flow is the goal (batch size of one) • Order what is needed, when it is needed • Use kaizen to change (improve) the process to add more value
Connect the production system to the customers by making what they want, when they want it	• Produce to market’s takt time[17] • Minimize set-up and changeover times • Minimize demand variability • Define supplier policies and their capability requirements • Use labor as a true variable (add or subtract according to production rate)
Human infrastructure (patiently select and invest in people’s knowledge and skills)	• TPS does not necessarily mean “lean” (i.e. minimum number of people) • Worker training and discipline to add value through daily work and to improve processes; solves problems by root-cause analysis and countermeasures • Team leader must be the most knowledgeable and skilled person in the work zone; and be the best leader–teacher • Group leader must have skills of team leader plus broader system knowledge • TPS is a fact-based, no-blame system that is built on trust and dependability

Basic concepts in lean production

According to Womack and Jones, there are five main elements of lean production:[18]

• **Value**	• **The value stream**	• **Flow**	• **Pull**	• **Perfection**

Value implies determining what the customer really wants to have from the product or service. This can only be defined by the ultimate customer, or end-user. It is surprising how many companies never directly ask customers about their needs, likes and dislikes, problems, complaints, etc.

The **value stream** encompasses the entire set of activities required to bring a product from conception to detailed design, order taking and scheduling, production launch and physical transformation of raw materials, and finally to delivery into the hands of the customer. In the value stream there are three steps that can consume human and material resources:

(1) Steps that unmistakably create value. Examples of this would be spot welding the frame of a car together, or a taxi driving a passenger from point A to point B.
(2) Steps that create no value, but are unavoidable given the current technology and production equipment (this is known as “type-I muda”). An example is inspecting welds on an aircraft engine to ensure quality.
(3) Steps that create no value and are immediately avoidable (known as “type-II muda”). An example would be the unnecessary double-handling of an invoice by two clerks in the accounts payable department.

Flow is the general term for production in *small* batches and, ultimately, *single-piece flow* (i.e. batch size = 1). Use of a batch-and-queue system should be avoided whenever possible, although there are situations in which it is necessary. This is often the case when performing operations such as chrome plating, where large batches are placed in plating tanks. In a wrench-manufacturing operation, for example, steel forgings might move in a single-piece manner through a U-shaped machining cell, but then queue up at the end of this cell before being moved to the chrome-plating station. This operation would be an example of a hybrid system consisting of single-piece-flow in some areas, and batch-and-queue in other areas. In fact, very few manufacturers can say they have a pure single-piece-flow system throughout their entire operation.

Lean-production advocates use the term “pull” to imply not making anything until it is needed by the downstream customer, and utilizing a make-to-order (MTO) approach whenever possible. Pull techniques were pioneered by Toyota using their JIT production methods. In some industries, make-to-order production is the de facto way of doing business. This is a very common technique used in the personal-computer business. Dell, for example, uses their “direct sales model” to convert telephone orders from customers into finished personal computers ready for shipment in about four hours! The initial "pull" in this case is the telephone or electronic order from the customer. This method also allows Dell to customize each unit to the customer's specifications.

The complete elimination of muda (waste), so that all activities along a value stream create value is known as "perfection." Elimination of waste is a goal of any enterprise, yet it is unrealistic to assume that *complete* elimination is possible. Efforts focused on the *reduction* of waste are often pursued through continuous improvement or *kaizen* events, as well as radical improvement activities (kaikaku). Moving or eliminating machines to facilitate better material handling and faster throughput would be an example of kaikaku. In contrast, improving a work area by developing a new quick-change fixture, and organizing the area and its tools, are often the types of actions performed during kaizen activities. Both initiatives in this example reduce muda, although the term kaikaku is generally reserved for the initial rethinking of a process. The main point of lean thinkers is that perfection should be the goal for the value stream, but the journey to perfection is never ending.

The Lantech case

A classic example of the successful application of lean techniques is the transformation of Lantech, a manufacturer of commercial stretch-wrapping machines for pallet loads.[19] Lantech initially had a traditional batch-and-queue system (with departmentalized batch methods), and would make 10–15 machines of one type at a time. Many of their manufacturing steps added no value to the value stream. Lead-times for machines were so long that the sales force would order machines based on speculation, before confirmed orders were received. Expediters would move through the plant with a "hot list" to meet customer delivery demands.

Lantech had implemented many changes over the years to counter increasingly strong competition, including: reorganizing itself into profit centers for "standard products" and "specials," implementing TQM, empowering its employees, building inventories of major components in advance in order to cut lead-times, and buying better information technology. Management discovered lean techniques quite by accident when they hired Ron Hicks as the new Vice President of Operations, in March 1992. Hicks had experience with lean production from his work at Danaher Corporation.

Over the next four years, under the guidance of Hicks, Lantech developed a series of new initiatives, including: untangling the flow of value by making cells for each product family, "right-sizing" machine tools by getting rid of *monuments* (only a paint booth survived this kaikaku phase of improvement), and standardizing work tasks so that a given task took the same amount of time every time it was performed. Hicks also instituted production based on time, by making the stretch wrappers one at a time, in direct response to customer demand. Changeover (set-up)-time reduction efforts were instituted, as well as JIT deliveries from suppliers. Probably the most important policy change was that

Lantech decided that any improvements achieved from the conversion to lean production were not to result in layoffs.

The initiatives that Hicks set forth had a dramatic impact on Lantech's performance. For example, Lantech's average manufacturing lead-time was reduced from approximately 16 weeks in 1991, to between 14 hours and 5 days in 1995. Their total product-delivery lead-time prior to the lean transformation was between 4 and 20 weeks.[20] In 1995 this figure was between 1 and 4 weeks, most of which was time spent waiting for a production spot, because demand had exceeded capacity. Total development time for a new-product family was reduced dramatically from 3 to 4 years to around 1 year.

Flexibility in manufacturing and its relationship to lean production

Flexibility is described in Table 9.1 as one of four important manufacturing outputs. More precisely, there are external forms of flexibility, i.e. what the customer obtains, as well as internal forms, i.e. the manufacturing capabilities that support those external needs.

In a sense, competing on flexibility is similar to competing on quality in that flexibility is a vague concept, which, like quality, has multiple dimensions. In fact, it is quite common to find firms that do not really know what flexibility is or what it will mean for their business. These firms know only one thing; they must become flexible.

There are three types of internal manufacturing flexibilities that have been identified:[21]

- ***Operational range***. This is the ability to produce a wide range of variation in the product being produced, on a day-to-day basis. Producing cars with many different options is an example of operational range.
- ***Operational mobility***. This is the ability to quickly switch between products, on a day-to-day basis. If the company is manufacturing small, four-door wagons and can then rapidly switch to mid-size, four-door sedans, high operational mobility is achieved. A more-drastic example might be to switch rapidly from producing toasters to blenders.
- ***Operational uniformity***. Ability to produce uniformly (in yield or quality) across the range of products produced.

Flexibility is an important element of manufacturing strategy and is a key concept within lean production. The following example illustrates the importance of developing flexible production systems. During the 1980s General Motors was touting its "reindustrialization" operations strategy. This initiative required spending approximately $80 billion worldwide to update and automate GM's assembly plants, gradually transforming them into showplaces of automation, brimming with sophisticated robots and automated high-tech equipment. The theory was that GM could significantly reduce direct labor costs associated with vehicle manufacturing by using technology, and essentially outspend and thereby leapfrog the competition. General Motors, however, knew little of lean manufacturing, and paid no attention to one of the very important elements: flexibility. The GM plants were designed and constructed to produce just one model! The new automated plants produced the same vehicle models and body styles, year after year, with GM assuming that whatever they chose to produce and make available to the consumer would drive demand. When consumer tastes changed, GM could not adjust quickly or easily to the demand for new styles and models.

General Motors' assembly plant in Fairfax, Kansas was a victim of this ill-fated policy. Fairfax was rebuilt in 1987 to be highly automated, utilizing over 200 different robots. Unfortunately, it was designed to build only the Pontiac Grand Prix. It was not flexible enough to build other GM models such as the Lumina or Cutlass Supreme (although the plant has since added the Oldsmobile Intrigue to its model mix). The annual design capacity of the plant was 250,000 units, but it wallowed for many years making around 100,000 units because GM could not sell more of that model.[22] The TPS, on the other hand, is extremely flexible and each assembly plant can build three or more models or platforms. If one model is not selling well, it is then a simple matter to shift production to a better-selling model.

Process and capacity planning

Process-flow design and analysis

Management techniques for *process planning* for a new product include assembly drawings, product structure diagrams (assembly charts), and operation sheets. Two diagnostic tools for *process analysis*, when planning improvements, are the process-flow diagram (or process flow chart) and the process map.

Assembly drawings depict component parts of the product in an exploded, often three-dimensional or isometric, format. Consumer goods that are put together by the end-user frequently include assembly drawings with the product.

A bill of materials describes all items that go into the final product, including information such as part number, quantity per next higher assembly, assembly sequence, lead-times, and revision number. An example of a product structure diagram for a gear box is shown in Figure 9.3. In this figure, lead-times are abbreviated to "LT," and the number 2 in parenthesis after part number C4002 implies that there are two of these parts required for each gear box end item. For complex products, separate diagrams are needed for each subassembly.

Operation sheets give instructions for the operations required and the routing to process a particular part. They typically specify such things as the equipment needed; the time required to set up and run each operation; and any special tools, fixtures, and

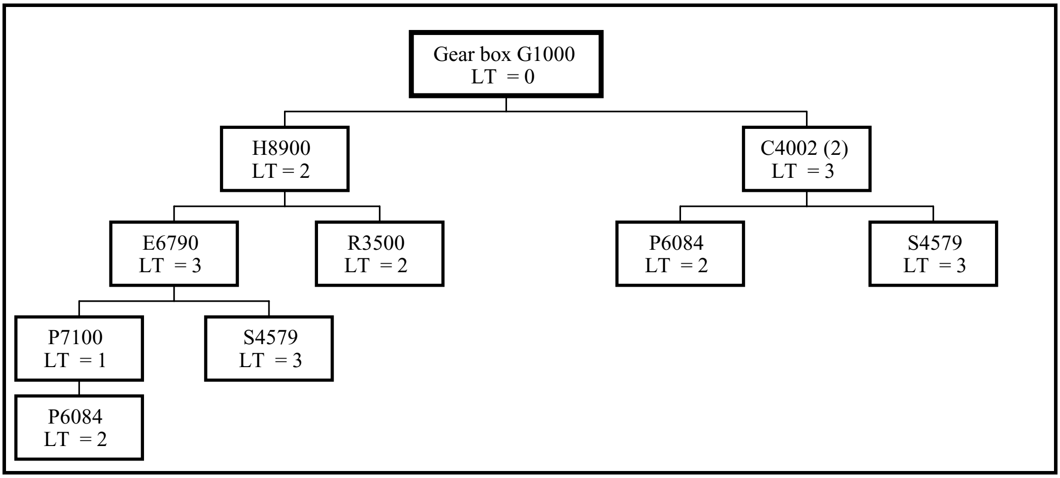

Figure 9.3 Example of a product structure diagram (LT, lead-time, in weeks)

Part name:	Hanger bracket	Material:	Stainless steel	**Original issued:**	5/23/00
Part number:	HGC45789			**Last revision:**	C
Usage:	Gear enclosure			**Revision date:**	8/15/00

Op. No.	**Description**	**Dept**	**Machine**	**Set-up (hour)**	**Run (hour/part)**	**Tooling or fixtures required**
010	Shear blanks to 12 × 18	Fab	Shear 100	0.17	0.008	
020	Punch (3) 0.250±0.030-in diameter holes as shown	Fab	Turret press 210	0.083	0.006	
030	Punch special shaped hole at location shown	Fab	Punch press 215	0.50	0.003	Punch fixture PF3400H
040	Bend long edge at 3 in. Radius, 0.030 max.	Fab	Press Brake 300	0.083	0.004	Bending fixture BF2890
045	Gray prime coat	Paint	Prime booth		1.0	16 gang hang rack
050	Paint with color C7866	Paint	Paint booth	0.33	1.0	
060	Inspect for cosmetics	Insp			0.004	

Figure 9.4 Operation sheet for a sheet-metal part

gauges required. Operation sheets are also called operations process charts, operation and route sheets, or routing sheets. An example of an operation sheet for a fabricated part is shown in Figure 9.4.

The **process-flow diagram** is very useful for understanding how parts and material flow through the process, and for graphically representing the overall behavior of the operating system. In a typical process-flow diagram, tasks are represented as small rectangles, flows (both physical as well as informational) are represented using arrows, inverted triangles represent inventory storage (incoming material as well as work in process), and circles represent the storage of information. Adding cycle time and set-up time information to the diagram, simplifies calculating manufacturing lead-times and

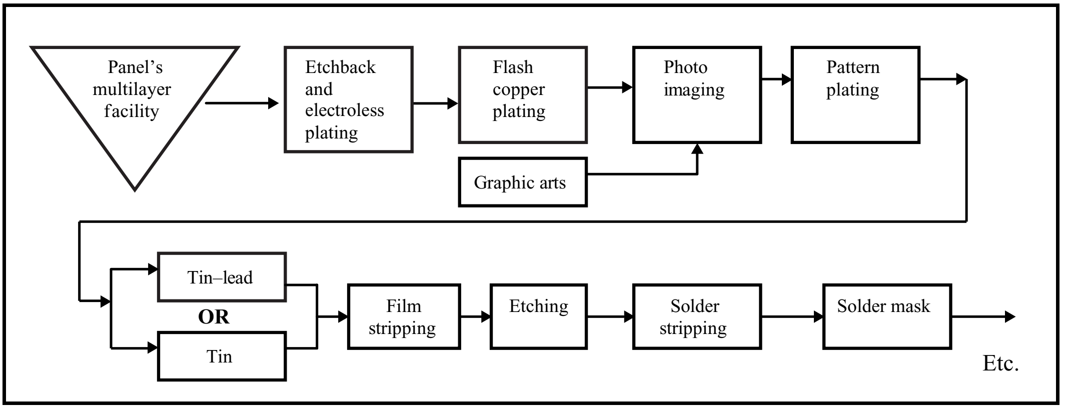

Figure 9.5 Process-flow diagram for the printed circuit board example

All factory processes

Customers	Etchback and electroless plating	Flash plating	Photo imaging	Pattern plating	Film stripping	Etching	Solder stripping	Solder mask	Hot-air solder level	Reflow	Lettering	Electrical test	Rout	Gold plating	Final inspection	Shipping
Smith	1	1	1	1	1	1	1	1	1		1	1	1		1	1
Electroweld Corp.	1	1	2	1	2	1	1	1	1		1	1	1	1	1	1
DC Electronics, Inc.	1	1	1	1	1	1	1	1		1	1	1	1		1	1
ADZ Corporation	1	1	1	1	1	1	1	1	1		1	1	2		1	1
Acheson Co.	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1

Note: "2" indicates a second trip through the process.

Routing department processes only

	Router A – large panels	Router B – small panels	Router C – small production runs	Router D – large production runs	Second drill	Milling	Beveling	V-groove	Beveling
Smith			1			1			
Electroweld Corp.	1							1	
DC Electronics, Inc.						1			
ADZ Corporation			1						1
Acheson Co.		1							

Figure 9.6 Process map for the printed circuit board example

capacities, and identifying bottleneck areas. Figure 9.5 is an example of a process-flow diagram for a printed circuit board manufacturer.[23]

Figure 9.6 shows a process map for five of the manufacturers' customers. A process map is essentially a matrix with each factory process listed along the top and each product listed down the left side. Numbers in the matrix represent how often each process or machine is required for each product. By grouping together products with similar patterns, overall process flow can be improved. An exact match within each group is not necessary, a 70 to 80% overlap is sufficient. For example, instead of the traditional departmental organization, 1 or 2 of each of the company's 5 electrical test machines, 10 routers, 5 print machines, or 20 inspectors could be grouped into a series of cells, each cell working on only one product.

Capacity planning and management

How many units a manufacturing plant can produce during a given time period is called *capacity*, e.g. parts per day, liters per hour, cars per day. In service-sector companies such as banks and restaurants, the number of customers served or processes per hour is used as a capacity measurement. How much of the design capacity is utilized is known as the *capacity utilization rate*. Design capacity is defined as the level at which the facility can operate for long periods without major breakdowns. Although not a good long-term strategy, the capacity utilization rate of a facility can actually exceed 100% for short periods (implying that the design capacity is being exceeded). Techniques to achieve this include using overtime, outsourcing, using the third shift for production instead of for regular preventative maintenance, and hiring temporary workers. The practice of exceeding design capacity is not a good long-term plan, because of employee fatigue and low morale, machine breakdowns, and quality problems, but it is sometimes useful for firms that experience seasonal spikes in demand.

How much capacity is enough? Consider the following example. In the late 1980s, a major golf-ball manufacturer was experiencing an unexpected surge in demand for several of their latest "improved" golf-ball models. Its single facility had insufficient capacity to meet demand for the new products, and still maintain required production levels of existing products. To add capacity the manufacturer decided to build another facility, smaller than the existing plant and several hours away, to produce a limited variety of well-established core models. The goal was to free-up capacity at the main plant in order to produce larger quantities of the latest models.

In less than two years, the satellite plant was constructed. There were a few minor start-up difficulties, but by and large the plant operated as expected. In fact, productivity and efficiencies were higher at the new plant than at the existing plant! This was because the new plant was non-unionized, had a lower wage structure, was located in an area that had lower tax rates and general overhead expenses, and was a "focused" factory that concentrated on a small number of similar models. Unfortunately, by the time the plant was constructed, the company's overall golf-ball demand had decreased, demand for some new models had dropped way off, and foreign competition, particularly from Japan, had increased. The company had too much capacity and was forced to reduce production levels across the board.

This example illustrates the difficulties associated with capacity planning for new products. Among the difficulties experienced by the company were:

- The decision to add capacity was based primarily on high demands for new products. There were no historical data to analyze since the product had never been sold before.
- The lead-time for constructing additional capacity was longer than the life cycle of some of the new products.
- Competition was stealing market share and developing new products more quickly.

In large global supply networks, companies often expand their capacities when a new product is introduced. This is because the supply network must first be filled with the new product to provide retailers with sufficient inventory levels, creating an initially high demand at the factory. As the inventories fill and pull from consumers is initiated, demand at the factory may actually decrease. The manufacturer in the previous example experienced this phenomenon because wholesalers were excited about the new ball models and consequently placed orders for them in large quantities. Unfortunately, actual retail sales were not spectacular. This, and a long period of poor weather, caused a sharp dip in manufacturing demand.

During the 1990s, automobile manufacturers built new factories ahead of increases in demand, and thereby developed excess capacity worldwide. One reason for this strategy was to maintain visibility in new markets. In Brazil, for example, there is much more automotive capacity than required to satisfy existing Brazilian domestic demand. The automotive industry felt that South America was a potentially large future market, and manufacturers wanted to begin scaling up and build a presence in the region before it was too late. Excess capacity has also been caused by lack of flexible facilities. Recall from the section pertaining to lean production that, due to its inflexibility, the General Motors' assembly center in Fairfax, Kansas had an annual design capacity of 250,000 units, but was assembling only 100,000 cars annually. Only the Pontiac Grand Prix was assembled there because the plant was not flexible enough to build other models.

Companies competing in areas of rapid technology development face difficult capacity-management decisions. Technology in the flat-panel display industry, for example, has been advancing rapidly since the mid-1980s. Flat-panel displays are used on such things as laptop and desktop computers and in on-board automotive navigation systems. In the early 1990s a joint venture of IBM and Toshiba, located in Japan, was manufacturing flat-panel displays based on thin film transistor–liquid crystal display technology (TFT-LCD).[24] Since demand for their panels exceeded capacity, management decided to double capacity as quickly as possible. Management considered three alternatives to increase capacity:

1. Raise yields and output of the existing process through continuous improvement or kaizen efforts. This would increase capacity only in small, incremental steps.
2. Simply duplicate the existing production line, thereby utilizing established "older" technology with its associated lower yields.

3. Switch to a new technology, which employed a larger substrate and an advanced handling system that enabled a single-piece flow process.

They decided to focus first on continual improvement of the existing process (option 1), while working on developing and testing the new process. When the parameters of the new process were understood, the plant would be switched to the new technology. The risk of being unable to supply enough panels in the short term was offset by the rewards of the new process. This capacity-planning example also illustrates the classic long-term-thinking philosophy of Japanese management.

Supply-network design (supply-chain management)

Strategic outsourcing

An important strategic issue in production and inventory management is that of the "make-versus-buy" dilemma. Outsourcing, or the use of outside suppliers to provide services or products, frequently offers a cost-competitive alternative to performing the required activities in-house. The decision whether or not to produce an item or service internally can influence short-term market share, as well as long-term competitiveness and corporate survival.

Outsourcing is identified by *Harvard Business Review* as one of the most important management practices of the past 75 years. In the United States, spending on outsourced business services was projected to triple, from $100 billion in 1996 to $318 billion by 2001.[25] This has resulted in a new practice among business executives: rather than using internal resources by default, managers now justify why a company should not outsource an activity. Wall Street looks favorably upon outsourcing; research shows that a company's stock price usually rises after an outsourcing announcement is made!

Bob Curtice, a Vice President at Arthur D. Little in Cambridge, Massachusetts, believes that the make-versus-buy decision boils down to a simple rule to live by: perform internally only the functions that the organization absolutely has to perform in order to offer a competitive advantage over others, and nothing more.[26] A similar strategy was proposed in the seminal work on the subject of outsourcing by Quinn and Hilmer (Quinn & Hilmer, 1994). They suggested outsourcing any activity except those by which you can achieve definable pre-eminence and provide unique value for customers, or those for which you have a critical strategic need.[27]

Other outsourcing experts promote the idea of concentrating on proprietary components pivotal to product differentiation that can become sources of competitive advantage. They argue that management should outsource commodity-like components with mature technologies that add nothing to qualities important to customers. It is known that companies will also often over-invest in expensive and time-consuming "world-class" manufacturing programs (e.g. TQM, JIT, and CIM) which are misdirected toward commodity parts, when efforts should be concentrated on in-house production of proprietary components that can become sources of competitive advantage.[28]

Why has outsourcing become so popular?

Outsourcing has become very popular for a number of reasons. The first reason is corporate downsizing. Companies must still perform all of the necessary business functions, but with fewer employees. Secondly, the outsourcing of an activity is often less costly than training or managing employees to perform that same function in-house. The third reason that outsourcing has become popular is because for many companies, outsourcing has become a part of their philosophy and strategy, and it is seen as the first step towards becoming a virtual company.[29] Outsourcing is also related to capacity-planning decisions. The question arises whether to spend money to build more internal capacity, or to outsource the service or manufacturing activity.

Success stories have also encouraged and sustained the practice of outsourcing. For example, in the latter half of the 1980s, using extensive outsourcing, Sun Microsystems achieved higher productivity, growth rates, and return on investment, than did vertically integrated IBM and Digital Equipment Corporation (DEC). This ultimately allowed Sun to out-perform IBM and DEC.[30]

Nike has taken outsourcing to a new level: the *virtual company*. Nike outsources all of its manufacturing through the use of a multi-tier partner strategy. The Washington-based company has three sorts of partners: developed partners, volume producers, and developing sources. **Developed partners** produce Nike's latest and greatest "statement products" (20,000 to 25,000 units/day). Nike tries hard to stabilize volumes for developed partners. Developed partners can usually produce lower volumes, co-develop products, and co-invest in new technologies. **Volume producers** produce a specific type of footwear and are vertically integrated. They are expected to handle most surges in volume themselves, and are above average in size (70,000 to 85,000 units/day). Nike does no development work with volume producers because each company may produce for seven or eight other buyers. **Developing sources** have low labor costs and produce exclusively for Nike. Nike tries to link them (through joint ventures) with developed partners. Developed partners then try to move some of their own labor-intensive activities to developing sources.[31]

Core competencies

In the vernacular of outsourcing, the phrase "core competency" is used extensively, sometimes excessively and to the point of becoming a cliché. A popular philosophy built around this notion of core competency considers any activity that is not part of a company's set of core competencies as fair game for outsourcing. Honda, for example, is highly competitive in a variety of market sectors, including automobiles and outdoor yard equipment, yet it is world leader in only one, i.e. motorcycles, because it is the world's leading manufacturer of small engines and power trains.[32] Honda decided to retain the manufacturing of small engines and power trains, because those items form the heart of all motorized equipment, and are considered a core competency at Honda. Many other activities not considered part of Honda's set of core competencies were considered fair game for its outsourcing programs.

Critical processes

Not all outsourced functions are unimportant. It is often the case that a *critical* process is outsourced (e.g. shipping parts or keeping workstations running) that is not a *core competency* of the company. For example, Picker International, a Cleveland-based supplier of medical diagnostic imaging equipment, uses SonicAir to deliver critical parts (some worth as much as $20,000) when they are needed, within a matter of hours. Picker's customers need to know exactly when parts are going to be delivered and when their equipment is going to be repaired so they can schedule patients for diagnostic procedures. SonicAir maintains 13 depots around the country that warehouse crucial parts for Picker, accounting for 15 to 20% of SonicAir's deliveries. Picker chose to outsource this function because it simplified the delivery process, and because it was more difficult to keep track of parts and their condition when Picker used their own 26 district offices to inventory parts.[33]

Learning in production as a source of competitiveness

The experience curve, based on an earlier concept called the production learning curve, first came to prominence in the 1960s. It was during this time that the Boston Consulting Group demonstrated that unit costs in many industries decrease due to cumulative volume in a predictable and exponential way.

Experience curves graphically portray the relationship between learning and strategy. They measure the effect that **accumulated** production experience with a product or family of products has on the unit cost of production. The exponential nature of the experience curve means that every time a plant's cumulative production doubles, its production costs decline by a specific percentage. Experience curves are often graphed using a log–log scale so that data points tend to fall very close to a straight line.

The rate at which the organization learns is for many their only sustainable competitive advantage, particularly in knowledge-intensive industries such as electronics. The steady decline in the price of integrated circuits (ICs) over the last 35 years is a classic example of the experience-curve effect. In very mature industries, such as the automobiles industry, the impact of accumulated experience tends to taper off. It is unlikely, for example, that quantum leaps in automotive manufacturing technology will occur, drastically cutting the production cost of automobiles.

Many companies, such as Bausch and Lomb (contact lenses) and BIC Corporation (disposable ballpoint pens), have been very successful in building and maintaining market leadership using their knowledge of experience curves and experience-based pricing. Furthermore, learning advantages, based on depth in core competencies, are not just limited to manufacturing companies. Wal-Mart, for example, has been very successful in capitalizing on its experience with supply-chain logistics, and the "share and compare" learning philosophy of BancOne has had much to do with its continued success.[34]

Experience-based strategies often fail to live up to expectations, because the strength of the experience effect is sometimes overestimated, with anticipated cost reductions failing to materialize (e.g. Monsanto in the acrylonitrile industry).[35] Another flaw in traditional experience-curve thinking is the assumption that all competitors learn at the same rate. This assumption was challenged in the 1980s, by observations that the Japanese automobile industry learned at a faster rate than the US automobile industry, with substantially less volume. Simply put, the Japanese were the more-efficient learners and because of their continuous improvement efforts, they were able to catch and surpass their US counterparts.[36]

By the 1970s, economies of scale and the experience curve effect had given Chrysler Corporation the lowest per unit production costs among all US automobile manufacturers. Unfortunately for Chrysler, the cars they were building at the time were not what customers were looking for, and so sales plummeted. To make matters worse, they could not sell enough vehicles to keep their large assembly plants operating at design capacity levels, and that drove up unit production costs. The quantitative aspects of the experience curve are covered in Chapter 10.

Outsourcing trends and concerns

The future of outsourcing practices looks strong. Companies are outsourcing such activities as telecommunications, system operations, management of PCs and the computing infrastructure, and even strategic planning. Research conducted in 1999 using more than 500 executives indicated that firms in dynamic markets (e.g. high-tech products, telecommunications, and professional services) already source more than 40% of their operations outside.[37]

Despite the apparently bright future of outsourcing, a nine-year study conducted by Rudy Hirschheim and Mary Lacity at the University of Houston concluded that there is an inexorable move toward "*backsourcing*" among companies that had outsourced their information technology (IT) functions (Hirschheim & Lacity, 2000). In other words, companies that had outsourced their IT operations were beginning to pull these functions back in-house as outsourcing contracts expired or were terminated. The study also determined that the press most frequently covered outsourcing arrangements during the "honeymoon period," when both supplier and client were excited and satisfied, and speaking highly of one another.

There are several dangers inherent with outsourcing. First, even in the closest outsourcing relationships, partners will always remain potential future competitors, where one partner may prosper at the expense of the other. Key competencies of IBM for example, passed quickly to upstream suppliers such as Intel and Microsoft.[38] Secondly, an organization may be mortgaging its future for only a fleeting, short-term competitive advantage. Key skills may, over time become lost forever. Should the outsourcing plan fail, skills needed to perform the work in-house may be difficult or impossible to recover.

The Chief Resource Officer

According to the Outsourcing Institute, an emerging position that oversees management of contract manufacturing and outsourcing service agreements is the Chief Resource Officer (CRO). According to the institute, an effective CRO should possess the following skills and personal characteristics:[39]

- Experience of managing different businesses.
- Experience of managing costs.
- Skilled at project management.
- Successful at contract negotiations.
- Political and cultural consciousness.
- Ability to think outside the box.
- Comfortable with change.

Modularity and modular assembly

In many industries, it is currently common practice to outsource a large proportion of manufactured components, as well as services (e.g. heat treating, information technology, health-plan administration). Outsourcing the entire product and maintaining no in-house manufacturing capability is another popular manufacturing strategy. This is the so-called “virtual-company” approach taken by Nike as described earlier. There is also a third important and unique supplier arrangement known as “modular assembly,” which produces fully finished products by assembling only a handful of pre-assembled chunks (the “modules”). The modules, or subassemblies, are built by suppliers located either in a closely situated off-site plant (in a “supplier campus” arrangement), or within the customer’s facility. Suppliers may also provide workers to assemble the modules to each other, working in cells located along the assembly line. In a typical arrangement, *tier-3* suppliers provide parts to *tier-2* suppliers, who in turn provide sub-components to the *tier-1* module suppliers. Broadly defined, any arrangement where a handful of suppliers are providing a customer with physical subassemblies, containing significant value-added content, can be called a modular arrangement.

Recent developments suggest that modular assembly is one of the latest manufacturing trends in the automotive industry. By 1998, the “Big Three” (GM, Ford, and

Daimler-Chrysler) each had new modular plants under construction in Brazil, and the possibility of replacing some of their aging, inefficient US plants. This development implies that a rethinking of the methods of traditional automobile manufacturing is underway, which might slash costs by thousands of dollars per vehicle, resulting in lower retail prices.

In the automobile industry, the contributory roles of tier-1 suppliers and original equipment manufacturers (OEMs) vary greatly. In a pure **modular consortium**, suppliers are really co-investors and each module supplier assembles their module, and provides on-line assembly of their module onto the vehicle. Variations on this scheme abound, including arrangements that allow the OEM to assemble the modules to each other.

Supporters argue that modularity drastically cuts costs and increases productivity (essentially by reducing hourly headcount, and engineering design costs). Modularity should also provide greater flexibility to respond to schedule changes because there are fewer suppliers, improving JIT deliveries and reducing inventory-holding costs.

Critics view modularity as little more than a corporate shell game. Their assessment is that labor is simply shifted from one facility to another, without reducing the *total* amount of labor needed. Japanese manufacturers such as Toyota have been slow to embrace modularity for exactly this reason, arguing that labor cost is just shifted to suppliers, forcing them to raise prices. Proponents would argue that suppliers tend to pay lower wages than the automobile manufacturers themselves, and therefore some of this "transferred cost" simply does not exist.

Most of the early experiments in modularity took place in Brazil. Volkswagen's truck and bus assembly plant in Brazil is a good example of a modular consortium and is a facility that many other vehicle manufacturers measure themselves against. The Resende plant, located in the state of Rio de Janeiro, opened in November 1996 and utilized seven modules to initially produce 30,000 trucks and buses per year. The operation consists of seven basic modules: cabin structure, painting, engine, cabin assembly, wheels and tires, chassis, and suspension. Suppliers have full responsibility for their assembly cells, from purchasing to inventory control, tool maintenance, quality, worker safety, wages, and even labor grievances. VW provides only the plant's basic utilities such as water, heat, and electricity.[40]

Early in 1999, GM proposed *Project Yellowstone*, which would have led to the construction of three new modular assembly plants to produce small cars in North America. The United Auto Workers (UAW), however, made it clear to GM that their modularity initiative would be strongly resisted and could even lead to a strike. The union was concerned that since supplier plants are typically not as unionized, any modular plant in the United States or Canada would employ fewer unionized workers. In the summer of 1999, under increasing UAW pressure, GM decided to cancel, or at least postpone, Project Yellowstone.

The Dell direct-sales model

A young Michael Dell developed his "direct-sales model" during the early 1980s, when he observed that the high price of personal computers was due largely to a very complicated selling and distribution process. Dell reasoned that selling a computer directly to the user, and eliminating the time and cost of third-party distribution could significantly reduce the selling price. When Dell achieved great success and growth in the 1990s, many leading firms, including non-computer companies such as Ford, began to benchmark the Dell supply chain and production process.

In Dell's make-to-order system, most computers are not made until the customer places an order, either on-line or via the telephone. For each order, the required modular components are gathered, and the computer is assembled and tested, typically in less than four hours. The remainder of the two- to three-day order-to-delivery time is due to shipping constraints. To minimize the inventory-carrying costs for Dell, suppliers own their inventory until it is actually used in production. Suppliers typically maintain nearby shipping points, located within one hour of a Dell assembly plant. Another way that Dell minimizes inventory is by frequently steering customers to PCs with high availability to balance supply and demand. Dell has focused on strategic partnerships with suppliers, reducing their supply base from 200 suppliers to 7.

The computer industry has adopted a classic "mix-and-match" architecture, where a complex PC is subdivided into individual modules, primarily the processor, motherboard, modem, network interface, video card, sound card, hard disk, and power supply. The modular nature and interchangeability of components allows Dell to quickly deliver up-to-date computer systems tailored to specific needs, and existing equipment and software. Mass customization is facilitated by the relatively low complexity of Dell products; typical PCs consist of 50 components, 8 to 10 being key, providing 100 product permutations.

In 1999, Dell was the E-commerce sales leader of the PC world, but Michael Dell felt that his supply-chain group was not using the power of the Internet, and therefore was not "eating their own dog food." A new initiative hard-wired dozens of suppliers to the company, allowing them to forecast more-accurately and manufacture on a real-time basis. Web cameras spot production bottlenecks, and web hookups help shippers arrange pick-ups. Plastics supplier Nypro has been able to cut the inventory it keeps on hand for Dell by 70%.

Another Dell innovation is "virtual integration." With virtual integration, suppliers assign engineers to a design team, but the engineers are treated like Dell employees. When a new product is launched, supplier engineers are stationed in the Dell assembly plant. Virtual integration implies treating supplier partners as company insiders. It is enterprise thinking at its best.

On the customer-side, virtual integration means ongoing market segmentation to give Dell better customer attention and focus, and installing customer-specific software before systems leave the plant. Dell has 30 people working at Boeing, but they behave and are treated like Boeing PC-department personnel. Dell also helps customers set up their own customized, internal versions of dell.com, and about 7,000 sites have been installed to date. Dell also uses 10,000 field service technicians around the world, only a small number of whom actually work for Dell, but most customers will never know that the person that just fixed their computer is not a Dell employee.

Primary strengths

- Superb customer knowledge.
- Suppliers provide component design and innovation.

Production strategy

- Modular-based architecture.
- Assemble to order.
- Pre-configure software.
- Steer customers to products with high availability to further reduce inventory.

Supply-network design

- "virtual integration."
- Customized dell.coms.
- Suppliers hard-wired.
- Internet cameras spot bottlenecks.
- Latest web techniques for suppliers.

Sources

Magretta, J., The power of virtual integration: an interview with Dell Computer's Michael Dell. *Harvard Business Review*, March–April (1998), 73–84.

Rocks, D., Dell's second web revolution. *Business Week*, September 18 (2000), EB62–EB63.

Process selection – internal or external?

Even when using extensive outsourcing or modular techniques, most producers must add extra value to products with in-house capabilities, processes, and equipment. Even a "virtual company," such as Nike, may need in-house packaging equipment to package finished products individually. A common method used when selecting the best option among a set of process or equipment alternatives is *breakeven analysis*.

The breakeven chart is a graphical depiction of expected revenues versus the number of units produced for several different processing alternatives. Breakeven analysis is most appropriate when initial investment into processes or equipment and fixed costs are large, and variable costs are proportional to the number of units produced.[41]

As a simple example, suppose there are three alternatives to choose from: (1) a part may be outsourced at $100 per unit (including materials); (2) it can be made in-house on machine "A" at $50 per unit (including materials); or (3) it can be made in-house on machine "B" at $10 per unit (including materials). The fixed cost to purchase machine A is $10,000, and the fixed cost to purchase machine B is $50,000. A summary of the total costs for each alternative is shown in Table 9.5.

Table 9.5 *Summary of breakeven example with three alternatives*

Alternative	Description	Equation for total cost curve (D = demand)
1	Outsource entire unit	$\$100 \times D$
2	Produce in-house using machine A	$\$50 \times D + \$10{,}000$
3	Produce in-house using machine B	$\$10 \times D + \$50{,}000$

Find the location of the breakeven points:

Point 1: $50 \times D + 10{,}000 = 100 \times D$
therefore $D = 200$ units

Point 2: $10 \times D + 50{,}000 = 50 \times D + 10{,}000$
therefore $D = 1000$ units

Therefore, for quantities less than 200 units, the cheapest alternative is to outsource the units. For quantities between 200 and 1,000 units, it is best to produce the parts in-house using machine A. When quantities exceed 1,000 units, it is most economical to produce the parts on machine B.

Supply-chain management implications

Supply-chain management (SCM) describes the aspect of operations management that deals with converting raw materials into final products, and the delivery of those final products to customers. (Supply-network implications have been developed throughout the text as a main external dimension). The American Production and Inventory Control Society (APICS) dictionary defines the *supply chain* as "the processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier–user companies."[42] For many companies, SCM means maintaining and operating a *network* of suppliers, manufacturing sites, and distribution facilities, around the world. The word "network" is more appropriate than "chain," because the latter implies a purely linear relationship between activities, whereas most realistic examples are network models. However, the simplified linear flow process, or linear supply chain is often used as a model when discussing supply-chain concepts related to production requirements.

Industry and the military use the term *logistics* to describe the act of obtaining, producing, and distributing material to the right place, in the right quantity and at the right time. In the military, logistics can also include the movement of personnel. If the term logistics is used to mean the management of *flows* (physical as well as informational), then SCM is the logistics of all forms of product information and movement. This requires looking as far upstream in the process as possible (e.g. to the supplier of your supplier's supplier), and as far downstream as possible (to the

Figure 9.7 Basic linear supply chain

customer's customer). Traditional logistical models looked only at simple incoming raw material and outgoing finished products.

Figure 9.7 is an example of a simple linear supply chain. In this section, the terms "chain" and "network" are used interchangeably.

There are many physical flows that can take place in the supply chain, including the following:[43]

- Raw materials from original source stocking point through to delivery to the customer.
- Machine tools and machines from one facility to another.
- Finished products between plants, the company's own warehouses, or customers' warehouses.
- Goods and parts to be repaired.
- Empty packaging returned from delivery points to loading points.
- Used/consumed products to be recycled, retrofitted, reused or disposed of (reverse flow).

Today, unique difficulties exist in the management of supply networks. New complexities such as *reverse logistics* (e.g. recycling) and *return logistics* (after all, what does Home Depot do with all of that returned merchandise?) have made the effective management of supply networks a difficult challenge.

The Bullwhip effect

Consider the simple linear supply chain shown in Figure 9.7. For the factory, demand is a collection of orders from distributors, wholesalers, and retailers. In such a situation, the variance of the order size increases as you move upstream in the chain. The size of this variance increases as the number of "links" in the chain increases and as the amount of information exchange between the links decreases (e.g. if order-size and inventory information is exchanged between adjacent links only). Therefore, the factory may perceive a large increase or decrease in demand when there really is none. This phenomenon illustrates the dynamic nature of supply chains and is called the "bullwhip" or "whiplash" effect, because a small variance in actual demand grows as it moves upstream and therefore "cracks the whip" for upstream suppliers.

Proctor & Gamble (P&G) experienced the bullwhip effect in the distribution of its Pampers disposable diapers. Consumers (mothers and their babies, in this case) consumed diapers at a steady rate, but order-size variabilities were amplified as the process moved up the supply chain. Sales were not varying excessively at the retailer, but distributor's orders and orders by P&G to its suppliers varied greatly.[44]

The Hewlett-Packard Deskjet printer supply network

Dornier, *et al*. (1998) provide an example of a simple supply network for the Deskjet printer made by Hewlett-Packard (HP).[45] The printers are manufactured by HP in Vancouver in a two-stage production process: (1) assembly and test of printed circuit boards (PCB); and (2) final assembly and testing [including assembly of other subassemblies (motor, cables, gears, etc.) and PCBs from stage 1]. Components needed for these two stages are provided by other HP divisions, as well as external suppliers. The supplier arrangement for the Deskjet is a good example of a typical global supply *network*, and this model is shown in the figure below.

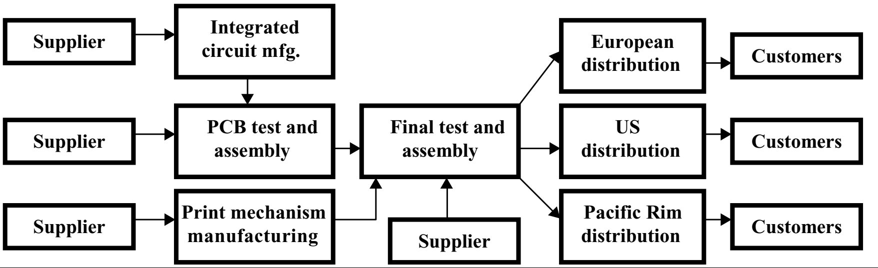

Figure 9.8 The HP Deskjet printer supply network

The following behavioral causes of the bullwhip effect have been identified:[46]

- ***Individual decisions***. Management may fear a product shortage and react by increasing safety stocks, and increasing orders from upstream suppliers. Unfortunately, the entire supply chain now thinks demand has increased dramatically.
- ***Inappropriate financial incentives***. Often, financial incentives, such as stock-outs costing twice the per-unit holding costs, create an exaggerated "shortage fear", which naturally encourages over-ordering to avoid stock-outs.

Four primary non-behavioral causes of the bullwhip effect are known to exist:[47]

(1) ***Demand forecast updating***. If all links in the supply chain do not have an accurate picture of the actual market demand, variation of forecasted order sizes upstream increases and goes unchecked. Long lead-times aggravate the effect of this situation. In an effort to eliminate some of these problems, companies have developed point-of-sale (POS) technology that enables current sales information to be sent to upstream links in the supply chain.

(2) ***Order batching***. Economies of scale prompted by long set-up times encourage accumulation of demand before issuing an order. Because it is preferable to deliver products on full trucks only, transportation costs cause similar ordering build-ups. By finding cost-effective ways to reduce batch sizes and promote more-frequent ordering, the effect of order batching can be minimized.

(3) ***Price fluctuations***. When prices are low, such as during a sale or close-out, a customer will buy in larger quantities than needed. For this reason, P&G and Kraft use a practice called "everyday low pricing" (EDLP) in order to stabilize prices and smooth out demand along the supply chain.

(4) ***Rationing and shortage gaming***. Manufacturers will often ration their products to customers when demand exceeds supply. This is typically accomplished by delivering in proportion to the amount ordered (i.e. the more you ordered, the larger your allocation). Unfortunately, this practice causes customers to purposely inflate their order sizes during short-supply periods and cancel or reduce orders in periods of plentiful supply. This customer practice is called "gaming of orders." To correct for gaming behavior, companies such as General Motors and Texas Instruments are allocating products to dealers by looking at *past* sales records.

Designing for manufacturing

The production aspects of concurrent engineering

As described in Chapter 7, product designers develop product specifications based on the needs and wants of customers and product characteristics, including material and dimensional requirements, and then pass their designs to manufacturing engineering for detailed process-plan development. Historically, designers were only vaguely familiar with the marketing and production perspectives. The consequence of this approach was a "we design it, you build it" attitude towards the manufacturing function. This resulted in a number of problems for manufacturing and production personnel including: products with tolerances that were difficult or impossible to hold with existing machine capability; components that were difficult to assemble; and products which met neither marketing expectations nor customer needs.

In general, activities during product development were handled sequentially, rather than concurrently. As a result of these shortcomings, a technique to allow all departments to communicate earlier in the design process was developed. Concurrent engineering (CE) developed as a product design philosophy that enabled all departments, especially production, to contribute simultaneously and early in the design stage of the product. The goal of CE is to ensure that external and internal customer needs are satisfied by requiring all parties affected by a design to have early access and input to design criteria.

CE seeks to reduce the time from product conception to market introduction, to prevent quality and reliability problems, and to reduce costs. An early example of the successful application of CE is the Ford Taurus program. Many design parameters can be addressed during CE activities, including: basic functional requirements, reliability, safety, human factors and ergonomics,[48] manufacturability, inspection, packaging, transportation, and storage.[49]

CE tends to generate more up-front design changes, and therefore shift more costs into the pre-production phase of the product life cycle, than is commonly seen in US companies. It may be preferable to make these changes in the later phases when their full impacts are apparent; however, it is far cheaper to make changes in design before,

Table 9.6 *Tolerance limits*

Type of tolerance	Example
Bilateral tolerance	1.000 ± 0.001 inch (2.54 ± 0.00254 cm)
Unilateral tolerance	1.000 + 0.000 and −0.002 inch (2.54 + 0.000 and −0.00508 cm)
Smaller-the-better tolerance	"Edge radius 0.010 inch (0.254 cm) maximum" (zero is the implied target value)
Larger-the-better tolerance	"100 lb (45.4 kg) minimum pull-off force" (infinity is the implied target value)

rather than after, the first unit of product has been produced. The Japanese have long practiced this idea of making as many changes as possible early in the design cycle.

Tolerance selection for production requirements

The selection of tolerance limits is a critical activity during product design and the selection of manufacturing processes. Tolerance limits can influence the product characteristics and the product's performance, the machinery and tooling required, and quality requirements (inspection, rework, scrap, etc.).

For each product characteristic a designer typically specifies: (1) a target or nominal value (the average value that can be expected during production); and (2) upper and lower specification limits (or tolerance limits). Upper and lower specifications limits (USL and LSL, respectively) represent values above and below the target value beyond which the product will not function properly. Tolerances with two non-zero limits are known as "bilateral tolerances," and tolerances with all of the tolerance on one side of nominal are called "unilateral tolerances." From a production perspective, it is also possible to have "smaller-the-better" tolerances where the implied minimum (or target value) is zero, with only a maximum value specified, and "larger-the-better" tolerances where only a minimum required value is specified. Examples of these four types of tolerance limits are given in Table 9.6.

Tolerance limits consider functional requirements of the product and process capabilities. In the ideal situation, design engineers have information on true process variability, but commonly a sample must be taken from the process to estimate the mean and the standard deviation of the process. The sample values are selected after considering the values the designer had in mind (if any), and the functional needs of the product. Tolerance limits that reflect actual variation of the process are sometimes called "natural tolerance limits."[50]

There are quantitative techniques for establishing tolerance values based on inherent process variation. When a new design is a variant of an older, existing design, an appropriate sample size of the older design may be collected from the process. The dimensional characteristic of interest would then be measured on each item. For example, if this is done and a sample mean of $\bar{x} = 2.54$ cm and a sample standard deviation, $s = 0.00254$ cm is calculated. Assuming the manufacturing process is approximately normally distributed, one common practice is to simply set the upper and lower specifications at $\bar{x} \pm 3s$, in this case 2.532 and 2.548 cm, respectively. Because the process is normally distributed (and hopefully stable enough to be predictable, as well as centered on target), we would expect to see approximately 99.73% of the units with our new design fall between 2.532 and 2.548 cm. To illustrate this, using basic statistics, the area under the normal curve to the right of $Z = 3.0$ is 0.00135 (using a table for the standard normal curve). Since the normal curve is symmetrical, the area under the curve to the left of $Z = -3.0$ is also 0.00135. The total area under both tails is $2 \times 0.00135 = 0.0027$, and the area under the curve between $Z = 3$ and $Z = -3$ is therefore $1 - 0.0027 = 0.9973$, or 99.73%.

Using three standard deviations in the tolerance calculation has a major drawback. The number of non-conforming parts per million (NCPPM) would be approximately 2,700 ($0.0027 \times 1{,}000{,}000$). This number is much too high by most current industry standards, particularly in electronics and aerospace. In fact, in many industries, the design for six-sigma concept of process capability is forcing companies to relentlessly pursue reducing process variation, with the goal of driving down the NCPPM to single digits.

Arbitrarily using a larger number of standard deviations in the above tolerance calculations would indeed yield fewer NCPPM (e.g. using $4s$ the NCPPM would be 6.8), but these wider tolerance limits might violate functional or safety requirements of the product. In fact, one of the criticisms of the six-sigma concept is that it is possible to reduce NCPPM values simply by widening tolerance limits (whether justified or not), without actually reducing process variation.

Designing for manufacturing and assembly (DFMA)

One of the benefits of CE practice is the attention it places on simplifying designs to make them more producible. A general term to describe this approach is “designing for manufacturing and assembly” (DFMA), often shortened to “design for manufacturability” (DFM). DFM was introduced and discussed from a design perspective in Chapter 7. The DFM&A philosophy emphasizes reducing the total number of parts contained in a design and reducing the total number of *different* parts. Ultimately, the best part design is elimination of the part altogether! Limiting the number and variety of parts reduces the total number of manufacturing operations, and assembly and quality problems. Another primary goal of DFM&A is to minimize the total number of fasteners in a design.

One classic example of the application of DFM&A techniques is their use by NCR to design their Model 2760 cash register. NCR analyzed potential designs for the

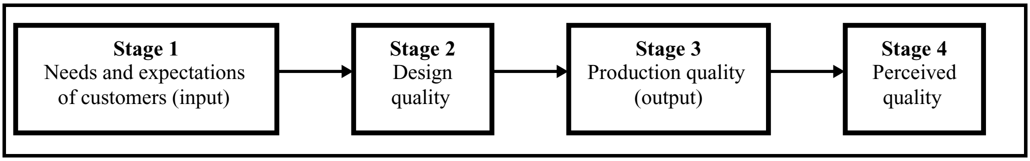

Figure 9.9 A simplified view of the customer-driven approach to product design and manufacturing

cash register using software developed by Geoffrey Boothroyd, Professor of Industrial and Manufacturing Engineering at the University of Rhode Island. Boothroyd is the co-founder of Boothroyd Dewhurst, Inc., a small company that develops DFM&A software. Boothroyd strongly believes the biggest gains in simplification of a design for manufacturing come from the elimination of screws and other fasteners.

NCR began the design process by generating three-dimensional computer models of the parts and simulating assembly to see how they would fit together. Using Boothroyd Dewhurst's software, NCR reduced the number of parts on the Model 2760 by 65%. The design was so simple that the manufacturing manager was able to assemble the register without using any screws or fasteners, in less than two minutes – blindfolded. The final cash register design consisted of just 15 supplier-produced components, reduced from an initial 28.[51]

When the final assembly of a product is done by the *customer*, the assembly part of DFM&A is critical. Consumer products are often shipped "partially assembled" and require more time and skill to finish assembling than the packaging implies. Products that are commonly only partly assembled by the manufacturer include gas barbecue grills, toys, bicycles, and computer furniture. Many consumers have frustrating experiences with these products and are happy to have the improvements in ease of assembly that the DFM&A approach generates.

Customer-driven design and manufacturing

The goal of manufacturing is to satisfy customer needs and expectations from design, to the production processes, and to delivery to the customer. A model of this approach is shown in Figure 9.9. In a "balanced" system, the quality perceived by the customers at stage 4 properly reflects their needs and expectations at stage 1. A major problem with practicing the customer-driven approach to product design is that many customers do not speak the "language" of engineers (i.e. technical jargon), and many engineers do not always understand the "language" of customers (e.g. non-specific clichés). Because of this language gap, even accurate and detailed information on customer needs can get lost during translation and interpretation by engineers. The challenge, therefore, is for engineers to accurately and thoroughly translate customer needs and expectations into engineering specifications. These engineering specifications, when applied in production, influence the output quality of the product.

Finally, the perception of engineers regarding the importance of design features can often be different than the actual customer needs. For example, engineers might change a part from steel to plastic to save weight, when in fact the steel made the product very durable, which satisfied the customers.

Concluding remarks

In this chapter, the four classic manufacturing performance measures were presented (i.e. cost, quality, delivery speed, and flexibility). It was shown that they are critical metrics that all companies should assess when addressing customer requirements. Production-system design has a significant influence on these performance metrics. Production systems take raw material or other resources as inputs, and through a series of activities, convert these resources into usable outputs. This conversion process should be optimized and designed to add value at each step in the production stream. Several different process-flow structures have been developed to accomplish this conversion from input to output. Systems that minimize waste and maximize value-added time during the transformation process are the focus of modern managers. The Toyota production system is one system receiving a great deal of attention, and the principles of this model are being studied and adopted by companies worldwide.

Manufacturing enterprises must also develop flexible operations. Due to fickle customers and rapidly changing market conditions, what sells well today may be unwanted, obsolete inventory tomorrow. In order to react to market changes, manufacturers must be able to switch quickly between different makes or models.

Outsourcing and the use of outside suppliers to provide services or products are current trends, but these practices should never be considered a panacea. Manufacturers are still struggling with the “make-versus-buy” dilemma, but the “buy” decision seems to be winning out more often than it did in the past. Companies know that long-term competitiveness and survival can depend on selecting the right blend of in-house production and outsourced activities.

Modular assembly is a unique outsourcing arrangement that provides companies with the opportunity to simplify their supply chains further. Modularity can reduce direct labor requirements and capital expenditures, but the practice poses significant risks as well. Loss of core design knowledge and quality control, as well as potentially contentious labor issues means careful study and planning are required before this strategy is pursued.

Designing products that are easier to manufacture and assemble is a critical requirement for the customer-driven enterprise. By assessing and improving manufacturability early and up-front in the product life cycle, firms can significantly reduce the costs due to design changes and production problems. Concurrent engineering is a philosophy that enables all departments to contribute simultaneously and early in the design phase. This practice has served to simplify designs and, by limiting both the number and variety of parts, the total number of manufacturing operations can be reduced, thereby reducing assembly and quality problems.

Manufacturing or operations can be a significant competitive weapon in introducing new products to the market place. Superior products are holistic and represent superior processes and practices across the product delivery system. The best-designed products that meet customer expectations are not superior unless they are produced to the highest quality levels possible and include contributions from supply networks that are aligned with the management system.

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10 Financial applications and implications

Introduction

This chapter focuses on the financial methods and techniques used during the new-product development (NPD) process and their applications and implications. The purpose of the discussions is to provide an overview of the essential elements of selected quantitative methods to assess new-product opportunities and programs from a financial perspective.[1] The theories and concepts outlined in the supplement to Chapter 6 established the foundations for the content discussed in this chapter. The content of the chapter covers several important financial techniques that are imperative for making effective decisions during the NPD process.

The chapter flows from the specifics of determining unit costs to the broader perspectives of assessing the financial implications of the NPD program. The essential question for any new product is: Does the new product generate and sustain sufficient value for the participants involved in the process and their constituents to justify the time, money and effort, i.e. the investment? Moreover, the question revolves around the overarching view of the "reward-to-risk" relationship. Are the rewards worth the risks? The answers are complex and depend on the circumstances of the business environment, and the capabilities and resources of the enterprise.

New-product development is inherently risky.[2] Even the most well-understood NPD situations and well-articulated NPD processes have many unknowns and uncertainties. Every development decision has the potential to create problems and liabilities or, on the other hand, to achieve great successes. The main premise of integrated product development (IPD) is that a systematic, fully articulated, and conscientiously implemented NPD process can minimize mistakes, defects, and risks from a business and financial perspective.

For existing products, the market place becomes the laboratory as hidden product difficulties are gradually discovered. A central theme of the NPD process is to discover potential difficulties and hidden problems before commercialization and take corrective actions. Indeed, IPD and the NPD process focus on discovering all of the implications as early in the process as possible and initiating every means possible to rectify the consequences. However, occasionally the true effectiveness of the new product cannot be ascertained until after the product is being used by customers. In such cases, the NPD effort continues until the negative impacts and their consequences have been mitigated to the greatest extent possible. Due to the ongoing changes in the business environment, and uncertainties in general, perfection is difficult to realize.

Other critical questions are: What are the most important financial implications of the NPD program? and How can a more-comprehensive understanding of the negative aspects of a product be developed prior to incurring any undesirable ramifications (during the NPD process or after launch)? While the general perspectives are positive when creating new products, management has to ensure that the new product and the NPD program are in balance with the best interests of the enterprise. The new product can be a financial success but have a negative impact on other product lines or the reputation of the company.

Chapter 10 includes the following topics and learning objectives:

- Constructing a model of the cost structure of the product.
- Forecasting sales volume and revenue streams over the life of the product.
- Determining the appropriate levels of operating expenses.
- Building a cash-flow model for financial analysis.
- Using financial analysis and decision making to determine appropriate courses of action.
- Using sensitivity analysis for understanding financial risks.
- Evaluating risk and reward.

Unit-cost calculations and implications

Overview

In simple terms, the cost of the product can be simply stated as the price minus the required gross margin (see Chapter 2). However, greater precision is required as the process moves from the conceptual level to the Design and Development Phase and beyond. The simplified approach is useful for determining the target cost, while a more-sophisticated approach is necessary to convey to the decision makers and NPD professionals what is achievable, based on the actual flow of costs from suppliers through to production and distribution. Because costs often have a dramatic impact on the success and failure of new products, the cost model has to include all elements and consider the expected business environment of the new product. Unit cost often varies with production volume, making cost a variable rather than a fixed number. Generally the cost of the product declines as volume increases.

The first step is to determine the design and production aspects of the new product. Detail information and data evolve during the phases of the NPD program. Engineering and technical experts analyze the product specifications and make selections about

Table 10.1 *A simplified bill of material and product-cost schedule*

Item No.	Qty	Description	Manufactured or sourced	Costs ($)		
				Material	Labor	Total
1	20	Injection-molded parts	Sourced (average cost $.25 each)	5.00		5.00
2	1	Body	Sourced	10.00		10.00
3	2	Strapping	Cut to size	1.00	0.17	1.17
4	2	Aluminum parts	Cut to size, deburr and drill	6.00	4.37	10.37
5	1	Other parts*	Manufactured	10.00	3.50	13.50
6	Lot	Hardware	Sourced	1.50		1.50
7	1	Set-up			1.33	1.33
8	1	Assemble and test			3.66	3.66
		Product cost		$33.50	$13.03	$46.53
			Packaging cost	2.80	0.67	3.47
			Totals	**$36.30**	**$13.70**	**$50.00**

*Miscellaneous parts.

product characteristics and manufacturing approaches. Usually the required information is listed in a "bill of material" which defines the technical requirements for the production of the product and a "routing sheet" which outlines the production process. The bill of material identifies the line items for each part or material going into the product construct, the quantity of each item, and the sequences of the product construction. The routing sheet provides an overview of how the materials, parts, and components flow into the product during production. If it is a service, the focus is on how the services are provided.

Table 10.1 shows a simple example of the bill of material of a manufactured product that has purchased materials and parts; it also has an assembly step.

The product cost is the summation of costs for the materials, purchased components, and manufacturing and assembly. The total product cost includes the product cost plus the cost of packaging and instructions. This view of product cost is somewhat static since it does not reflect the potential cost reductions due to volume considerations.

The cost model for the new product is based on an analysis of all of the inputs from suppliers – generally raw materials, parts and components – and all of the direct and indirect costs to convert the inputs into products. It is based on the implications of improvements in the cost structure over time due to increased volume or enhancements in purchasing or production efficiencies.

The learning-curve or experience effects

Many products, especially new products, exhibit learning-curve or experience-curve effects. This phenomenon was discussed in Chapter 8. The concept is simple. The cost structure for a new product generally declines as additional volume is generated for mass-produced products. The theory suggests that the costs decrease at a given rate as cumulative volume doubles. The phenomenon is attributable to the fact that it often takes less time to accomplish tasks as the workers gain experience in performing their tasks. Less time means lower costs. Likewise, as production volume increases, the purchased items can be bought in greater volume at a reduced cost per unit. For example, if the producer of a food product wishes to purchase a kilogram of sugar, the cost is $1.00 for a 1-kg bag. However, if there is a need for 5 kg, purchasing a single 5-kg bag makes more economic sense than buying five 1-kg bags. Indeed, the cost of the 5-kg bag is $2.50 or $0.50/kg. The concept of bulk purchasing continues as larger quantities are required and justified. The sugar can be purchased in 50-kg bags for $0.25/kg. It can also be purchased in full-truck loads and even rail-car loads. Eventually the cost may reach the low point of say $0.15/kg. Great care has to be used in the analysis of an NPD situation to ensure that other costs, such as storage costs, do not become more significant as purchased costs are being reduced. However, such cost reductions are typically available only when the new product is not related to existing products. Indeed, for existing products, the quantities may already be sufficiently high, enjoying the full economics of large-scale production or purchasing.

Nevertheless, the learning- or experience-curve phenomenon has to be seriously evaluated for a new product. In many NPD situations, the rate of improvement with respect to production time and materials is predictable. If the new product is related to the product lines of the organization, the historical rate of learning may be applied with reasonable accuracy for the new product. For products like aircraft, jet engines, and automobiles, there is a standard rate of learning that can be used for the new product. It must be recognized that the rate is basically an assumption, but as long as there are no significant changes within the overall structure, the assumption may hold over many new-product generations. The learning rate is the rate at which the number of units of labor required or the cost declines for each doubling of cumulative volume. Table 10.2 gives the logarithmic equation for the learning curve (the standard form of the equation). The equation can be stated in terms of costs or labor hours.

Judgement is necessary when using the learning-curve phenomenon. Mistakes can be made on both sides of the argument. If there is a learning effect and it is not considered, the cost-structure model reflects cost assumptions that are significantly higher than the real case and the model overstates costs. This makes the pricing model less aggressive than it could be if it was based on the true costs. On the other hand, if costs are not reduced with higher volume and there is an assumption that they would be, then the

Table 10.2 *The standard form of the learning-curve equation*

$y = ax^n$

where:

x = unit number
y = number of hours or cost to produce the xth unit
a = number of hours or cost to produce the first unit
$n = \log b/\log 2$, b = the learning rate (based on doubling)

Example

The cost estimate to produce the first aircraft is \$100 million; thus a = \$100 million. Assume that the learning rate is 95%; $b = 0.95$, a good rate for aircraft production. What is the cost for the 100th unit?

$$\begin{aligned} y(100) &= ax^n \\ &= (\$100 \text{ million})(100)^{\log 0.95/\log 2} \\ &= (\$100 \text{ million})(0.7112) \\ &= \$71.1 \text{ million} \end{aligned}$$

profitability and cash-flow models tend to overstate the financial implications of the new product. The projected outcomes of the financial models may reflect positive results while in reality the results may be marginal or worse.

The concept of yield

In constructing a cost estimate, a comprehensive analysis of the parts and materials is required. If a given part is manufactured from a raw material, the yield of the manufacturing process is an important determinant of the cost structure. The theoretical yield is not always realized. Some of the finished parts or even products may be damaged or have unacceptable quality. In addition to the defective outcomes, the product may consume more material than expected. In chemistry, the concept of stoichiometry describes the theoretical requirements of reactants in a chemical combination of two or more materials to produce the resultant product. The stoichoimetric amount represents the best outcome. For example, carbon burned in air results in carbon dioxide gas (carbon plus two oxygen molecules equates to carbon dioxide, CO_2). In a real-world process, the equation is carbon and air producing CO_2 plus excess air with the possible production of carbon monoxide, due to incomplete combustion, and of nitrogen oxides. This means that, compared with the theoretical amount, more input is required to achieve the required level of output; in addition, the output is less than expected and waste streams are generated. The added production processing and the waste streams both result in additional costs. The implications of yield are described further in Chapter 11.

Table 10.3 *Techniques for handling yield problems – advantages and disadvantages*

Approach	Advantages	Disadvantages
1. Use the actual cost based on the yield problem and essentially pass the cost on to the customer.	Using the actual cost is simple to handle, i.e. no special accounting. It may force solutions since the implications should be obvious.	Such practices could make the competitive situation more difficult, especially the pricing of the product vis-à-vis competition. If costs are reflected in the pricing, it shifts the burden to the customers.
2. Assume that the cost of the part is what it will be at the expected higher yield level when production problems have been resolved.[3]	This approach reflects the long-term perspective and reduces the burdens associated with a new-product launch. The unabsorbed cost could be accounted for using a special account for the start-up situation.	The yield may never be improved and the unit cost structure reflects an optimistic case that will never materialize. Participants may not have a sense of urgency to focus on the causes and the problems are allowed to exist for an extended time.
3. Assume a yield that represents the best compromise between the short-term and long-term situation and build it into a long-term situation.	This approach builds stability into the solution. The cost model represents an average cost position over the life of the product. It tends to minimize the number of changes in the cost model during the product life cycle.	It tends to distort reality. The cost model understates the actual cost during the early stages of the life of the product and overstates the cost during the later stages. This could be a serious problem if there is limited competition during early commercialization and fierce competition in the later periods.

The following is an example of a business case. Assume that 100 parts produced from a manufacturing process provides only 90 parts that are defect-free and 10 parts are defective. In order to obtain 100 parts, approximately 111 parts have to be put into production. Because of the poor yield, which is common for a new-product situation, the cost for the part is about 11% more than the theoretical case. This has an important implication, since it indicates weakness in the competitive situation. It suggests that a competitor with better production capabilities could improve its cost structure. This has an important impact on pricing strategies, since cost influences price (as discussed in Chapter 8).

A key question pertaining to the yield issue is how to handle the cost increment due to the production inefficiency or poor quality during the initial stages of production when problems may have a significant negative influence on costs. Table 10.3 provides an assessment of several ways to deal with the cost implications.

The right answer for most situations is to improve the yield immediately and move closer to the theoretical cost structure. The theoretical cost structure, if it can be determined, provides a valuable target since it represents the best-cost position given the prevailing architecture of the product.

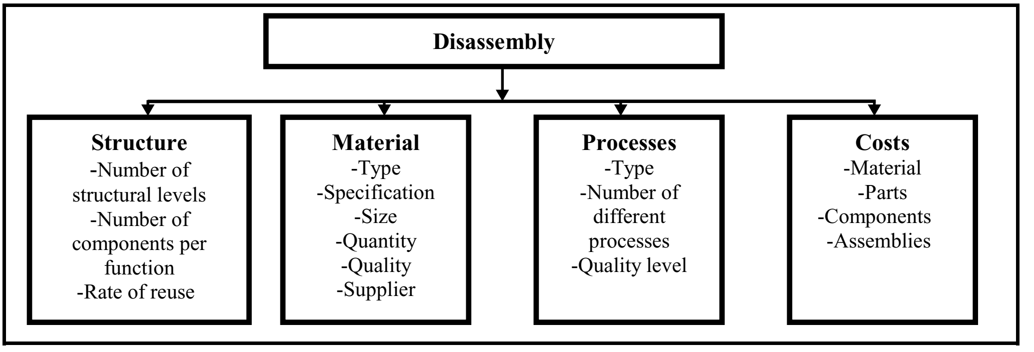


Figure 10.1 Disassembly of process elements for cost comparison[4]

Cost comparison and competitive cost analysis

A cost comparison with similar products of selected competitors provides valuable insights into the cost determination and analysis of the cost equation. Determining the cost structure of competitive products requires considerable effort. The old notion of "reverse engineering" (obtain a competitive product and examine how it was designed and built by reversing their processes) has been updated into a new concept of "benchmarking products through disassembly." The process follows a logical sequence of disassembling competitor products and determining how they were constructed. The objective is to obtain a sense of how close the design and cost model are relative to the best position possible. Figure 10.1 depicts the elements of the process.

The process may require sophisticated analysis for proprietary products. However, for standard products, which contain parts and components from well-established suppliers that serve the entire industry, determining the cost structure is easier and more achievable. For example, most personal-computer manufacturers purchase components from suppliers like Intel and assemble the components into a finished product. Table 10.4 indicates how the data can be used to assess the product characteristics and determine the necessity or opportunities for improvements. The model assumes that such costs can be determined based on knowledge of the competitor's processes and market share.

The analysis provides powerful insights about the new product's position vis-à-vis its competitors. The best combination cost is determined by taking the cost element from the competitor with the best cost position for the given element. An evaluation of the situation for the new product in the example suggests that it has the best cost structure among the existing competitors and that it is only 3% higher than what would be deemed as the target (best) cost structure. If the cost structure is close to the theoretical best point, the work to improve the cost structure might be close to completion. Conversely, if the estimated cost structure is more than 10% higher than the target cost for the product, every effort should be taken to improve the cost structure to ensure that it is

Table 10.4 *Cost comparison (hypothetical) – the best cost for each item is indicated by bold type*

Item	New product	Competitor A	Competitor B	Competitor C	Best combination
Part 1	12.00	**11.00**	11.75	12.00	**11.00**
Part 2	**5.00**	7.00	5.50	6.50	**5.00**
Component 1	20.00	**19.00**	20.10	20.20	**19.00**
Component 2	**25.00**	26.00	25.50	26.00	**25.00**
Assembly 1	30.00	30.00	**29.00**	**29.00**	**29.00**
Assembly 2	**10.00**	11.00	12.00	12.00	**10.00**
Total	102.00	104.00	103.85	105.70	**99.00**
Comparison	100%	102%	102%	104%	97%

not only cost competitive in the short term, but it is well positioned to challenge any potential low-cost opponent.

Implications of cost structure

Estimating cost is an iterative process that may take many trials before arriving at an acceptable solution. If the cost structure meets market expectations, further analysis may not be necessary. However, if the cost is significantly out of line with market norms, the design and production decisions have to be examined to pinpoint areas where cost reductions could be made. Typically, the problem is providing features that customers are not willing to pay for, or if there are functions without benefits associated with the extra costs.

An acceptable cost structure is often crucial for achieving success during the early commercialization of a new product. If the cost target came from the pricing requirements specified by potential customers, it usually provides a reliable indication of what the market expects. If the target cannot be realized even after considerable effort to improve the cost structure, alternative actions should be explored before determining whether to proceed. This is particularly important during the Design and Development Phase. If the cost structure is higher than expected the following actions can be considered:

- Focus or reposition the new product into a market segment that has the ability to pay for the additional value-added.
- Eliminate some of the features and/or functionality that may not be necessary for success in a particular market segment; this action may be implemented in concert with the first action.
- Reduce the performance package and the product specifications in order to reduce the costs.

- Seek alternative inputs (materials) and conversion options (production) that have a lower cost structure; this may in turn mean lower performance, fewer features, and reduced benefits.

The overall objective is to find a solution that meets the needs of customers, stakeholders, and the organization from a financial perspective. Such actions generally improve the value of the new product from the view of all of the participants, thereby making it more likely to succeed.

Forecasting sales volume and the revenue stream

Overview

Forecasting is complex and difficult. New-product forecasting involves more variables than simply forecasting demand for the subsequent periods for existing products. The forecasting techniques used in a given situation depend primarily on the type of new product. For products that are simple replacements or are incremental changes to existing products, sales data from the marketing function are usually available providing a good estimate of the potential for the new product. If the new product represents a significant change to the previous product, forecasting becomes more complicated since changes like adding new benefits or reducing the cost/price may improve the value proposition and the attractiveness of the product, thereby potentially increasing sales volume. In such cases, the overall market size and market share might be improved. The general approach is to estimate revenue based on a forecast of the market size and a calculation of market share on a pro-rata basis.

$$\text{Revenue} = \text{Market size} \times \text{Market share} \times \text{Price of the product}$$

Market size can be determined using primary or secondary data. In most cases, secondary data are readily available and accurate. Market share can be assumed to be the same as the prevailing situation. For example, Coke and Pepsi each have approximately 40% of the market. The assumed value would be related to the existing situation. For a new-to-the-world product, the initial market share may be assumed to be 100% but would be expected to decline at some rate as competitors enter the market. Similar to the method used to manage yield problems, the estimate for market share can be determined using various approaches. Table 10.5 provides three options. For standard products that are well established with an industry structure, forecasts of product demand are available from reliable sources including US Department of Commerce, industry and trade associations, and research organizations. The automobile industry has a number of organizations that forecast the number of units sold per year. To estimate market demand, a market research report may be required or simply obtained from the industry trade association. A survey instrument might be used to determine customer demand from a sample of the market.

Table 10.5 *Techniques for determining market share – advantages and disadvantages*

Approach	Advantages	Disadvantages
1. Use the predicted market share for each period (year or quarter) and make adjustments each period to reflect assumed changes.	Uses the best estimate for determining the expected market share. It forces participants to think about the dynamics of the market place and the effects of competition.	Such approaches are more complicated and are subject to making more assumptions about the effects of market variables over time. It may lead to a wide range of expected outcomes that are far from reality since the model is based on an assumed value for each period
2. Assume that the market share is the expected value for the family of products or the prevailing competitive situation.	This approach reflects the long-term perspective and reduces difficulties associated with determining the dynamics of the situation during launch. It assumes that the new product will be similar to the existing products. This approach simplifies the estimates for replacement products.	The assumptions may overstate the market-share position if the new product is not as successful as the previous product. Obviously it can understate the position if the converse is true. The approach is not dynamic and reflects an expected case that may not materialize.
3. Assume that market share is a function of the expected results from the marketing campaign. Market share improves as the marketing campaign expands.	This approach assumes a direct relationship between marketing efforts and outcomes in the market place. It is useful for launches that expand the market geographically and where market share is related to the reach of the product and the marketing effort.	The approach is complex and requires outstanding understanding competitive responses. It is difficult to correlate the results of the marketing campaign (market share) with the investments into the marketing efforts. Spending money on marketing does not guarantee results.

For significant, even radical, changes pertaining to the market prospective, as in the case new-to-the-world products, open-ended forecasting techniques are generally required for consumer products.

The A–T–A–R model provides a useful approach.[5] The model simply suggests that potential sales are equal to the estimated market population multiplied by the percentage of the customers in the market segment who become aware (A) of the new product, multiplied by the percentage who try (T) the new product, multiplied by the percentage who have the product available (A) to them, multiplied by the percentage who repeat (R) using the product. If the overall population is known, the first step is to determine how many potential customers will become aware of the new product. This is typically based on the expected reach of the marketing effort, say the expected number of people who read the newspaper advertising the new product. Usually it takes several hits before awareness is built. Often the media outlets have good estimates about their readership and the effectiveness of advertising. The number of potential customers might be some percentage of the total number of people reached through the marketing campaign. However, not everyone tries the product. The population that tries the product can be estimated using a testing methodology, or a survey instrument can be used to ascertain the potential users. The next step is to determine whether the product will be available to all those who wish to try it. Usually in a new-product situation, the distribution channels or other outlets for the new product are still being developed; therefore, there is a percentage of the market not being served. The last step is to estimate what percentage of those that tried the product will be repeat buyers (Sales potential = market population × %A × %T % × %A × %R). It requires a considerable effort to obtain accurate data for the calculation.

For situations where accuracy is not critical and the expectation is simply a good estimate, using historical data from analogous product introductions can be used in lieu of conducting market research. The purpose is to develop a "ball-park" estimate.

A–T–A–R model example

The company plans to introduce self-watering devices for Christmas trees. US market data indicates that 30 million freshly cut trees are sold per year. The company plans to sell its product only through Wal-Mart, Target, Home Depot, and Lowe's stores. If all of the stores in those chains carry the product, it is estimated that the market reach is 90% of US households. Assuming that there are 120 million households, the estimated market potential is 25% of the households (30 million ÷ 120 million). Through market research it is estimated that 50% of the households are potentially interested in such a product and have become aware of it through advertising and point-of-sale displays. The effective market size is 30 × 0.50 = 15 million devices. Of those aware of the new product, it is estimated that 20% would purchase the product (3 million). Only 90% would have the product available to them, so the estimated market is 3 million × 0.90 = 2.7 million. If the product has an ongoing purchase need, as with food products, the final market estimate would be adjusted by the percentage that repeats the purchase. In summary the market estimate is 30 million × 0.5 × 0.2 × 0.9 = 2.7 million.

Estimating market potential

The market potential estimate is the sales in terms of units or revenue that is available:

- At given point in time.
- Under the prevailing social, economic, and market conditions of the business environment.
- Using the marketing effort of the organization.
- Using the industry efforts to promote the product.

The market potential and the estimate of units or revenue thereof are dynamic, not static. They change as the prevailing conditions and trends change. They are also dependent on the marketing resources and the commitment of the organization to expand the reach of the new product into the market.

The general formulas for the estimate are:[6]

Unit estimates:

$Q = nq$

where:

$Q =$ market potential
$n =$ number of potential purchasers in a product/market segment under prevailing conditions
$q =$ quantity purchased by average buyer
$p =$ price of the average unit

Revenue estimate:

$Q = nqp$

The equations provide a straightforward estimate of the potential for the total available market. However, the actual market that is available to be served at a given point in time is usually much smaller. It is rare when the messages about the new product reach the entire market segment. The potential is dependent on how effective the organization is at getting its message out to customers. Therefore, the equations require a factor to provide a sense of the percentage of the market penetrated by the marketing campaign. Generally, the more money invested into the marketing campaign the greater the reach into the market.

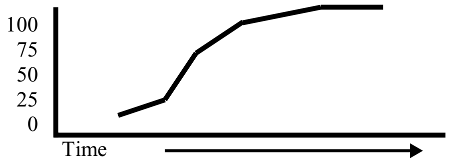
Sophisticated organizations understand the correlation between marketing expenditures and the ability to reach potential customers. The phenomenon often follows a curve similar to the “S” curve. It takes a considerable amount of money to get any effect at all, after which results improve dramatically as the investment increases, and eventually the additional investment produces only marginal gains.

Forecasting models – qualitative methods

Adaptive model

The simplest technique is to obtain previously published data from credible sources forecasting the market. This approach relies heavily on the sources and reliability of the data. For many industries and markets, the federal government, industry associations, and trade groups provide detailed estimates about the various market segments. The estimates are often developed by industry experts or through detailed analysis by agents of the government, contracted individuals, or research groups.

The adaptive model is inexpensive and fast. It can be completed in a matter of days. The main disadvantage is the reliance on existing estimates that may not reflect the



Year	Market size
1	10% = 10,000
2	20% = 20,000
3	50% = 50,000

Figure 10.2 Using the "S" curve as a forecasting method

new realities or conditions created by the new product. It is also not very well suited for new-to-the-world products that are radically different from their predecessors.

Expert opinion

Market estimates are also available from experts within the organization such as the marketing or sales professionals, or from external sources such as industry analysts. Such methods offer fast and cost-effective responses for building a forecast model of the market. The principal weakness is the potential for bias. Insiders may be predisposed to a given outcome, either proceeding with the new product or terminating the program. Their personal views may hinder their ability to estimate the potential of the new product. The bias may suggest a distorted view of the market. For example, the marketing team may want to fill out the product line for its customer regardless of the financial implications. On the other hand, the sales force may not want to stretch its resources by having to take on another new product, especially if the launch requires a large effort without much reward during the first year or two.

Even an external source of information may taint the true picture. External entities often have their own agendas for the market and its potential. An industry group may encourage any activity that supports the growth of the industry and its own impact within that industry.

The adoption technique

The "adoption" technique requires an estimate of the overall market size and assumes that market penetration builds over time as potential customers become aware of the product and purchase it. The standard model assumes that adoption of the new product will follow a typical distribution for a new product like the "S" curve. The "S" curve assumes that the penetration rate will be modest at the beginning of the new product's life during launch; then grow dramatically during mid-life and level off as the product matures. For example, assume that the market size is 100,000 units and it will take three years to obtain a 50% awareness of the product in the market. Figure 10.2 depicts the situation in simple terms. The actual approach is slightly more complicated given that the estimate should be based on a monthly forecast, but the example makes the point.

This approach often has to be modified based on the type of product and the effects of seasonality on the product demand. If the new product is a derivative or is directly related to existing products, the seasonal effects are well known and the new product generally fits into the seasonal flow of its predecessors.

Seasonal effects

Seasonality is a critical concern when analyzing market demand and the flow of revenue. Most products exhibit seasonal effects – especially clothing, sports gear, toys, gifts, and other products related to the human condition and lifestyles. For example, Lego Systems sells about 70% of its product on the retail side during the holidays from November until the end of December. Seasonality has huge impacts on production, distribution, and cash flow.

Cash flow is an important consideration when assessing the financial viability of an NPD program. Two critical factors have to be examined in detail. One factor is the timing of the expected revenue streams based on the sales spikes due to seasonal effects. The effect on cash flow may be severe if there are significant outlays for production and inventory and the receipts of cash from revenues occur many months downstream. The second factor is the possibility of missing the prime season for the product if the launch date is missed by a month or two. The typical expectation for missing a launch target date by a month is that the cash flow would be delayed by a month or so. However, the impact may be an entire year, not a month. If a company misses the peak selling period of November and December, it cannot make up the sales in January and February. New products not available during the holidays are of little consequence until the next season.

Seasonality is the primary reason why the cash-flow statements should be detailed on a monthly basis for at least the first year. Unless the cash-flow statement indicates when the cash is expected on a monthly basis, the full consequences of cash flow may not be apparent. The annual view may suggest that the cash flow is adequate, but it may mask the need for cash reserves because of lumpiness in the flow of cash. Moreover, macro-economic effects such as recession or inflation may affect the channel's ability to move the product at the optimum prices.

Operating expenses considerations

Ordinary operating expenses

Operating expenses are the necessary requirements for operating a business and for developing and launching a new product. They include the normal expenses for salaries, professional services, rents, equipment, insurance, legal fees, utilities,

Table 10.6 *A simplified worksheet of operating expenses (by month or by phase)*

	Jan	Feb	Mar	*N*th	$\sum$ Year	Phase 1	Phase 2	Phase 3	Phase 4	Phase *N*th
Technical										
Salaries and benefits										
Consulting services										
Suppliers										
Equipment										
Testing/prototypes										
Sub-total technical										
Marketing										
Salaries and benefits										
Commissions										
Advertising										
Promotions										
Trade shows										
Travel										
Sub-total marketing										
Production										
Salaries and benefits										
Facility expenses										
Tools and supplies										
Utilities										
Sub-total production										
General and administration (G&A)										
Accounting										
Salaries and benefits										
Legal										
Insurance										
Office expenses										
Permits, fees, taxes										
Telephone										
Utilities										
Sub-total G&A										
Total operating expenses										

Note. The aim of the table is to illustrate examples of operating expenses; it is not intended to provide a comprehensive listing of elements.

telecommunications, etc., as well as expenditures of engineering, R&D, production, and marketing. The simplest way to account for operating expenses is to prepare budgets for each of the major areas of expenditure. The budgets can be developed on a per month basis, per quarter, or per annum. The alternative method is to divide the expenditures on the basis of the NPD phases, assuming that the phases have definitive elements that can be easily defined.

Table 10.6 is an example of some of the main elements.

The budgets might be readily available from estimates prepared by the teams as they examined the requirements for the various functional programs, such as marketing and production. The operating expenses are summaries taken from the budgets of the individual areas. Either way, the operating expenses are the flow of funds required to finance the NPD program prior to launch and the means to support the growth of the new product after commercialization.

Conventionally, expenses are estimated by the month, since it provides a sense of how expenses are expected to flow over time and influence the requirements for cash. They may also be estimated on a per phase basis. For fast-paced NPD programs, a break-down by quarter or per annum usually provides insufficient detail for effective decision making. Production expenses are typically a part of the cost of goods sold. It is important to recognize that some of the methods used for analysis of the NPD situation may not precisely fit the accounting rules for preparing financial statements. The purpose of the worksheet is to provide decision makers with an understanding of the financial implications of the NPD program during the development process and just after commercialization.

The estimate of operating expenses can be used to determine the total investment required for the program. The investment is the sum of the operating expenses incurred before the launch, the capital expenditures necessary for plant and equipment, and the potential losses incurred during the early stages of commercialization. It might also include the procurement of assets prior to launch, such as inventory that are not normally viewed as capital investments.

Capital investment

Capital investment includes land, plant, buildings, leasehold improvement for rentals, machinery and equipment, office equipment, automobiles and other transportation vehicles, etc. The list is dependent on the NPD program, the type of new product, and the ability to leverage existing assets.

New-to-the-world products may require significant investments into new facilities, especially if the technology is radically different from previous forms and therefore requires whole new ways of producing the product. However, such requirements are not always necessary for incremental innovations. Incremental improvements to existing products usually require minimal changes to the capital base which often means very few new capital assets are needed.

Financial statement pro formas and analysis

Overview

The income statement is a basic financial statement used to understand the financial implications of the NPD program. It provides the basic flow of revenues, costs of goods, operating expenses and interest expenses, and tax aspects. It offers a simple view of the potential profitability of the program. However, it does not give a precise perspective of the funding required, because the cash flow from revenues or expenses is usually not synchronized with the sale of goods. Therefore, cash-flow statements are used to provide a more-comprehensive understanding of the funding requirements and the actual receipt of cash. Cash-flow statements are more complicated to prepare and are highly dependent on the sources and applications of funds.

For the purpose of the discussions in this text, a simplified model is used to explain the analytical techniques involved for new-product situations.[7] It is assumed that practitioners carrying out the analysis described herein have a working knowledge of accounting and financial management. The alternative is to seek professionals or colleagues who are familiar with such methods and engage them in the preparation and analysis of the financial statements.

The basic goal of the new-product practitioner is to understand the financial implications and to make appropriate decisions related to the NPD program. The financial professionals translate the analytical forms of financial statements into the actual financial reporting mechanisms for controlling the investment and ensuring that the financial policies and procedures are followed.

Pro-forma income statement

The pro-forma income statement in its simplest form provides a snapshot view of the expected results. It presents the salient information for decision making in a format that facilitates analysis as well as an awareness of the financial implications. The standard approach used for new-product development includes the identification of the price and expected market share so that these variables can be analyzed. Table 10.7 presents a simplified format for the income statement on a per annum basis.

The statement for the first year or two should be presented on a monthly basis to discover the implications of seasonality or other effects that have an impact on expected results. The monthly projections are very important when analyzing cash flow. The

Table 10.7 *Simplified pro-forma income statement*

	Item	Base unit	Year −2	Year −1	Year 1	Year 2	Year 3	Year 4	Total
1.	Unit selling price	Price							
2.	Market size								
3.	Market share	%							
4.	Sales volume (units)								
5.	Revenues	$							
6.	Cost of goods sold	$							
7.	Gross margin	$							
8.	Gross margin ratio	%							
	Operating expenses								
9.	Technical, R&D, etc.	$							
10.	Marketing	$							
11.	Production	$							
12.	G&A	$							
13.	Total operating								
14.	Profit before taxes	$							
15.	Return on sales	%							
16.	Taxes	$							
17.	Profit after taxes	$							
18.	Cumulative profits	$							

Note.

Years –2 and –1 are the development years, while years 1 to 4 are the years of commercialization. Some practitioners use a Year 0 for the first year but that practice tends to confuse others not directly involved.

Item 1 is the established selling price which might change over the course of time. Item 2 is the forecast of the market size. Item 3 is the estimated market share of the new product, which would be expected to change over time.

Item 4 is the product of item 2 multiplied by item 3. Item 5 is the product of item 1 multiplied by item 4. Item 6 is taken from the cost-structure calculation; it is often dependent on volume, item 4. Item 7 is the difference between item 5 and item 6. Item 8 is the ratio of item 7 divided by item 5.

Items 9 to 12 are obtained from the budgets. Item 13 is the sum of items 9 to 12. Item 14 is the difference between item 7 and item 13. Item 15 is the ratio of item 14 divided by item 5. Item 16 is the taxes due on item 14. Item 17 is item 14 minus item 16. Item 18 is the sum over time of item 17.

monthly statements should provide a full year summary. The statement should include as many years into the future as the time horizon suggests.

The income statement offers many different ways of assessing the potential value of the new-product opportunity. It is critical to examine the relationship between selling price and market share. A higher price does not always produce more revenue, especially if the market is very sensitive to price as discussed in Chapter 8. Moreover, there is potentially a double impact on gross margins, if the higher price reduces the sales volume of the organization. Lower sales volume affects the cost of the product, since in many cases the cost structure varies with volume (the learning or experience curve).

Gross margin is crucial for long-term success. A high gross margin provides the funds for a more-aggressive marketing campaign as well as other benefits. Proctor & Gamble uses its high gross margins to finance aggressive advertising campaigns, which are approximately 10% of revenues. Indeed, a low gross margin may suggest that the new product is basically a commodity and that cost control and leadership are critical factors.

Operating expenses during the development period are typically a significant proportion of the investment required for commercializing the new product. There may be an upper limit for such expenses based on the analysis of the financial benefits of the NPD program. Most of the operating expenses can be budgeted to determine the feasibility of the opportunity. There is always the possibility of unexpected expenditures, cost overruns, and the like. Historically, contingencies were added to provide solutions for such problems. The addition of such factors makes sense given the difficulty of estimating the expected expenditures for marketing, engineering, and production because of the uncertainties of product development. However, the generally accepted method today is to develop the best estimate for each element and use sensitivity analysis (see section on "Sensitivity analysis") to determine the vulnerabilities. This approach tends to prevent the skewing of the financial picture toward the negative, thus increasing the probability of committing a type-II error;[8] i.e. rejecting an NPD program that could be successful.

Pro-forma cash-flow statement

Cash flow is the essence of the financial aspects of an NPD program. Cash-flow analysis provides the best sense of the economic value of the new-product opportunity. The investment period ends when the cash flow from customers turns positive. The critical question is how long is required to reach that point and what are the cash requirements per month during the investment period. The typical program requires cash injections during the development phases as described above; it often also needs additional cash injections during the early launch as customers purchase the product, but cash flow remains low as accounts' receivables build because of the lag between the sale and the

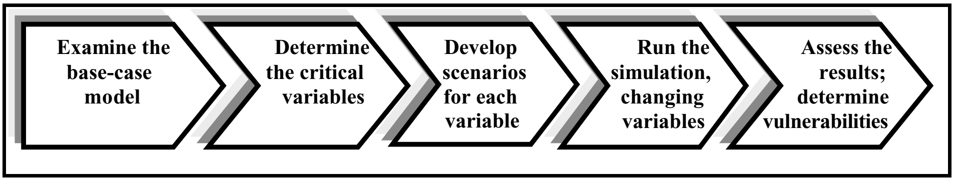


Figure 10.3 Sensitivity-analysis model

receipt of the money. The ultimate objective is to have customers provide the necessary cash flow.

The simplest way to assess the needs for cash is to prepare a cash-flow statement on a per month basis. For a new product, the pro-forma cash-flow statement includes only those items directly linked to the program. This approach can be viewed as the simplified form, since it does not include the capital-market implications or the other sources or uses of funds, just the flow of cash from operations related to the new product.

The most important considerations are the funds to finance working capital, especially the requirements for accounts receivables. The sources of funds to some extent might come from suppliers as accounts payable offset the accounts receivable. Of course, depreciation if used in the income statement should be added back, since it is a non-cash transaction. Accounts receivable can be estimated using the historical ratio (accounts receivable divided by revenues) for similar products. The inventories can be estimated in the same way (ratio of inventory to revenue).

$$\begin{aligned}\text{Cash flow} = {} & \text{Net income after taxes from operations} + \text{Depreciation expenses} \\ & - \text{additional capital expenditures} \pm \text{Changes in working capital}\end{aligned}$$

The major impact item in a new-product situation is often accounts receivable; therefore a good estimate of cash flow can be derived from the income statement with the addition of depreciation and the addition or subtraction of changes in accounts receivable.

Sensitivity analysis

The preferred approach for understanding the financial implications is to construct a "base case" using spreadsheets of income statement and cash-flow projections. One or more variables are then changed to determine the impacts on the key metrics of net present value (NPV) and internal rate of return (IRR). If the spreadsheet is constructed properly with the essential variables used as the basis for the equations, then changing variables (one at a time or in combination) provides a simulated outcome that shows the impact on the entire spreadsheet. The method is relatively simple. Using the cash-flow projection, the base values are established and analyzed to ensure their accuracy. The sensitivity-analysis process includes five steps; they are depicted in Figure 10.3.

The base-case model in its simplest form shows the projected cash flow of the program over the expected life cycle of the product. The base case represents the expected outcome of the NPD program. It provides an indication of what is expected if everything proceeds as planned. However, it is rare when a program unfolds perfectly according to the original plan. There are always variations. Moreover, the external dimensions usually induce changes to the expected case that are difficult to predict and assess.

The first step is to present a cash-flow statement. It is analyzed to ascertain the critical parameters that may be at risk to changes in the base values. For instance, if the target price is $100, there may be pressures in the business environment to increase or decrease prices due to such factors as inflation or weak demand.

The second step is to select the critical variables. The following are some of the most important variables that are typically examined and some of the reasons why the base-case numbers may vary:

- ***Sales volume***. The expected sales may not materialize or the sales forecast may be faulty; therefore, the projections are not attainable. The sales volume might be higher than expected and the implications of this also have to be studied.
- ***Sales price***. The pricing strategy may have to be adjusted to reflect the realities of the market. Competitors may enter the market resulting in pressure to reduce the selling price.
- ***Cost structure***. The cost structure may be higher due to unforeseen difficulties. The estimate may have failed to include every cost element or there may be hidden costs. The cost estimates may have been overly conservative on the positive side of the analysis.
- ***Operating expenses***. The level of support needed to bring the product to the market may require more resources. The marketing programs may be insufficient to generate the appropriate awareness for the product. There may be additional technical expenses involved in solving unexpected difficulties.
- ***Investment***. The funds required to launch the new product successfully may be higher due to unforeseen problems, unexpected requirements, or poor estimates. The investment might also be lower, if there are certain breakthroughs or savings in time to market or development costs.
- ***Time to market***. The NPD program may be delayed during one of the phases or during launch. The investment may be higher and the positive cash-flow streams may be more heavily discounted due to the time-delay factor.

The number of variables studied depends on the actual NPD situation and the confidence that the organization has in its projections. In many cases, there is a high level of confidence in certain variables and a lower level in others. For instance, if the estimate for unit cost is based on a solid foundation of leveraged production capabilities, the variability of the estimated value may be small; therefore, there is great confidence in that particular variable. The typical case usually has variables that are more precise, having low uncertainties, and others that are questionable. For example, the NPD program may be on schedule and the investment required to get to the market is in line with expectations. However, the main concerns might be market size and response (i.e. sales

Table 10.8 *Example of simplified base case of cash flow*

	Item	Variable	2005	2006	2007	2008	2009
1.	Selling price ($)	$100	100	100	100	100	100
2.	Market potential (000 units)	1,000	1,000	1,000	1,000	1,000	1,000
3.	Market share (%)	2%	2	4	8	16	32
4.	Sales volume (000 units)		20	40	80	160	320
5.	Sales revenue ($000)		2,000	4,000	8,000	16,000	32,000
6.	Cost of goods sold ($000)	$50/unit	1,000	1,800	3,240	5,760	10,080
7.	Gross margin ($000)		1,000	2,200	4,760	10,240	21,920
8.	Operating expenses ($000)	700	700	900	1,400	1,700	2,000
9.	Income before taxes ($000)		300	1,300	3,360	8,540	19,920
10	Taxes ($000)	40%	120	520	1,344	3,416	7,968
11.	**Net income/cash flow ($000)**		**180**	**780**	**2,016**	**5,124**	**11,952**

Note.
Item 1 is the selling price for the base case. The third column is used in the spreadsheet for the variable, basing the equation on the base value and changing it for sensitivity analysis. Item 2 is the market size. In the example, the market potential is assumed to stay constant; that assumption is used for simplicity. Item 3 is the expected market share. Item 4 is the product of item 2 multiplied by item 3. Item 5 is the product of item 1 multiplied by item 4. Item 6 is the cost of goods sold, which exhibits experience-curve phenomenon. Item 7 is item 5 minus item 6. Item 8 is based on budgets. Item 9 is item 7 minus item 8. Item 10 assumes for simplicity that the tax rate is 40%. Item 11 is equal to item 9 minus item 10. It also assumes that cash flow is equal to net income. That assumption is usually not a good one, but for the sake of simplicity, it is used.

volume per annum) and the acceptable market price due to the competitor situation (i.e. pricing strategy). Therefore, the primary focus in such cases would be sales volume and pricing. A secondary concern, although it could be a major concern as well, would be the appropriate level of operating expenses, especially marketing expenses, necessary to launch the new product successfully.

The third step is to determine reasonable variations from the base case and determine the consequences of the potential shifts in outcomes. The typical analysis includes two or three data points, plus and minus, from the base case. Thus, the analysis might include the base case, ±5%, ±10%, and ±20%. These are the rules of thumb, but there are many alternatives to this view.

The fourth step is straightforward when using a computer software program such as Excel. The spreadsheet program can run through the variations and plot the results. The outcome can be analyzed to determine the most critical variables. Sensitivity analysis is simply selecting the essential variables,[9] then changing the value by ±5% and ±10%, maybe ±20%, plotting the results, and studying the implications. The analysis is often done to determine which variable produces the largest effect. From a risk perspective, the focus is on negative effects. Figure 10.4 shows the effects on IRR of changing selected variables of the cash-flow statement shown in Table 10.8 (NPV could be used).

Table 10.9 *Sensitivity analysis for price, cost of goods, and investment*

Variable	−30%	−20%	−10%	Base	+10%	+20%	+30%
Price							
IRR (%)	**10**	**24**	**38**	**52**	**63**	–	–
NPV ($million)	(0.05)	0.8	1.9	3.0	4.2	–	–
Cost of goods sold							
IRR (%)	–	–	**57**	**52**	**47**	**41**	**36**
NPV ($million)	–	–	3.5	3.0	2.5	2.1	1.6
Investment							
IRR (%)	**68**	**63**	**57**	**52**	**47**	**44**	**40**
NPV ($million)	3.6	3.4	3.2	3.0	2.8	2.6	2.4

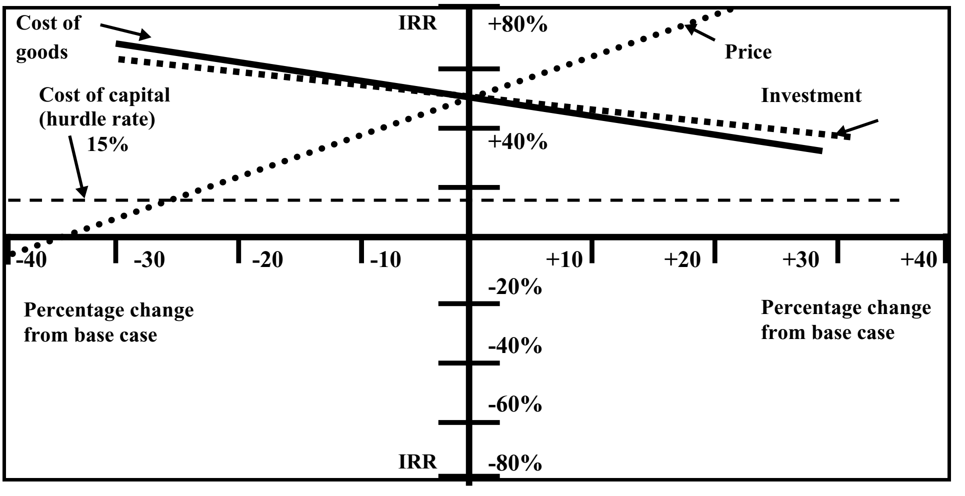


Figure 10.4 Sensitivity-analysis plot for the data in Table 10.8

Based on an initial investment of $2 million, the IRR calculated using the assumptions in the notes equals 52%. Since the analysis is based on assumptions, there is no point using numbers that are more significant. Table 10.9 provides a sensitivity analysis for price, cost of goods sold, and investment. The analysis is based on the "base case" presented in Table 10.8. Price, cost of goods sold and investment were selected for the analysis, suggesting that they were the variables with the greatest uncertainty.

By showing cost of capital or required rate of return (the hurdle rate), the potential problem areas and the financial implications can easily be seen in terms of the variables that have the largest negative impact. From Tables 10.8 and 10.9, and Figure 10.4, it is obvious that price has a greater effect than does either cost of goods sold or investment. Not only do cost of goods sold and investment have similar impacts, they remain above the required rate of return beyond the +30% change. Price is more sensitive that the other two and becomes a major concern if the price level is reduced by 25% (the point where the line intersects the required rate of return or the cost of capital) due to market forces. Of course, other key variables have to be tested as well, especially time to market (delays being the concern).

The analysis is actually more complicated than suggested by Figure 10.4. All of the key variables should be tested. Moreover, the analysis should be dynamic, testing each of the selected variables together rather than just one at a time. Not only is it important to determine at what point a change in a variable causes the financial metric to reach the unacceptable level (below the hurdle rate), but it is also important to study how combinations of negative changes effect the metrics. For example, the data used in constructing Table 10.9 indicate that a 16.5% decline in price and an increase in the investment and cost of goods sold by the same percentage would bring the expected IRR to the cost of capital (hurdle rate).

The final step is to assess the results and determine the implications. The essential concerns are the variables in which a small change in the value of the input variable results in a significant change in the financial outcome of the program. For example, there is approximately 14% reduction in the IRR for every 10% reduction in price. If the selling price is reduced by 10%, there is a 36% reduction in the NPV of the program, This indicates that the program is most vulnerable to the pricing level, since a relatively small change of just 10% in selling price seriously erodes the financial benefits of the program. In summary, a 1% change in price means a 1.4% change in IRR or 1% means approximately $105,000 in NPV. Likewise for cost of goods sold, a 1% change translates into approximately $50,000 in NPV or 0.5% in IRR. For investment, 1% change means $20,000 in NPV or 0.4% in IRR.

Additional financial and NPD-program considerations

The total program investment tends to be a difficult value to actually determine. The base investment is the budgeted amount for the engineering, technical, design, marketing, production, and testing programs during the NPD program. Essentially, it represents expenditures for all activities and purchases (cash flow) during the NPD process, including building a facility and buying equipment for the production of the product, if necessary. But, generally, the base-investment figure understates the total investment. Often a substantial amount of inventory is purchased or produced prior to launch. While inventory goes on the balance sheet as an asset, it involves cash flow, which can be viewed as part of the investment. In many cases, the investment into inventory may not be taken into consideration in the analysis of NPV or IRR. The question is, should it be included in the investment? If the product fails completely, the inventory would most probably be worthless. Therefore, it can be argued that the total investment should include the base investment, the inventory prior to launch, possibly accounts receivables, and the losses incurred after launch prior to breakeven. This approach presents a more-accurate view of what is at stake.

Obviously, there is more at risk than just the total investment. Failed new products might incur product-liability cases, costing money in the future. A failed product may damage the good name and reputation of the organization, having incalculable effects on the image and standing of the company. The Firestone/Ford Explorer situation (for further details see boxed text in section on "Risk assessment and financial implications") is a good example of how product failures can result in the loss of billions of dollars and the tarnishing of corporate reputations.

Analyzing expected results

In the final analysis, calculated metrics like IRR and NPV are distributions of possible outcomes rather than deterministic results. In reality, the calculated metric is the expected value or the most likely result. The total view requires a sense of the variance of the distribution. The smaller the variance the better the calculated metric represents expected outcomes.

If a choice has to be made between two NPD programs, one having a lower metric and a low variance, and the other a slightly higher value but with significantly higher variance, the outcomes can be compared on a risk-to-reward basis.

Investment curve

The investment curve for most NPD programs is not linear with respect to time. Proportionately less money is spent during the early phases and significantly more during the later phases. This phenomenon helps the discounted-cash-flow calculation. If investments are made toward the end of the NPD program, less money is required to make the investment (time value of money).

In reality, the actual curve depends on the type of product and the situation. Consumer products require heavy investments in marketing, which typically consume about 80 to 90% of the total investment with most of the money being committed or spent toward the end of the program.

There is a huge benefit if a disproportionate amount of money is spent during the later phases, because as the phases are completed the confidence in the NPD program should increase dramatically. In a good program, the confidence curve should be similar to the investment curve. For new-to-the-world products, significant investments may be required during the early phases to prove the technologies or to validate the market requirements.

Is the investment *worth* it?

Is the investment *worth* it? It is a simple question that requires in-depth and ongoing analysis. The answer is complex and it is not just based on the financial aspects. Firstly, an NPD program usually has many objectives. Achieving a balanced set of objectives is critical for success. The NPD program might not meet the financial targets, but it could achieve strategic needs, market, technical, and/or organizational learning goals, making the investment worthwhile. Learning is often not included as basic objective. Moreover, it is difficult to measure the value derived from the learning acquired during the NPD program.

From a financial perspective, the answer is dependent on the level of risk. The most common way to reflect the degree of risk is to add percentages to the cost of capital to calculate the required rate of return, where the required rate of return equals the cost of capital plus some additional increment for risk. The required rate of return is used to calculate NPV or to compare it with IRR. The decision-making process always involves critical thinking and judgement. NPV or IRR metrics suggest that if the NPV is positive and the IRR is greater than the required rate of return (hurdle rate), the NPD program is acceptable from a financial perspective. Often, additional methods are used to make the final determination. For example, an investment index can be used to compare the NPV of various programs. The investment index is simply the NPV in terms of the investment (Index = NPV/Investment, where Investment is the total funding required).

Organizations may establish guidelines for evaluating multiple programs. The guidelines might establish zones of acceptability for an NPD program based on the level of perceived risks.

Level of risk	Index	Comments
Low	$0.1 \rightarrow 0.5$	Incremental changes; market-driven requirements
Medium	$0.5 \rightarrow 1.0$	Repositioning or significant enhancements with long-term impacts
High	Greater than 1.0	Strategic changes where there are several alternatives

Each organization would define the meaning of low, medium, and high risk. This concept is especially useful for small companies that may only have a few NPD programs. Statistical concepts, like expected value, work reasonably well when there are sufficiently large numbers of programs involved. This condition is rarely met in the case of small companies. They do not have expected outcomes that work out on average. The required ratio of NPV to investment depends on many factors including perceived risk and it is a key consideration from the beginning through commercialization and beyond. The required ratio often determines whether an NPD program continues or not.

Table 10.10 *Overview of types and categories of risks*

Source	Known	Hidden
Inherent	Hazardous materials that are explosive, flammable, or toxic; gasoline containing benzene is an example.	Trace contaminants with side effects; fatigue failures in metals; uncertainties about actual customer applications.
Design	Exceeding shelf life; product-life limits that can be calculated in terms of mean time to failure.	Design defects of unknown origin; unexpected consequences; burdens associated with product uses.
Manufacture	Process quality capability with known defect rate. Emissions from manufacturing processes.	Unexpected defects during manufacture due to unknown factors.
Marketing	Overstating the positive aspects and understating the known negative aspects of the product; inadequate labeling; not conveying the full message; selling to the wrong party; misinformation.	Misunderstanding of the essential messages by customers or stakeholders; product is resold through improper channels; claims about the product by external parties which are beyond intended specifications.
Markets	Selling to the wrong customer, too young or too old; ergonomic issues.	Lack of essential training on the part of a secondary user; unforeseen use of the product; over-use of the product.
Stakeholders	Failure to include or meet government regulations; not meeting industry standards.	Unexpected stakeholder-group issue; unexpected impact on the environment.
Related industries	Not compatible with ancillaries; not synchronized or compatible with industry standards.	New standards; new technologies; not compatible with trends.
Infrastructure	Lack of support structure; missing elements.	Capability to handle unexpected changes; the capacity of the infrastructure.

Risk assessment and financial implications

Definitions and categories of risks

There are two main categories related to the issue of risk: known and hidden. The known category is usually based on decisions made during the product design. It includes decisions about material selections, market choices, design selections, marketing messages, distribution choices, and decisions by suppliers. The hidden category includes design defects, production problems, marketing errors, and uncertainties associated with the applications or uses of the product by customers. The situation is complex and it is very difficult to summarize effectively or correctly. Table 10.10 provides an insightful overview. The list could be very lengthy to cover all of the bases. The intent is simply to provide an overview for consideration, rather than being comprehensive.

The methods of examining the hidden aspects as well as the obvious ones are critical techniques for minimizing risks and mitigating liabilities. Such approaches should focus on the crucial areas, recognizing that the risk elements are not independent. Inherent risks cut across every facet of new-product development. It is virtually impossible to design and build a product using materials, parts, or components that are free of all concerns, especially if the company is attempting to design an innovative product. It is difficult to find a risk-free product. For instance, gasoline is a ubiquitous product, yet it contains many toxic substances, including suspected cancer-causing constituents (benzene). Not only is it toxic, it is flammable as well. However, there are few options or substitutes, and consumers and industry participants have successfully learned how to handle the product safely. Technology also plays a significant role. Leaded gasoline was the solution for improving the combustion process to obtain more power output by eliminating the “knock.” The solution became a problem as lead poisoning from leaded gasoline was recognized in the 1970s as a major health issue. The phasing out of leaded gasoline was seamlessly implemented during the 1980s, as society was no longer willing to suffer the negative consequences.

The challenge with every product is to weigh the benefits against the potential harm that may occur. For the known problems, such analysis is relatively straightforward and is based on established methods. While weighing the benefits and risks appears to be easy, the challenge of actually making improvements can be difficult. A too-aggressive approach skewed toward focusing on the positive and accepting the negatives opens the door to liabilities or problems. The converse approach of being more timid may result in lost opportunities. Moreover, customers and society change their attitudes over time. The accepted approaches or conditions may become intolerable if a crisis occurs. For example, airport security was not viewed as a serious issue before September 11, 2001.

The question goes back to the overarching principles of “balance” and the “precautionary principle.” The “precautionary principle” suggests that decisions should err on the side of safety. The most effective means of mitigating risks is a thorough analysis of the situation using careful scruting during each phase of the NPD program. Through thorough analyses come solutions.

Defects are pervasive. Even the best processes and practices create defects; it is just a matter of how many. For instance, six-sigma (three plus defects per million opportunities) processes still produce defects. The most significant concerns are defects in design and manufacture. While there may be more defects associated with production aspects, design defects tend to be more costly and may affect the entire product line or output from the production processes. Moreover, such defects may have a dramatic impact on the image and reputation of the company. For example, the Firestone/Ford Explorer problems caused Ford to recall all of the tires on Explorers. See boxed text for further details.

Legal theories, laws, and judicial litigation hold that engineers, technical experts, and other design professionals have a fundamental duty to design products that are safe and appropriate for any reasonably foreseeable application and use. The main consideration centers on whether any feasible design alternative could have prevented or mitigated the problem. An examination of the literature suggests that preventive measures are cost-effective when dealing with design issues.[10] It has been shown that solving problems during the earlier phases is much more effective than finding solutions in the later phases. Techniques that improve the understanding of the strengths and weaknesses of the product design provide a positive means of reducing risks. Techniques such as quality function deployment and failure mode and effects analysis provide means to discover and mitigate risks.

Defects in manufacture are more common, but generally are more curable. They arise from inadequate or imperfect production methods, processes, or practices. While there is always a probability that something can or will go wrong during a manufacturing process, the major considerations are systemic problems that affect the entire production process. Such problems often lead to ongoing difficulties and the production of a large number of significant defects.

Another significant issue is the failure to inform or provide adequate instructions pertaining to the proper use of the product or the lack of warnings about inappropriate uses or prohibitions related to the product. It is essential in every case to inform the customer about all of the positive and negative aspects of the product, including how the customer should avoid any negative burdens or limitations. Such requirements are an absolute duty of the designer and producer. Some organizations believe that strong messages about the negative consequences are counter-productive from a marketing perspective. They believe that marketing is supposed to focus on the positive messages for selling the product, not the negative side that may inhibit sales. While such views are prevalent, if there are significant risks and potential liabilities, the best overall approach is to terminate the NPD program or withdraw the product from the market.

The Firestone Wilderness tire recall: product failure leads to loss of billions

In August 2000 Bridgestone Corporation, Japan's largest tire maker, began recalling 6.5 million 15-inch (0.4 m) Firestone Wilderness tires because of defects that left them vulnerable to tread loss, particularly at high operating temperatures. Firestone is the US subsidiary of Bridgestone Corporation. In the spring of 2001, Ford initiated an extensive replacement program of its own to replace 13 million Wilderness tires on all of its vehicles. The National Highway Traffic Safety Administration (NHTSA) had linked Firestone tires to 271 fatalities and 800 injuries. Catastrophic tread separation on the Wilderness-brand tire was causing vehicle rollovers, primarily on Ford Explorer sport utility vehicles. The majority of the accidents occurred in hotter southern states. The accidents prompted the US Congress to request a rewrite of federal tire standards that had not been revised since 1967. The dispute over ultimate responsibility for the recall also ruined the 94-year relationship between Firestone and Ford.

Firestone eventually widened its recall to include even more Wilderness AT tires after the NHTSA said it found a safety defect in Wilderness tires produced at two plants *before* 1998. Those tires had been linked to 25 deaths and about 50 injuries. Firestone said it produced 3.5 million of the newly recalled tires, but estimated that only about 885,000 were still in use at the time of the recall.

In September 2000, a group of state attorneys general formed a task force to determine whether Firestone and Ford had intentionally misled consumers into accepting defective tires. The resultant state investigations into Bridgestone's handling of the recall ended in a settlement in November 2001, requiring Bridgestone to cooperate with the attorneys general in their ongoing investigation of Ford. The settlement cost Bridgestone at least $41.5 million; $10 million in legal fees, $5 million in consumer education programs, and $500,000 to each state, Puerto Rico, Guam. The case charged that the company engaged in deceptive and unfair trade practices when it sold the tires. The Firestone settlement followed weeks of negotiations with officials at the US Department of Transportation. Firestone was said to have lobbied hard with White House officials, warning them about the impact of a recall and that 40,000 jobs were in jeopardy. The ongoing investigation of Ford is focused on whether the automobile company knew about performance problems with Firestone tires before it pressed Bridgestone into the recall.

Despite the embarrassing recall, which threatened to crush the Firestone brand, Bridgestone is rebounding. The company reported strong profits for the first half of 2002, and was turning itself around by emphasizing Bridgestone as a premium brand, and selling Firestone as the mass-market brand. The company also began selling less to car-makers and more to consumers. By selling to consumers, Bridgestone can make more profit on each tire, since automobile manufacturers typically pay only half the retail price for the tires they buy.

The Wilderness tire recall ultimately cost Ford Motor Company at least $3 billion and exacerbated its already poor financial condition caused by the recession and the September 11th terrorist attacks. The recall cost Bridgestone more than $1 billion.

Sources

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Mitigating liability and reducing negative financial impacts

The NPD process is a powerful technique for discovering and curing product difficulties and defects before they become challenges to the success of the organization. Given that new-product development is a systematic approach for identifying, analyzing, and developing new-product opportunities, risk assessment and risk mitigation are embedded into the very fabric of the methodology. The main premise of integrated product development is to determine the critical issues early in the NPD process and invent solutions to achieve an improved product position and success in the market place. If a solution is not readily available or cannot be constructed in a cost-effective way, then the NPD program can be terminated or reconstituted without any serious long-term implications.

The NPD process is designed to provide management and practitioners with a periodic review of the decisions that have been made. It also includes an ongoing review of the business environment and the prevailing conditions and trends. The underlying theory focuses on the ability to make adjustments as soon as possible during the process. Management's attention is crucial in order to understand the need for assessments and changes in direction when appropriate.

The extensive use of testing throughout the NPD process is the primary mechanism for reducing risk. Each step from concept testing to product-use testing is deployed to discover problems or to ensure that the design is free of defects. Testing sheds light on solutions as well as on problems. The central point of testing and validating a design, and the related production and marketing elements, is to assure management and potential customers and stakeholders that every precaution has been taken to alleviate risks, liabilities, and problems. While it is difficult to calculate the impacts of defects and the like, it is clear that such difficulties are costly and that the later they are discovered in the NPD process, the greater the potential for adverse effects.

The notion of "design for the environment" or "green marketing" can play an important role in mitigating risks. Truthful marketing and selling can improve the image of the organization as well as increase the trust customers have in the product. Avoiding overstatements about the benefits or understatements about the harmful effects is an effective way to build customer and stakeholder confidence. In addition, customer confidence is a key to success. For example, marketing communications and promotional materials should be carefully screened to eliminate exaggerations.

Risk-to-reward relationship from a financial perspective

The implications of financial risk have to be viewed based on the rewards involved. Generally, high risks require higher rewards. The required rate of return (hurdle rate) provides criteria for acceptable reward, but it has to recognize that not all NPD programs are equal. While the required rate of return can be and is adjusted for risk, often the risk has to be examined in the context of the reward. Any return less than the required rate of return is unacceptable from a financial perspective. If an upper limit of financial risk can be identified, then that value, either in investment level or percentage of available cash flow for the organization, provides a sense of the maximum risk permissible. For

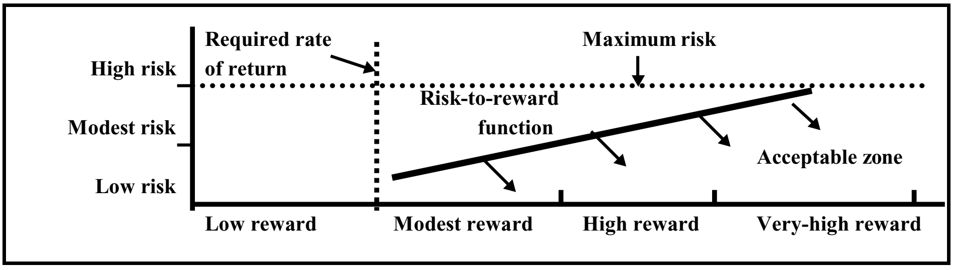


Figure 10.5 Risk-to-reward relationship from a financial perspective

instance, a company may establish a criterion that no single NPD program can place at risk more that 10% of the available cash flow of the organization or that the total investment cannot exceed $100 million.

Figure 10.5 presents the acceptable and unacceptable zones. The zone of acceptable outcomes is characterized by the relationship of risk to reward, where the solution set is the area under the function. The function is the acceptable risk-to-reward ratio. Theoretical solutions are rewards that are greater than the corresponding risks at each point. Figure 10.5 depicts the solution set as the area to the right of the arrows under the function line. In reality, the function line represents a distribution of possibilities with acceptable solutions above the line as long as they are reasonably close to the line. Statistically, the maximum spread should be set at three standard deviations if there are sufficient data to determine the function. These points are addressed again at the end of Chapter 12 to include the broad view of financial and non-financial risks. While a very-high reward with low risk seems to be the ideal point (lower-right side of Figure 10.5), such positions are sought by competitors as well and they often have only a short window of opportunity as others attempt to exploit high rewards at low risks. It can be argued that such situations are not realistic in the long term. Additional competitors enter the market space given such conditions and the rewards decline and the risks increase. If such events occur the risk-to-reward ratio moves toward the standard relationship (function) and the great opportunity evaporates.

Summary and closing comments

The primary objectives of the financial analysis of an NPD program are to support decision making and to determine the viability of a new-product opportunity during the NPD process. The most important outcome of the analysis is a clear understanding of the financial implications.

The techniques discussed in this chapter provide the means to implement the phases of the process from a financial perspective and guide the development along pathways that result in achievable outcomes. The expectations are proper decision making and valid determinations. Given that new-product development is always risky, success has to be measured in terms of making good decisions, not always achieving success in launching a new product.

There are numerous techniques for analyzing the financial implications. It is imperative to keep track of development over the course of the NPD program and after the launch of the new product. The financial assessments made during the early phases of the NPD program are subject to many forces that can substantially change the opportunities and the prospects for success. Competitors in particular have enormous impacts on the conditions and trends in the market space. There are many examples of leaders faltering after gaining initial successes. Great opportunities attract attention. For example, the Ford Mustang was the first "pony car" but General Motors caught up with Ford during the early 1970s. More recently, the wireless telephone market is evolving dramatically in terms of leading competitors, usage patterns, and pricing schemes. Great care has to be exercised when making forecasts and projections that indicate steady or stable conditions. Revenues and market shares can change radically in a short space of time. Management and practitioners alike have to continuously examine their financial plans and ensure that they are a reflection of reality. Financial models and projections are simply estimates of what is expected. They are not guarantees.

Notes

1. Note that there are numerous concepts and techniques that could be discussed in this chapter. Since the focus is on new-product development and decision making, a select group of financial concepts and techniques have been included in the chapter.
2. While it is recognized that the innovation programs are inherently risky, doing nothing, maintaining the status quo, or exploiting existing products to the very end of their life cycles are likewise risky. It can be argued that innovation may be less risky in the long term than the latter approaches. The stories of keeping existing technologies or products beyond their viable life are vivid reminders of the risks. Good examples are: NCR with mechanical cash registers; Underwood with typewriters; and the Ford Mustang of the 1970s.
3. Note that this does not assume that the yield will be 100%. For example, the yield for microprocessors at the beginning of the production for a new generation is approximately 35%; however, even after significant improvements and much experience, yields never get to 100%.
4. H. Wildemann, Product clinic. *Logistiknews – TGW*, August, 2004, p. 19. The method shown here was adapted from Dr. Horst Wildemann.
5. The A–T–A–R model is a traditional method. C. Merle Crawford and C. Anthony Di Benedetto use it as a primary forecasting technique in *New Product Management* (New York: McGraw-Hill, 2000, pp. 161–167).
6. The formula is based on the approach used by Philip Kotter in his various books on marketing.

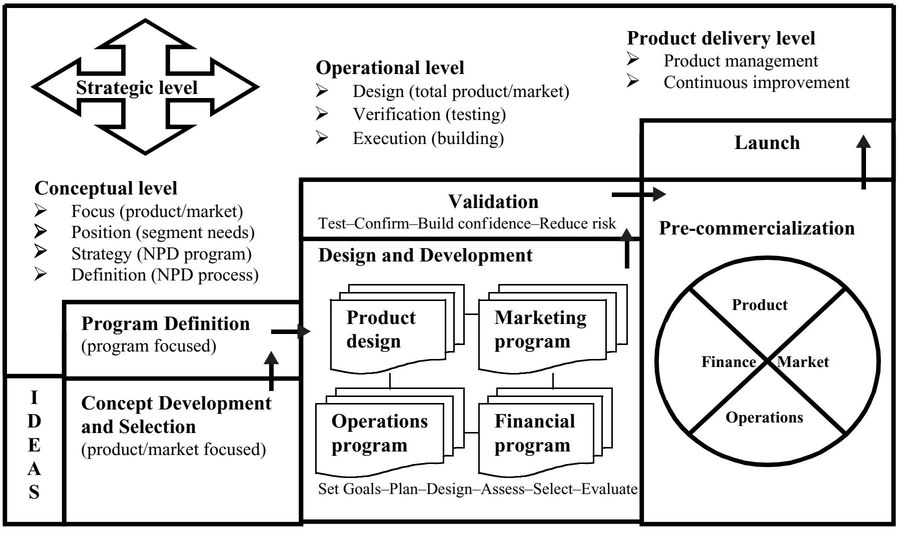
7. The basic reason for the approach is to avoid presenting all of the financial techniques covered in texts on accounting and financial management which would extend the book by hundreds of pages.
8. A type-I error is proceeding with a defective program that results in failure. A type-II error is terminating a potentially successful NPD program because of missing information or faulty decision making.
9. The most important variables used in sensitivity analysis are typically price, unit cost, sales volume, market size, time to market, program investment, and any other factor that has a high level of uncertainty.
10. There are many citations.

Part IV

The operational level and concluding remarks

The new-product development (NPD) process builds on the analysis, insights, and decisions of the upstream phases as the process proceeds toward the ultimate goal of commercialization. The operational level involves the implementation of the design and development elements along with the validation of the decisions and the preparations for launch. The operational level focuses on the design and build of the product and the related program elements. It is based on the precursors developed during up-front phases. The operational level translates concepts and theories into reality. It represents a significant shift in thinking and commitment. The emphasis changes from discovering and understanding opportunities, and defining and selecting the best candidates, to the actions required to execute the NPD program and produce and market the product.

It is more expansive and includes revisiting some of the elements of the Concept Development and Selection Phase and the Program Definition Phase. The figure below portrays the power and significance of integrated product development (IPD) as the NPD process moves into the operational level.



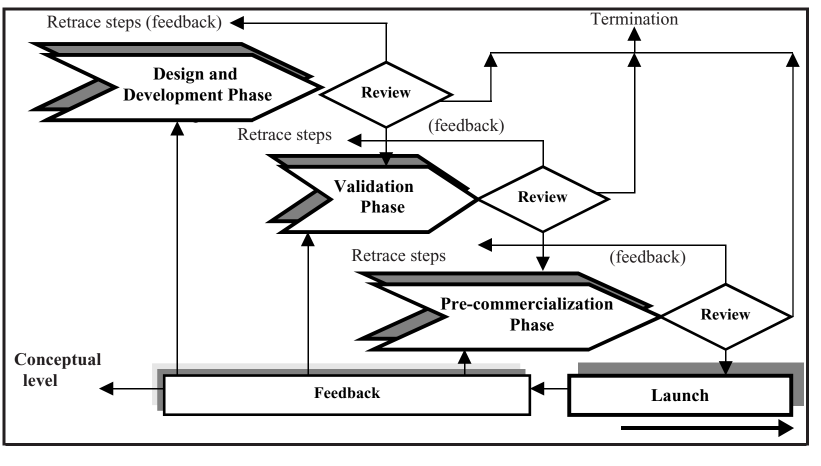
During the operational level, the product concept is transformed from a theoretical or abstract view into a practical solution for meeting the needs of customers and other constituents. The approaches shift from "do-ability" questions to "how to do it" answers. The operational level is often linked with the product delivery system as the NPD program makes the transition from formulation to implementation.

Part IV involves the design, validation, and commercialization phases of the NPD process. It also includes comments about future directions of IPD. Part IV includes the following chapters:

- **Chapter 11 Design and Development (Phase 4)**
- **Chapter 12 Validation (Phase 5)**
- **Chapter 13 Pre-commercialization and the launch (Phase 6)**
- **Chapter 14 Concluding remarks and insights about product innovation in the twenty-first century**

The primary phases of the operational level are the Design and Development Phase and the Validation Phase. While the Pre-commercialization Phase is important in many situations, it can be incorporated as part of the launch or embedded in the preceding phases. The Pre-commercialization Phase involves preparing the capabilities, resources, and processes for addressing the market(s) and business environment. Likewise, the Validation Phase can be integrated within the elements of the Design and Development Phase. It can be linked with the design elements and implemented immediately after the preceding steps have been completed.

Based on the philosophies of IPD, the activities follow the principle of "a holistic approach" using parallel processing to the maximum. This means that activities are started as soon as it is viable. The phases of the operational level are not in series but are executed in parallel to the greatest degree possible. Indeed, the three phases can be fully integrated into a single phase that includes design, testing, and preparing for launch. This theory implies that the essential elements of validation can be started before the Design and Development Phase has been completed. The graphic below depicts the approach.



The theory suggests that selected activities in subsequent phases can be started early if there is a high degree of confidence that the preceding steps have been properly completed and integrated into the NPD program. The elements of subsequent phase that are started early have to be independent of the outcomes of the remaining elements of the preceding phase that have not been completed. Such action is totally consistent with the principles of IPD. It encourages practitioners to think about relationships between activities and what has to be done to get to the market before competition.

The work elements that are started early can be suspended if the review at the end of the preceding phase indicates that several steps have to be retraced or if the NPD program should be placed on hold or terminated. The implications of starting early depend on the objectives of the NPD program. If time is of the essence, then starting early is often worth the consequences. If time is not critical and risk mitigation is crucial, then a conservative approach is a more-reasonable course of action.

11 Design and Development (Phase 4)

Introduction

This chapter discusses the conversion of the conceptual level into an operational reality during the Design and Development Phase of the new-product development (NPD) process. It bridges the chasm between intended functions, features, and benefits from the market perspective with the physical and psychological aspects of the new-product architecture. Product design is the process of defining and creating the product attributes necessary for meeting customer and stakeholder expectations. Design and development include the full package of the requirements to commercialize the new product, including technical design, marketing, production, and financial implications.

The Design and Development Phase translates customer needs and the intentions of the concept into design specifications and technical instruments to create a producible and marketable product. It involves the concurrent development of the product architecture with marketing, production, and financial functional programs. The Design and Development Phase includes the following essential elements and learning objectives:

- Positioning the new product in the light of market realities and building flexibility into the process.
- Reaffirming the proper product attributes and understanding the functions and benefits from the perspective of customer and stakeholder needs and wants.
- Ascertaining the critical driving forces pertaining to customers, stakeholders, supply networks, related industries, the infrastructure, and competitors.
- Building an effective and integrated design process that leads to successful commercialization.
- Choosing the right marketing programs for the introduction of the product.
- Selecting the best means for producing and delivering the product to the market.
- Managing the financial implications to ensure that the product is and remains viable.

The Design and Development Phase, therefore, includes designing the product, selecting the marketing programs, determining the production and delivery methods, and understanding the financial implications. The flow is both integrative and iterative. The upstream phases provide the inputs, which are refined and analyzed before

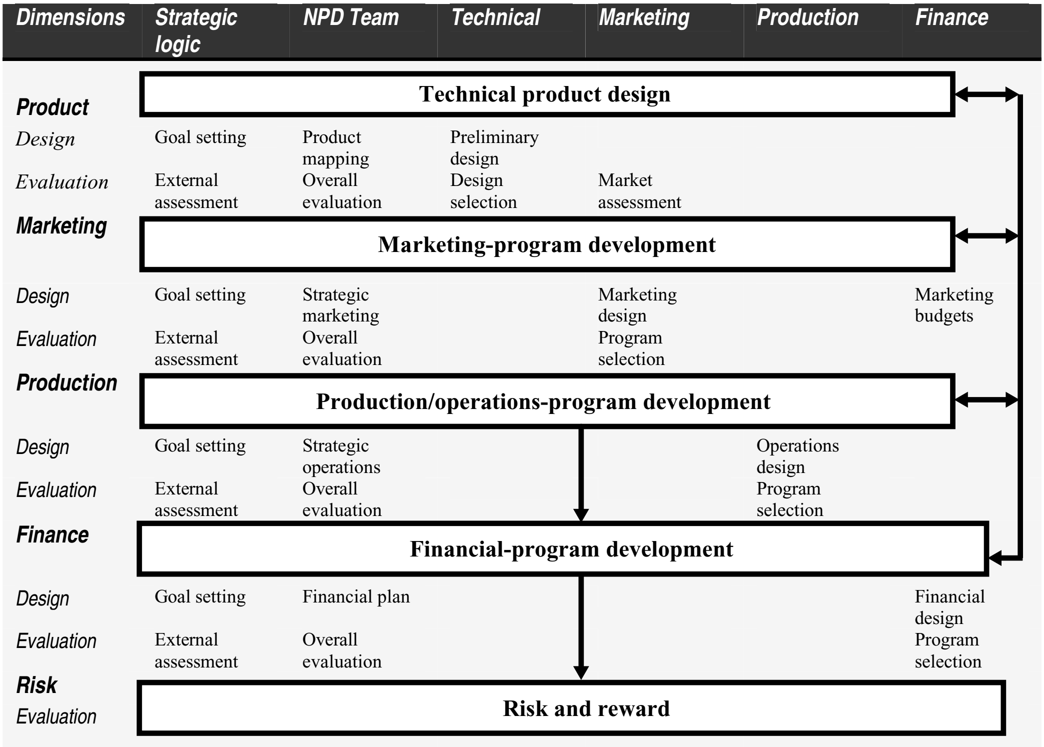


Figure 11.1 Design and Development Phase flow chart (Phase 4)

inclusion into the final design selections, and the outputs are subsequently verified and refined during the downstream phases of Validation, and Pre-commercialization and Launch.

The Design and Development Phase flow chart

The design process starts with reaffirming the positioning of the new product based on the market needs and the requirements of stakeholders. It includes designing the new product with attributes that emphatically covey a positive image using effective marketing programs. The marketing program should be developed concurrently with the product design. The new-product situation requires analysis and careful consideration of the marketing program choices. The marketing plan is based on the objectives and goals, the financial and core capabilities, and the ability to implement the program.

Figure 11.1 illustrates the flow of the design and development of a new product. Although it suggests a linear flow, in reality, all of the internal dimensions are developed concurrently.

The external dimensions are integrated in the process flow of the internal dimensions. While the “assessment” activities are not identical, they have the same principal dimensions as employed throughout the book and use a similar format. The most significant facet of the overall Design and Development Phase described in this chapter is that each of the primary internal dimensions uses an identical methodology, which allows the participants to link and communicate via a common language. All activities and requirements proceed in parallel and are managed systematically. Systematic flow provides everyone with a clear understanding of the process and the expectations. Even new participants should be able to contribute to the NPD program without any significant time delay or confusion.

The following sections detail the elements that are mapped out on the process flow chart. Each of the main sections of this chapter is linked to related chapters that appear earlier in the book (i.e. Product design and development program is related to Chapter 7; Marketing-program development is related to Chapter 8; Operations-program Development is related to Chapter 9; and Financial-program development is related to Chapter 10). The discussion on risk assessment and mitigation is covered in Chapter 12 for better integration.

Product design and development program

Product design is a technical function, based on the insights gained during the Concept Development and Selection Phase and the application of the methods, tools, and techniques described in Chapter 7. The technical design process has sequential and parallel flows that examine the product goals on a continuous basis to ensure that the end result meets the expectations of customers and stakeholders, and the objectives of the organization. If discrepancies or changes in the business environment develop during the NPD program, then the design process and the overall development of the product can (has to) be modified to accommodate the new conditions. Maintaining flexibility and agility is critical for achieving success. It is *imperative* that the design process reflects new information and knowledge gained throughout the phase. Indeed, the design process incorporates mechanisms necessary to ensure that product design includes all available information and resources, both internal and external.

The starting point is often the product specifications as defined by the voice of the customer, and qualitative and quantitative analyses, such as mapping of the market space and selecting the product characteristics through tools like quality function deployment (QFD). While there are numerous methods for determining the product architecture and the product configuration, product design focuses on inputs from the technical people and participants from marketing. The design process focuses not only on creating the product design in terms of drawings, bill of materials, and the other means to define the product; it also transforms definition and specifications into reality.

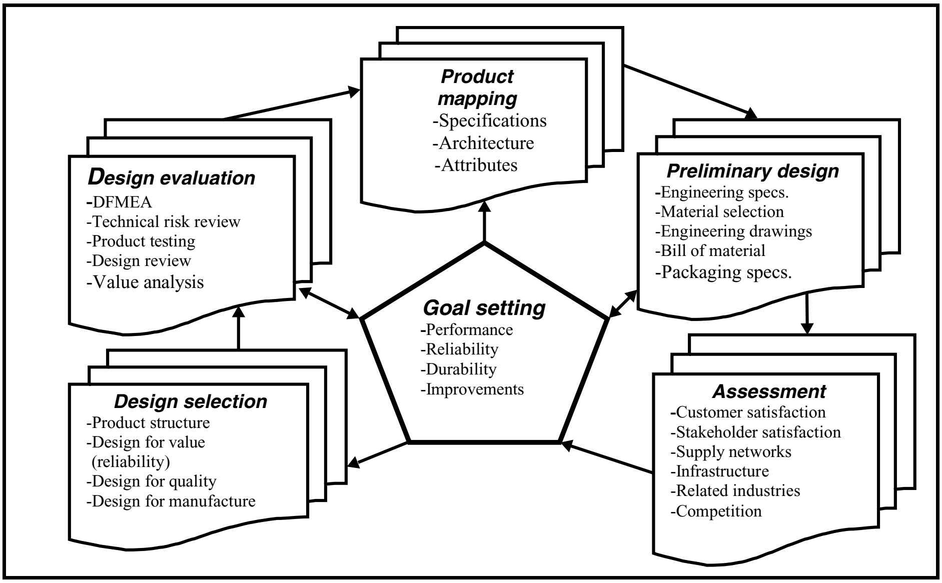


Figure 11.2 Product design and development

Figure 11.2, Product design and development design process, maps out the six essential elements of the process. Goal setting is the centerpiece. After each step, participants assess how their contributions affect the goals of the product, the NPD process, and the NPD program. Each element builds on the previous one and provides additional insights concerning the viability of the new product in the light of the business environment.

Goal setting

Goal setting is a necessary starting point in the design process. It is based on the goals and objectives for the entire NPD program and the requirements of customers and stakeholders. (The strategic logic of Phase 0 defines the organization's expectations and the strategic and market-related objectives.) The strategic position of the organization and its capabilities and resources drive the goal setting of the NPD program, and determine what is achievable. The NPD program goals are usually established during or before the Program Definition Phase. The customer's voice is essential, and helps provide a balanced perspective.

The program champion and the team participants are critical in articulating the goals. The goals stipulate the performance that the new product must achieve. Goal setting also identifies other critical product-design requirements such as the reliability and durability of the product. In many cases, the goals specify the level of improvement that has to be obtained. For example, each new generation of microprocessors has to be at least a two-fold improvement over the previous generation. The goals are typically based on the analysis of the needs of customers, stakeholders, the preliminary product specifications, and characteristics of the product. If QFD is used during the Concept Development and Selection Phase, which includes an analysis of the product targets, the goals can be based on the critical requirements identified through customer and stakeholder analyses.

The goals are often established by policies or guidelines set forth by management. For instance, General Electric's "Design for Six-Sigma" program examines what is critical to quality (CTQ) and determines goals and metrics to ensure that the CTQ items are achieved. United Technologies Corporation (UTC) has a Design for Environment, Health and Safety program that stipulates a rate of improvement for each new product. Its new "Green Engine" is expected to be 100% recyclable.

Product mapping

Product mapping includes the product specification, the architecture, and the attributes. They are based on inputs from customers and stakeholders, along with contributions from the NPD team and other participants from the organization. Product specifications, voice of the customer (VOC) and QFD provide insights for determining product form, function, features, and benefits. The analysis must examine the cost implications of the design decisions as well. Such an analysis can be performed as part of the design or concurrently determined by financial experts.

Product specifications provide a good overview of the essential aspects, but usually lack the details necessary for definitive decision making. VOC and QFD are effective tools for translating customer requirements into product characteristics. They are useful for following the customer requirements through the design process to the manufacturing level, to show how each design element contributes to customer satisfaction. The product map shows the entire chain of decisions from the customer needs to engineering specifications, through manufacturing processes and operations. If the decision options are clearly understood by the participants, the organization is better prepared to make good selections.

Product mapping also indicates the relationships between the key elements of the process. It begins with the strategic alignment of the product with the existing businesses and product lines of the organization. It ties the physical and psychological aspects of the product design to the needs and wants of customers and the requirements of the stakeholders. It relates the product, parts, processes, and operations with the suppliers, the infrastructure, the related industries, and potential competitors. It provides a pathway for the overall design process. It shows the relationship between the key areas and the interfaces that have to be managed.

Product mapping provides a breakdown structure to view the internal design processes as they relate to the external dimensions. Product mapping expands on the framework established during the Program Definition Phase, creating the outline for

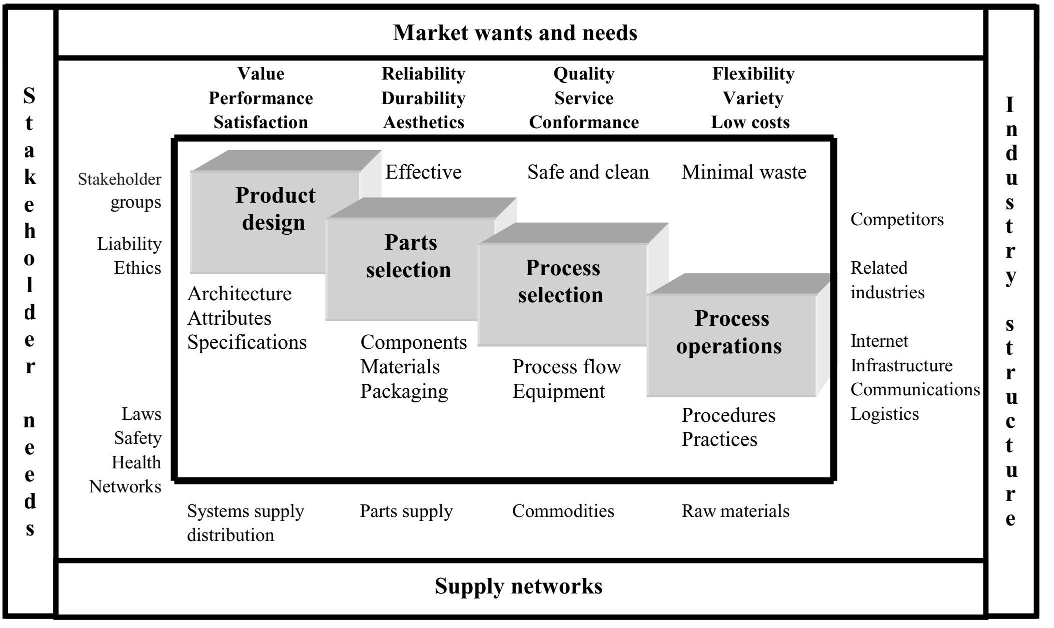


Figure 11.3 Concurrent engineering of the technical functions

the product-design participants so that all of the essentials are considered. It sets the stage for a holistic design sequence by showing the critical relationships between the internal and external players.

The mapping process is based on the experience and knowledge of the NPD team gained from previous NPD programs. Once the process map is determined, an action plan is developed for pinpointing the required deliverables.

Figure 11.3 shows the relationship between the critical dimensions. The elements include those that are typical for a new-product design process. For an actual situation, the NPD team considers internal and external dimensions, and maps out the design process. It is virtually impossible to include everything affecting the process at the beginning of the phase. The fundamental approach is to identify the essential elements, to discover the other important relationships, and to map out the process.

Preliminary design

The preliminary design includes translating product specifications into engineering instructions and detail drawings that define the basis of the physical aspects of the product. The engineering of the product involves a work breakdown structure of the entire product into subsets and then a building-up process of pieces into parts and components, modules, and the final product. The actual methodology used depends on the type of product, and the processes and the prevailing knowledge about the product structure. Work breakdown structure is effective for complex products

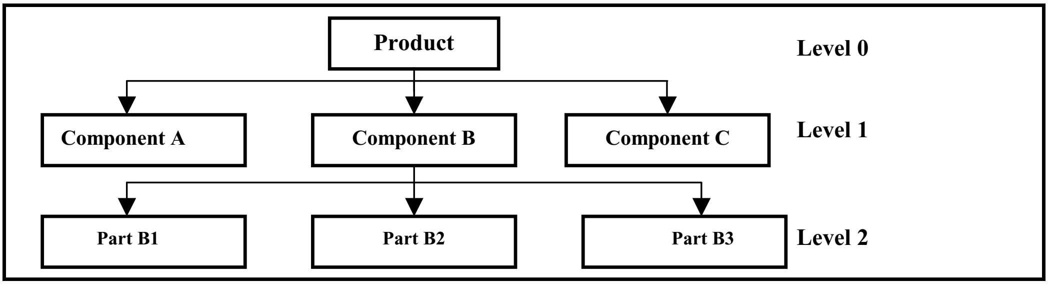


Figure 11.4 Product structure

or new-to-the-world products that have components or modules requiring significant development. The product is broken down into its basic elements following a logical flow path of increasing level of detail and understanding.

The process continues until the product is characterized in elementary items. The engineering of the product includes calculations for determining the material requirements, the strength of the materials, and the arrangement of the components and parts. The design parameters are stipulated in terms of dimensions and tolerances. The design parameters are based on performance requirements, and industry and government standards. Figure 11.4 is an example of the product structure.

Material selection is an important step during the engineering stage and has critical implications. Material selection includes the identification of the materials incorporated in a product, the determination of the quantities to be used, and their suitability for the product. The process flow chart and the material selection data provide the inputs for the bill of material (BOM) for the product. The BOM gives the information necessary to determine the options for the source of supply, the quantities required and the cost structure depending on the supply options.

As discussed in the sections on computer-aided design and product data management in Chapter 7, many organizations have automated the design process to facilitate decision making, to expand the number of available options, and to minimize the time required to engineer the product.

Design-process assessment

The assessment step is a crucial element of the design sequence. A reflection on the preliminary design ensures that it incorporates as many of the needs and requirements of the external dimensions as possible. There may be reasons why certain legitimate needs cannot be fulfilled. For instance, corporate policies may restrict the use of materials or product forms. Aircraft manufacturers have strict safety rules for the design of aircraft engines and related components. They have stringent approval processes for the use of alternative materials such as new types of engineered plastics or composite materials. Even though important customers may want such new materials, certain manufacturers may not provide them until they are fully tested and approved for use. The assessment examines the design in the light of customer and stakeholder needs and wants. The critical question asks: Will the market segment and the customer groups be satisfied with the product? Customer satisfaction is one of the primary metrics of any product. The assessment includes assurances that the product accomplishes what is expected. Outputs from techniques like QFD provide a mechanism and the information necessary for making the determinations.

Stakeholder assessment is much more open-ended. It examines important stakeholders and their requirements. Government stakeholders are important because the new product has to comply with public policy concerns, and applicable laws and regulations. A thorough examination of the federal, state, and international laws and regulations is a good starting point. Legal compliance is not optional and, in many cases, regulatory mandates determine what can and cannot be done. Compliance issues may also have an impact on the time required to complete the NPD program. For example, if a permit is required prior to the application or use of a given material, process, or operation, then the time required for obtaining the permit is critical to the program.

The public may be interested in a new product or the manufacturing system for its production. Concerns may include safety and/or human-health implications of the manufacturing processes. The stakeholder-assessment step includes a full analysis of the implications of the public concerns and those of special-interest groups. The assessment provides information and analyses, and results in statements or conclusions about the issues. If it appears unlikely that an issue can be resolved or mitigated, then an alternative course of action may be required to solve the problem. The purpose of the assessment step is the discovery, analysis, and resolution of potential problems as early in the design process as possible. The organization has the most leverage during the early phases of the program or during the early steps of the product design process.

Life-cycle assessment is a special methodology for analyzing selected environmental issues and impacts. It is used to systematically analyze and evaluate resource requirements and environmental burdens associated with the product, and its related processes, distribution requirements, and applications. The analysis is undertaken to identify, quantify, and evaluate the materials and energy employed to produce and use a product over its entire life cycle. It is a multi-stage input–output model that examines all of the inputs and their impacts, and all of the outputs and their impacts – including products, derivatives, by-products, and wastes. The model evaluates the current picture and explores the possibilities for systematic improvement through product design considerations.

Supply-network requirements necessitate a comprehensive review of the sources for material, parts, and components to ensure their suitability, availability, and affordability. It is essential to explore the feasibility of the supply-network requirements as early in the design as possible. Some suppliers may be selected as strategic partners, given that their contributions are critical to the success of the program. Other sources have to be checked to ensure they are available and stable. Corrective actions have to be taken if problems are discovered. In recent years, organizations have streamlined their supply networks to improve customer service, reduce excess inventory in the system, cut costs from the network of suppliers, and facilitate interactions and communications with suppliers. The primary goal is to obtain a competitive advantage by improving the cost structure, reducing waste, and eliminating inefficiencies.

Life-cycle costs

Using life-cycle assessment to analyze the environmental impact of a product is part of a general methodology known as the "life-cycle-cost" concept. A life-cycle cost can be defined as the total cost to the user of purchasing, using, and maintaining a product over its life. For many consumer items – such as hamburgers, train tickets, or soap – the total cost of using the product is reflected in the purchase price. However, for more-complex, durable goods, the purchase price may also reflect additional operational and maintenance costs. After-sales costs may even exceed the original purchase price for some products.

It can be argued that the best strategy for product designers is to consider all of the cost elements, and then design products with minimum life-cycle costs, even at the expense of a small increase in the original selling price. Marketing could then tout the virtue of life-cycle design as a market differentiator, in terms of the savings over the life of the product. Using this approach, customers could buy a product by comparing life-cycle costs for competing brands. This practice is commonly seen in the marketing of air conditioners and other appliances that consume large amounts of electricity. Appliance manufacturers are now required to display yellow tags on their products which contain estimates of the annual operating costs, based on average usage. This information is meant to encourage consumers to consider life-cycle costs when making purchasing decisions. However, there is an initial purchase price at which many consumers will balk, regardless of the annual energy savings. For other consumers, lowest initial price is the only priority.

The logic of designing for minimum life-cycle cost is sound, but widespread acceptance has been slow. There seem to be two primary reasons for this slow pace of adoption. First, estimating future costs of operation and maintenance is difficult. More importantly, there is cultural resistance from product designers, purchasing, and marketing people, whose engrained practices are based on the concept of minimizing the original purchase price.

Life-cycle-cost ratios for various consumer products

Ratio of life-cycle cost to original price			
Range, gas	1.9	Room air conditioner	3.3
Refrigerator	3.5	Dishwasher	2.5
TV, color	1.9	Freezer	4.8
Washing machine	3.6	Range, electric	4.4

Source
Adapted from: F. M. Gryna, *Quality Planning and Analysis: From Product Development through Use*, 4th edn. (New York; McGraw-Hill, 2001, pp. 109–111).

The infrastructure plays a vital role in supporting product requirements. One critical consideration is the impact of the Internet. E-business has a powerful influence on almost everything. How the Internet may contribute must be assessed. It may offer a means for product sales or distribution. It might offer a promotion mechanism. The Internet provides a low-cost facility for disclosing product information. Regardless of the mechanism, the use of the Internet has to be evaluated.

The infrastructure provides the physical links to customers and the distribution channels. It is the means of completing the network of activities to get the product into the hands of the customer. The highways, railways, waterways, and airways are part of the existing external structure that makes business possible in most parts of the world. The assessment of the infrastructure ensures that the links are actually in place. This is particularly necessary when dealing internationally. Communications are a vital part of the product delivery system.

Related industries are also part of the support structure. For many new products, there are ancillary products required to make the new product viable. The automobile is of little value without petroleum products. Assessment includes determining the relationships with other products or industries, understanding the linkages and determining their probable stability over time.

Competition always has an influence on design. It does not have to be negative, at least from a new-product perspective. A competitor might assist in developing the market potential faster because its product(s) reinforces the company's technical design selections adding to the potential of making them the dominant design. Sony and Phillips combined to make their CD-ROM technical design the standard for the industry. Moreover, the competitor's product variation may give customers a more-balanced offering that contributes to the overall success of the industry. In some cases, a customer might not purchase a product if he or she is limited to only one supplier. This is often the case in business-to-business transactions.

The assessment of competition was described in Chapter 2. The focus during the Design and Development Phase is on the competitors' products and their features, functions, and benefits. The best approach is to study the competitors' product(s) so that the organization's new product can emulate the competition where required, differentiate where appropriate, and upstage when necessary.

The competitive assessment during this phase is a direct assessment. It examines the competitors' products that pose the greatest impact or threat. There are numerous ways to assess a competitor's product. QFD offers a mechanism to evaluate competitors' products. With reverse engineering, the engineering team disassembles a competitor's product to determine its advantages and disadvantages, and to learn how it was put together.

Design selection

Design selection is the refinement of the design considerations incorporating the information and knowledge gained during the assessment step. It reflects required changes due to the needs or pressures of the external dimensions. Design selection is based on the best fit of all of the inputs and a balanced perspective of all of the product requirements. Design selection attempts to incorporate the most important customer needs and wants with the most critical product characteristics. However, in special cases, there may be an overwhelming requirement that takes priority over the others and certain product attributes may have to be sub-optimized to fulfill the specific requirement. For example, safety considerations may force designers to incorporate features that make the product less aesthetically pleasing or more costly.

A design should reflect the external considerations and incorporate the design principles discussed in Chapter 7. The design should include design for value, design for quality, design for manufacture, and design for the environment concepts.

The design selection process should follow parametric-analysis guidelines such as axiomatic design principles, as discussed in Chapter 7. Parametric analysis compares and contrasts the parameters and selects the best choices, given the stated options. Although such analysis is often included in the logic of QFD and the other design tools and techniques, it is used during the design selection process to ensure that the best design emerges.

Design evaluation

The design-evaluation step includes a check to determine if there are any inherent defects or flaws in the design that would have a significant effect on its viability or suitability in the market. The step may include a design failure mode and effects analysis (DFMEA), a technical risk review, product testing, a value analysis, and a design review.

The DFMEA often takes a considerable effort as described in Chapter 7. While it might be possible to conduct the DFMEA earlier in the design process, it is frequently done at a later stage to ensure that the analysis represents a perspective of the design configuration that is likely to be close to the final design. The purpose of the DFMEA is to discover potential difficulties and effect a solution during the Design and Development Phase while it is relatively easy and inexpensive to do so, rather then finding problems after the launch.

The technical-risk review is a continuation of the process of finding potential problems and resolving those problems as soon as possible. Technical-risk assessment is an ongoing process incorporated into the overall NPD process. A major component of the technical risk associated with new-product development is uncertainty. Technical-risk assessment addresses the probability that the design will fulfill its performance requirements.

Product-use testing is an essential part of the new-product evaluation process. It is a formal construct for determining the suitability of the product for commercialization based on the actual use of the product through simulated applications and/or by potential customers. There are variations to the methodologies. Product-use testing is occasionally conducted using employees to obtain feedback about product attributes.

This approach should minimize the risk of alerting potential competitors to the advantages and disadvantages of the new product. If the new product is tested by a group of randomly selected potential customers, then the construct is typically referred to as beta testing. Beta testing is a form of product-use testing where customers evaluate the functionality and benefits of the new product in the user's environment. A major goal of such testing is to explore the pluses and minuses of the product with particular focus on finding defects that could significantly impair the success of the product or inadvertently create liabilities.

Product-use testing is often a precursor to market testing. Market testing, the next step, examines the product with its packaging and, most importantly, the marketing program. Customer analysis and feedback are sought to further refine the design and include the next level of customer input prior to the full development of the production and marketing campaign. Product-use testing is used to reduce uncertainty and improve the confidence in the design. Chapter 12 contains more-detailed comments and insights about testing.

The question of whether to employ product-use testing or not is still being debated, without any straightforward answers. Product-use testing takes time and money. If the time and effort required to execute the testing process mean that the NPD process requires additional time to bring the product to the market, then management decides upon the best course of action. Delays in commercializing a new product may result in an irretrievable loss of revenue and profits, especially for products with a short life cycle. The ultimate goal is to get the new product to market on time, within budget, having all of the appropriate attributes to achieve success, and with no hidden defects.[1] However, the "precautionary principle" suggests that safety and liabilities are important, and any concerns must be eliminated prior to launch. Customers expect products to be free of defects and burdens.

Value analysis is a review of the design from a market perspective. It evaluates the design from a customer's point of view. It reaffirms that the essential customer needs and wants have been addressed by the design. It ensures that the new product will meet the requirements for performance, reliability, durability, appearance, and costs.

Design evaluation normally culminates with a design review. The review may be part of the phase and review process to obtain approval of the design in order to proceed to the Validation Phase or it may be a precursor to those activities. The design review examines all aspects of the design and the tools and techniques to validate its suitability for the market. Design review typically includes the following specifics:

- Verification that customer needs and wants have been considered in the design; and that a high level of customer satisfaction can be achieved. (Value analysis.)
- Confirmation that all stakeholder requirements have been considered and that the design is in compliance with all laws and regulations, and industry and international standards. (Compliance review.)

- Validation that the design meets the technical standards of the organization and its design processes and that there is a means to confirm the accuracy of the data and engineering incorporated in the design. (Quality assurance.)
- Corroboration that the design meets the process requirements of the operating system and supply networks. (Systems integration.)

The design review ensures that the design meets all of the intended applications of the product and that the design objectives from every perspective are in line with expectations.

Marketing-program development

The development of the marketing program is based on the strategies formed during the Strategic Logic and Alignment Phase and the Concept Development and Selection Phase. The marketing program has to be developed concurrently with the product design process. It follows a similar construct to that of product design and the information flows in both directions. The marketing of the product is based on the tangible and intangible aspects of the product and its intended applications. The marketing program has to be aligned with the overall NPD program and the realities of the product/market itself.

Developing a marketing program for a new product requires innovative approaches. The standard marketing mix tools are not always suitable for a new-product situation. This is especially true for promotion. For example, advertising may not be a cost-effective method during the early stages if the market size is small and the distribution channel is limited in scope and geographic reach.

The marketing-program development starts with a re-examination of the essential marketing objectives. Figure 11.5 is a process flow chart that follows the same logic as the primary-design process flow chart. A strategic marketing plan, marketing design, assessment, selection and evaluation follow goal setting.

Again, after each step the participants should reflect on how their contributions to the marketing program affect the marketing and overall goals of the NPD program. Each step provides additional credibility to the overall program and confidence that the marketing campaign is moving in the right direction.

Goal setting

Goal setting is simply a reaffirmation of the marketing goals established during the Program Definition Phase or earlier. Marketing goals provide the direction for the development of the marketing program. They identify what is most important in the marketing of the new product and establish the focus of the marketing program.

The following are several examples of how goals provide inputs into the decision-making process for the participants and the dilemmas they have to deal with:

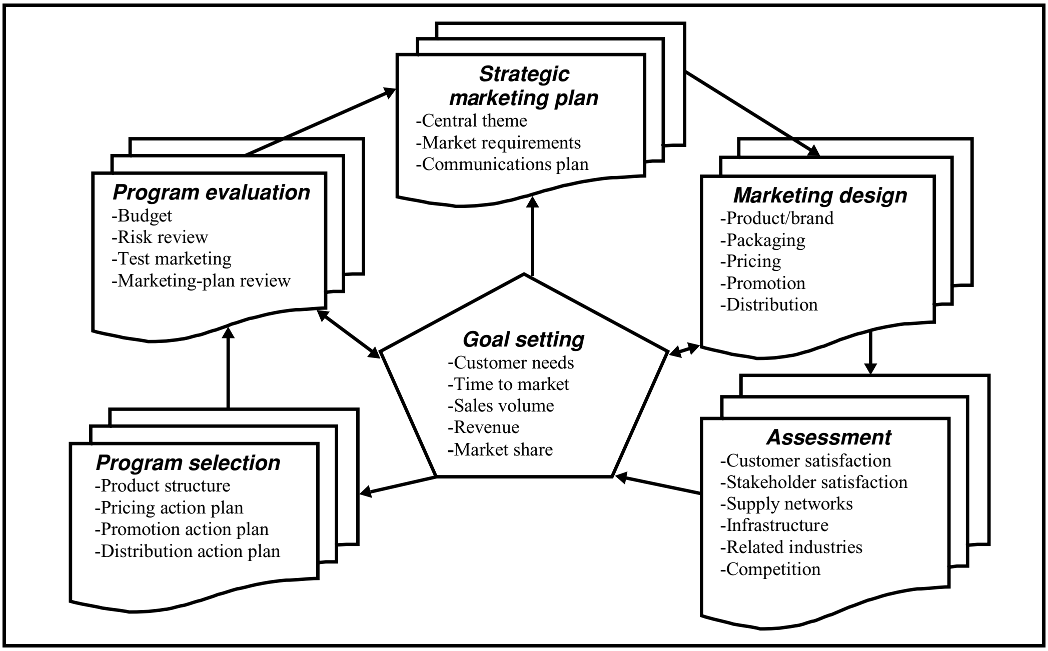


Figure 11.5 Marketing-program development

- ***Customer satisfaction***. High-power products provide high-power customer satisfaction. Potential customers have to be convinced of the benefits of the new product using a succinct message. Complicated messages may be difficult to understand. Simple message may not convey all of the salient aspects.
- ***Time to market***. Accelerated time to market may preclude the development of a time-consuming TV advertising campaign in favor of simpler AM radio spots in target markets or other similar choices.
- ***Sales volume***. The pricing strategy might use a more-aggressive pricing scheme to build sales volume quickly in order to achieve a more-favorable cost position, but revenue streams may be less favorable.
- ***Revenues***. Low prices have to be offset by a rapid increase in sales volume to generate the targeted revenue stream. Aggressive marketing campaigns might be used to build awareness, acceptance and ongoing success; however, such programs are expensive and affect cash flow.
- ***Market share***. Profitability might be sacrificed to achieve rapid market expansion and market-share positioning. High levels of marketing expenses might be used to capture market share.

The interrelationships discussed are only a few of the concerns that arise with respect to setting goals. It is imperative to stipulate the goals clearly and understand the interrelationship. The most important determination is the relationship between short-term and long-term goals.

Strategic marketing plan

A direct outcome of the articulation of the goals is the development of a definitive strategic marketing plan. It represents the big picture from a marketing perspective. The strategic marketing plan is based on the overall business strategy, and specifies the central message and the launch strategy. With the decisions made during the Program Definition Phase, or earlier, pertaining to the product/market leadership position, the organization affirms its decision to be the first to the market, a follower, an imitator, or other launch strategies.

The market leader has to establish the market and define the new product. This is usually expensive and requires a significant investment to inform potential customers about the new product and its benefits. The follower has a much easier task in marketing communications, since the leader has introduced the product and created an initial awareness. The follower can play off the goodwill already established in the market, develop a derivative approach to capitalize on specific opportunities, or select a different strategy for introducing the product. The imitator simply uses the proven strategies of the leaders and other predecessors into the market.

The strategic marketing plan focuses on selecting the marketing methods that create awareness, engender willingness on the part of customers to try the new product, build acceptance, and sustain the new product in the market. The plan is built on a central theme that conveys meaning to external constituents. The central theme is the critical message conveyed across the entire marketing program. It is the glue that makes the marketing program stick together. The first step involves creating a message that defines the new product and differentiates it from existing products or other options in the market place. Miller Lite's "tastes great, less filling" is a great example of the all-encompassing message that becomes the essence of the entire marketing program. The central message provides the mechanisms for linking the marketing programs and activities with each other and with other facets of the NPD program.

The second step is determining the most appropriate marketing mechanisms for the particular NPD situation and prioritizing their development. For example, advertising may not be effective during the early launch, whereas, sales promotions may be an essential requirement for selling the product through retail channels; therefore, advertising should be considered secondary to the other selected marketing tools in the commercialization plan.

The third step is to develop a communications strategy. The communications plan is the pivotal point of the marketing program. Building awareness is critical for a new product and getting the message to prospective customers is the most important step in the process. The communication plan links the attributes of the new product with the external dimensions of the enterprise. The principal objective is to develop the communications plan in parallel with the technical development of the new product. Concurrent development suggests that everyone contributes to the marketing effort and

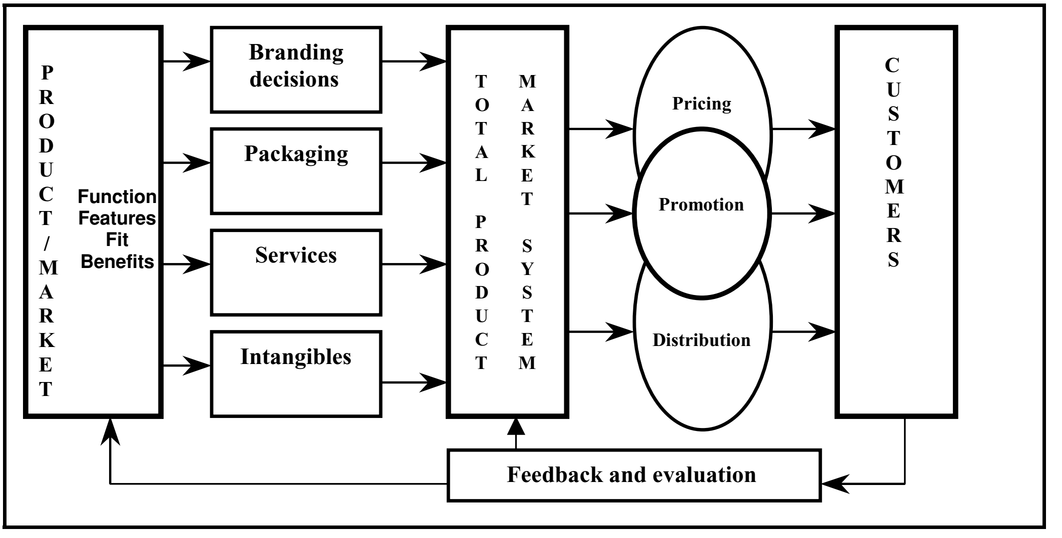


Figure 11.6 Product/market and the critical elements of the marketing plan

that the critical elements of the marketing and communications program are designed into the product. This approach eliminates the question of how to market the product after it has been completely designed.

Marketing design

Overview

Marketing design is similar to product design layout. It is simply a schematic that describes how the marketing action plans relate to each other. The schematic focuses on the design principles for guiding practitioners during the development of the marketing program. The quantitative and qualitative aspects of the product are defined during the technical-design functions. Product attributes, which are often locked-in because of technical-design decisions, become more difficult to change over time. Figure 11.6 depicts the relationships between the front-end of the marketing-plan elements and the critical decision elements of the back-end, which are in direct line with the customer.

The related product strategy decisions on branding, securing a trademark, selecting the type of packaging and provisions of services, and selecting intangibles have degrees of necessity and flexibility. The total product/market system is the combination of the technical product construct and the market-related product elements. Feedback and evaluation are part of the last step in the design.

Branding

The front-end marketing elements for many organizations, especially those that have an established presence in the overall market, tend to be preordained. An organization’s branding and trademarks are typically consistent over time. Brand equity is the term used for creating awareness and acceptance of the company's product as a "unique" position with its own attributes and value proposition. Branding connotes quality, value, and recognition. The intent is to establish customer loyalty and goodwill.

The branding strategy for a new product generally follows the "family traditions." If the new product is part of a product line, the organization usually exploits the power and benefits of the existing brand names and trademarks. Indeed, this form of leveraging reduces the investment required to launch the new product. Brands are powerful in capturing long-term value creation. It allows the company to promote the brand rather than the product itself. Often the brand takes on a broader definition than just the product. It often conveys all of the attributes, especially the intangible aspects. Starbucks is an excellent example of a brand that connotes more of the experience than the product itself.[2]

For a new-to-the-world product, additional investments have to be made to build the name awareness and recognition. However, there is normally a long-term competitive advantage associated with the added cost. With a brand name, logo, and/or trademark, the organization is investing in more than the one product. It becomes a unique position owned exclusively by the organization. Intel's Pentium name became part of Intel's identity, whereas the earlier "X86" designation was copied by competitors, and lacked the brand distinction. It became a generic term.

Branding is extremely important and powerful for product platforms where the company can leverage the good name of preceding products for the subsequent products. It is part of the overall leveraging strategy of exploiting the capabilities, resources, and intellectual properties of the organization. Using existing brands or building new ones is a means toward sustainable competitive advantage. Even in the cases where the new product is not successful from a financial perspective, gains can be realized if the related marketing and image-building campaign created favorable outcomes.

Companies may chose to forego building brand equity if the new product is intended to be a "non-normal" offering that the company does not want to spent large sums of money promoting. It may have a short time horizon or the most likely situation is that it represents an unconventional position for the company and might tend to confuse customers in the market place. For example, high-quality, high-performance manufacturers might sell their low-end products using an off-brand or no-brand-at-all approach. Avoiding a brand name is used if the long-term strategic direction has not been established and the focus is not clear. Occasionally new products are introduced to fill a gap required to support selected customers who are important to the company. However, the company does not view such products as its main interest and it wants to minimize the resources and impacts. The most important reason is the attempt to minimize exposure to negative responses, especially in those cases where the product is not central to the company. Small companies often simply do not have the resources to invest in branding their products. In many cases, they do not have adequate funding to market the new product. Whatever monies are available have to go to the absolutely necessary campaigns of selling the product.

Packaging

Packaging plays a multifaceted role for a product. It protects against damage or decay. It may simply be the means of containing the product during shipment. It provides an attractive means of displaying the product in a retail situation. It can provide an effective means of conveying vital information to customers about the product, and its specifications and applications. Some of the information may be mandated by government regulations for health, safety, and effectiveness reasons. Government regulations often stipulate that the contents must be disclosed – such as the ingredients in food products.

Packaging is a means of distinguishing the product from those of competitors. Graphic-design elements tie the new product to its producer. Such links can secure the benefits for advertising and promotion. These benefits may be seen in examples such as the color and graphics for the packaging of Tide detergent, which is just as well-known as the trademark of the product. Caterpillar employs a distinctive mark and color with worldwide recognition, and the shape and colors of the iMAC computer have quickly become a well-known symbol imitated by other NPD programs.

Services and after-market considerations

The total product includes support services and the after-market considerations, which provide ongoing solutions for the customer. The required support services vary considerably from product to product. Such services include installation, assembly instructions, guidelines, manuals, information on the Internet, help desk, etc. Services are often provided through the distribution channels, therefore, information, training, and support systems may have to flow to the channel for implementation by others.

Services are critical for success and, in many cases, they are the missing ingredients during product development. Indeed, in the capital-equipment categories, the after-market represents opportunities for generating future cash flow. Products like jet engines for aircraft are often sold at a breakeven point given the competitive pressures and the expectations of making high gross margins on replacement parts and related services. In the cellular telephone industry, the money is made in service provision; the handsets are often given away.

The ability to return or correct a definitive product is one of the most important services customers require of their suppliers and producers. While such services are not usually part of the primary marketing approach, they are critical for ensuring that customers enjoy satisfaction. Many companies fail to put adequate resources into handling negative comments or warranty claims after the sale. Such failures spread by word of mouth or through the Internet and become a barrier for future sales. While such requirements are not new and high-quality companies have realized the need to provide solid services to customers, the literature is replete with stories about the failure to adequately manage complaints, product problems, and defective merchandise. In the past, it often took years for customers to become aware of such failures or to realize that they were not the only ones with the particular difficulty. With the Internet, such information is widely available and is distributed almost instantaneously. New products are especially vulnerable to such adverse comments because early failures may dampen the demand for the product just as it was about to accelerate. During the early stages of launch, it takes some time to build the positive responses that could in the long term mitigate the influences of a few disgruntled customers.

Intangibles

The intangibles include psychological and other less-apparent aspects that may be important to customers and stakeholders. An assessment of the intangibles serves to minimize mistakes or oversights by reviewing all of the implications of the new product: environmental, economic, social, political, and technological; both in the current and the anticipated business environment.

The social aspects of a new product are usually the most important. For example, BMW sells status, prestige, and "fun" – as well as mobility and functionality. The intangible aspects include convenience, flexibility, worry-free ownership, and other lifestyle considerations. Customers are often willing to pay for many intangibles that provide economic and time-saving benefits. The added features may cost more, but the long-term intangible benefits may be seen as a great advantage. Cadillac, for example, offers cars that do not require tune-ups before 100,000 miles (160,000 km). This saves time and money over the life of the car.

The total product/market system

Reiterating E. Raymond Corey's points, the product is the total package of attributes (benefits) that the customer buys. The marketing design has to include all of the elements of the marketing program, and formulate and implement the plan based on the total product/market aspects. Care has to be taken not to focus on just one or so attributes of the product, or provide a lopsided marketing program. It is appropriate to use a focused approach for marketing the product in a select market segment but the marketing program should be comprehensive and provide a total solution.

Pricing program

Pricing is one of the most critical decisions for a new product. Pricing for existing products is often dependent on market conditions, resulting in less flexibility to the producer or provider. NPD situations demand insights into potential market conditions and trends to devise the best pricing strategy. The challenge is to develop a pricing strategy that is advantageous for both the short term and the long term.

The customer's value equation is affected by price. There is an inverse relationship between price and value; higher prices require greater benefits to provide the same value.

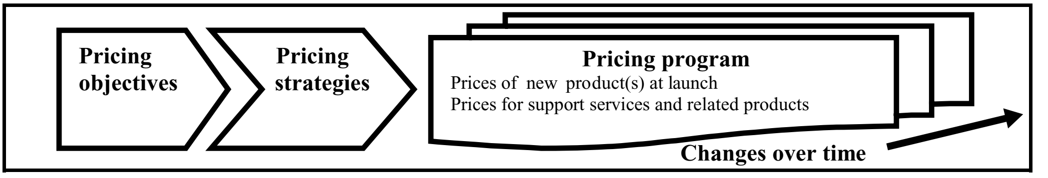


Figure 11.7 Schematic of pricing

Moreover, higher prices tend to support higher gross margins, but may adversely affect volume and total revenues. The overall objective of the NPD program sets the stage for the pricing objectives and strategies. The pricing strategies provide the direction but not the detail. The pricing elements provide the details for implementation.

The pricing program explains how the pricing strategies used to launch the new product are translated into actions. The program elements bring life to the strategy by establishing the initial price(s) and defining how the price(s) changes over time. Figure 11.7 depicts the pricing schematic.

One of the most significant marketing challenges with a new product is to secure the benefits of the investment to the organization and not for competitors. Pricing has to be a dynamic process to ensure that the benefits of the marketing and new-product programs are captured and sustained. While there is no generic perspective on pricing programs, it is essential to think about pricing in terms of programs and action plans and not just in terms of strategies. The pricing logic discussed in Chapter 8 should be helpful.

Communications and promotion programs

Promotion programs are typically simple to contemplate, but difficult to design. The standard advertising and promotion elements have to be carefully considered and evaluated for a new product, but the standard fare does not always work. For example, advertising may over-reach the target market, if the initial target market segment is narrowly defined. This is especially true if the segmentation scheme is geographic. Table 11.1 depicts a process for determining the elements of the advertising and promotion program for consumer and industrial products.

The elements of the marketing program must be identified and evaluated in terms of their desired impact on the successful launch of the product. In many cases, there are essential elements that are more powerful than the others, and are critical for success. For certain consumer products, an essential requirement may be "point-of-sales" displays to support the distribution channels. For industrial products, it might be a cadre of senior sales experts, who can convey, in a credible way, the technical details of the product to potential customers.

The critical factors of the overall design typically provide guidance for selecting the most appropriate marketing approaches. They often relate to the "must-do" elements.

Table 11.1 *Process for developing communications and promotion action plans*

Step	Guidelines for analysis	Process
1.	Benchmark other products (gather and analyze data to determine the requirements for success).	Select similar products or those related to the family of products and determine the marketing mix used during new-product launches.
2.	Determine the most effective elements (evaluate the effectiveness of the marketing elements).	Develop an effectiveness profile for each of the marketing elements: advertising; promotion; point-of-purchase displays; coupons; selling; etc.
3.	Link with product design, production, and finance (integrate marketing solution with other functions).	Determine the most effective and desired design parameters; examine the impacts on operations; and evaluate the financial implications.
4.	Prioritize the elements in terms of effectiveness (determine the critical requirements).	Identify the elements that are essential and determine how they fit into the program. Select supporting items.
5.	Develop an action plan for each element (map out the detail action plan for each element).	Determine the content of the action plans and the timing for their implementation.
6.	Develop a budget for the action plans (prepare a definitive budget for each of the required action plans).	Based on the content and schedule develop a detailed budget of the investment required to support the entire marketing program.
7.	Communicate the action plans.	Prepare a document and disseminate it.

They are the direct links to what has to be done and the resources required for achieving the objectives. The action plans define the essential elements and the budget specifies the resources. The budget provides the details needed, estimating the investment and determining what elements are to be implemented.

Distribution channel

The distribution channel provides a means to reach potential customers. It consists of intermediaries, wholesalers, retailers, and/or sales agents who link the organization with the ultimate customer and provide the flow of information and physical products, as discussed in Chapter 8. The channel may include many entities, which add value by providing specific functions to enhance the benefits received by customers, or it may be a single connection between the organization and its customers. Dell Computer is an example of a direct system. Dell connects with its customers by using a single delivery entity like United Parcel Services. On the other hand, food products are normally distributed through a maze of independent operators.

In designing the distribution system, the organization must select a channel outlet that is consistent with its strategic position and the inherent nature of the new product. Many organizations use a standard industry model for distributing their products and the new product often has to fit into the standard methods. Compaq Computer has traditionally used retailers as a means of selling its products. Dell's model is in a sharp contrast to the Compaq model. Which is better? Which mechanism is superior depends on the organization, its capabilities, and the needs of the specific market segment selected. Compaq's customers may need more direct personal attention and reinforcement than do Dell's customers. Other aspects also play a role. For example, some customers want instant gratification at the retail level. They want to buy the product and take it home the same day.

The key to the design situation is strategic alignment. The distribution system must be consistent with the attributes of the product, the benefits sought by customers, and the resources available to implement the action plans through the product delivery system. Direct selling must be efficient and the organization has to have the capability to sustain the effort over a wide range of sales volume. The costs depend on the potential customers, where they are located, and how diverse their needs are. The primary goal is to minimize logistical costs.

There are no simple answers to the distribution question. Distributors may allow the producer or provider to reach the market without setting up a sales structure. This is a significant advantage during the initial commercialization, since the organization can avoid making commitments and investments until the market validates the demand. However, distributors may not be willing to carry the product unless they have a specified level of marketing support for the new product. For example, distributors and/or retailers may demand point-of-sales displays or other promotional means to gain awareness for the product. Often, the channel entities may require a level of investment beyond the organization's capability.

The distribution channel must support the informational requirements and physical delivery of the new product. While the Internet offers a potentially low cost mechanism to reach customers, customers will not automatically be drawn to a site unless there is sufficient awareness about the new-product opportunity. Well-known and established companies may leverage their overall capabilities to use the Internet advantageously. It is unclear whether smaller companies can sustain success using an Internet presence without significant advertising. Priceline.com used television advertising to build awareness. The advertisements with William Shatner took a long time to create the critical mass that Priceline.com had hoped to achieve.

Marketing-design assessment

The marketing program design must address the needs of the enterprise and the external dimensions. Does the strategic marketing plan convey the right information to the targeted market segment? Does the marketing process provide value to customers and stakeholders? Are there missing elements that are essential for success?

The purpose of the assessment is to ensure that all of the marketing elements required for launching a new product have been considered. It attempts to minimize mistakes and oversights by reviewing all of the implications: social, economic, political, technological, and environmental. The assessment provides a view of the potential of the new product in a wide array of business situations. It focuses on:

- Market opportunities, customer needs and wants, product attributes, product and process specifications, marketing requirements, and technology issues.
- The interrelated effects of customers, consumers, stakeholders, regulatory agencies, and competitors.
- A review of the requirements and perspectives of the supply networks, infrastructure, and related industries.

Managing the flow of the product to the customer and supporting the customer's use of the product are fundamental steps in astute marketing. The marketing plan focuses on the most critical factors that have to be provided during commercialization and ensure that they have been covered. The marketing-design elements must be efficient and effective in terms of resource utilization and implementation. The assessment ensures that all of the right steps have been included and that there are no deficiencies in the overall program.

Marketing-program selection

Based on the design of the marketing program and the assessment of its fit into the external environment, definitive action plans are spelled out in sufficient detail so that the entire organization understands the program and its objectives. The program selection also reiterates decisions made during the analysis of the alternatives, in a succinct document. It basically follows the format described in Chapter 6 under the marketing-plan template as developed during the Concept Development and Selection Phase or Program Definition Phase. The program selection includes the following:

- Product structure.
- Pricing action plan.
- Promotion action plan.
- Distribution action plan.

While the reaffirmation of the selection process for the marketing programs appears to be redundant, it is crucial that there is a definitive process for selecting the elements of the formal marketing program. This approach is similar in structure to preparing the final design of product specifications from a technical perspective. Given that freezing the design or selection is difficult to achieve before the testing of the final marketing program is accomplished, the actual selection signals the end of exploring alternatives and that a definitive marketing program has been decided upon.

While there may be corrective actions and other changes if defects are discovered, the conceptual and analytical work ends and the demonstration and actions begin. From this point forward, the effort focuses on validation of the decisions and implementation of the action plans.

Program evaluation

The purposes of program evaluation are to determine the adequacy of the marketing program and to ensure that the organization is capable of, and has the resources for, implementation. This step of the process is often executed concurrently with marketing-program selection. The evaluation continues during the Validation Phase. Indeed, the elements covered during the evaluation are usually the most critical factors pertaining to the marketing program. They are usually the same factors that management examines during its management review at the end of the phase. The most important aspects are:

- Budget aspects.
- Risk review.
- Test marketing.
- Marketing-program review.

The budget review process examines the investment in marketing and determines its impact on revenue generation and cash flow. The marketing budget is a subset of the total investment required to design and develop the new product and to launch it successfully. The review also examines the financial resources to ensure that there are adequate funds available to execute the marketing program fully.

The risk review is an evaluation of the impact of marketing on the overall NPD program. It includes a determination of the investment in marketing and the probability of achieving the desired results.

The marketing-program review is a general review of the entire marketing program from the downstream perspectives and the perspectives that were prevalent during the decision making activities. Valuable insights are gained when one looks at the whole of the marketing program and not just the pieces. It may reveal some inconsistencies, redundancies, and gaps in the program that were not previously apparent. It is often a key element in the review at the end of the Design and Development Phase.

Operations-program development

The development of means to build the product or provide the service follows a similar construct to the product design process. The production process is a sequence of decision-making elements that result in action plans that are consistent with the resources and capabilities of the organization for producing the product. While the flow diagram suggests a simple approach, in most cases the actual requirements are complex. The approach described in this section relies on the material covered in Chapter 9. It has a general overview of the plan, assessments, and evaluations similar to those of the other functional programs.

The starting point is the product specifications and the implications they have for production or operations. The product design usually provides engineering specifications

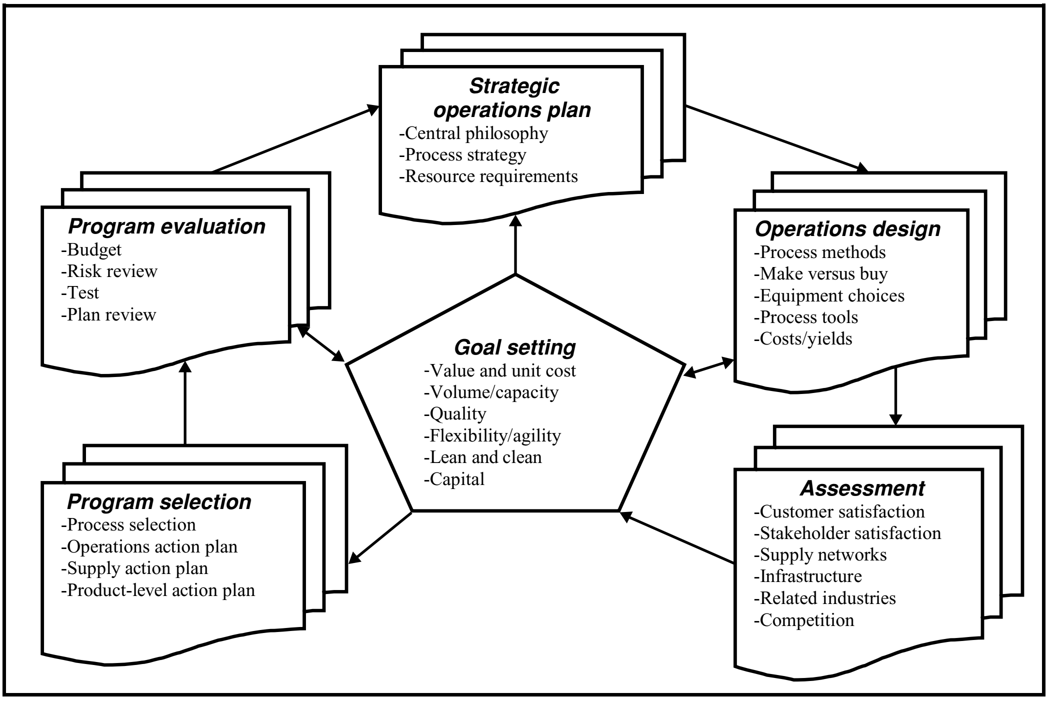


Figure 11.8 Operations-program development

and drawings that include the design dimensions, tolerances, and other technical characteristics. The development of an operations plan runs concurrently with the design process. The input data and information evolves during the product design process; therefore, the operations design process tends to lag behind the product or service design. Regardless, the up-front elements of goal setting, and the development of the strategic operations plan, can be refined during the early stages of the Design and Development Phase.

Process design builds on the decisions made during the Concept Development and Selection Phase, reinforcing the notion that NPD is a continuum. Process design analyzes and discusses the alternatives available for producing the product or providing the service that best fits the needs and wants of customers. It is integrated with the marketing and financial design elements as well. The goal of the process is to select an operating system that provides the right balance between costs, capacity, flexibility, agility, reliability, and speed. The design choices are based on the expected conditions and trends and the possible variations.

Figure 11.8 depicts the important elements of the process design. The process flow examines the alternatives in terms of the goals and the strategic implications, and produces value for customers, stakeholders, and the organization. The production-development model is a critical part of the value-creation process. Discussions about the procurement of plant and equipment are not included in this chapter. The topic is so broad that it requires several additional chapters just to cover the fundamentals. Given that such actions are normally executed by specialists who are not directly related to the NPD program, the subject matter is not covered in this text.

Goal setting

Goal setting for the operating system should be consistent with the goals of the overall NPD program. The primary perspective focuses on value. Reductions in costs and improvements in quality contribute directly to enhanced value for customers. Improved value provides a more-competitive position in the market place.

Unit costs are critical elements in the success of a new product. Cost structure typically varies with volume; therefore, unit costs are a function of capacity and the expected operating level. Low unit costs are extremely important for long-life-cycle products and depend on the costs of materials and components incorporated into the product, and the efficiency and effectiveness of the operating system. Low capacity utilization, inferior productivity, and poor yields are typical problems that have to be overcome during the start-up stages after the launch. Such problems contribute to higher costs and lower value, making the new product more difficult to sell. Customers are usually unwilling to pay more unless the new product offers significant benefits compared with other choices. New-to-the-world products typically have many such problems; however, they may also provide unique solutions for certain customers, who are willing to incur the higher market prices to obtain the desired benefits.

A crucial decision focuses on establishing a target number for expected sales volume over time. The sales-volume goal is based on the forecast, which is determined during the Concept Development and Selection, and Program Definition Phases, and is refined during the Design and Development Phase. The volume goals in turn are used to determine the capacity goals of the operating system for the new product. These capacity goals are the basis for decisions on processes, equipment, and operations.

Production quality is the underpinning for success. It can be expressed in quantitative and qualitative measures. The former may suggest a six-sigma goal. The latter may mean that perceived quality would always meet expectations.

Due to the relatively high level of uncertainty with new products, flexibility and agility have gained significant importance in the NPD process. Constantly changing customer requirements and market conditions mean that there is no single solution or universal formula for selecting the right operating system. Each organization must formulate its own approach. Moreover, since the business environment can change very quickly, maintaining flexibility and agility is important when selecting an operating system. Agility suggests that operating processes are selected and organized in a manner that can be quickly changed, if necessary. Agile organizations tend to compete based on the competencies of the people rather than the product delivery system and its production capacity. Such processes are dominated by the skills and knowledge of the people rather than the equipment and resources of the company. Such organizations are more open-ended using fundamentals and guidelines instead of rigid procedures and policies.

The concept of lean business practices plays a significant role in establishing the business goals for the new product. A lean operating system has less inventory and other dedicated resources so that it can change inputs or outputs quickly if necessary. Lean businesses use resources effectively and minimize waste generation. They use production processes that are environmentally sound in that they prevent pollution and meet regulatory mandates. Lean businesses minimize future liabilities by eliminating defects and burdens. Lean and clean practices provide both economic and environmental benefits through focusing on the ability to change. Both support agility and flexibility since lean and clean organizations have fewer internal constraints to change. Lean organizations have low inventories, require less space, have fewer non-essential employees, and have supportive suppliers. Lean and clean goals may stipulate the amount of inventory allowable, perhaps in terms of days of raw-material inventory or finished products, or the level of waste that can be generated by the operating system.

In certain cases, the amount of capital may be set as a goal. The goal may be specified in terms of the type of capital expenditures or the total investment into fixed assets. The specifics vary with the overall philosophy of the organization and its situation.

Strategic-operations plan

The strategic-operations plan reconciles the strategic alignment of the new product with the assets and capabilities of the production organization and the organization's philosophy on managing its core competencies and resources. The philosophy generally describes the organization's preferences for leveraging its existing base and the criteria for making decisions about the manufacturing of the product or the operating system for the service. The following are a few of the important questions that are addressed to provide direction:

- Is there an internal need or mandate to use existing production capabilities or capacity?
- Is outsourcing the new requirements to avoid capital expenditures a viable/preferable option?
- What are the priorities of the operating system? Minimizing short-term costs; minimizing long-term costs; reducing capital investment? Maximizing quality and productivity; maximizing capacity utilization and yield; etc.?
- What type of process is desirable during the early stage of commercialization: lean production; batch operations; mass production; mass customization; etc.?
- What are the essential requirements to support the product or service launch?

While there are many such questions, it is imperative for management, the NPD team, and the operating-system professionals to think about the essential requirements and to stipulate guidelines for the organization to follow. Such guidelines are typically based on the strategic direction of the organization, which is usually well known by the essential participants. The guidelines save time by establishing the criteria for the operating system for the new product. There is little point exploring options that are not feasible because of management dictates or the lack of capabilities and resources. However, in some cases thinking outside of the norm for the organization may lead to innovative solutions.

The process strategies articulate the philosophical views as well as the strategic priorities that set the stage for decision making. The process strategies outline the main operational perspectives. They are a means of determining and defining how resources are to be deployed. They concentrate on the core capabilities and the critical processes and bridge the gap between what has to be done and how the activities are actually implemented. They focus on the competitive advantages that are being sought.

Resource requirements are a critical element of the development plan. Outstanding NPD programs can fail unless the organization has the willingness and competence to commit and deploy its resources. Resources should be concentrated on the critical areas and decisively committed for the NPD program to achieve the primary objectives.

Operational (process) design

As discussed in Chapter 9, the process methods used during the commercialization of a new product depend on the actual situation and the availability of resources. In the strategic-operations plan, the most important decisions involve the determination of the initial process type and the operating mode. A key concern is balancing the short-term benefits of using low-output methods during the initial launch with the higher-output approaches – and their theoretically lower cost structure – as the new product gains acceptance. In simple terms, the question concerns building and utilizing capacity versus outsourcing all or some of the requirements. If capacity can be built one unit at a time, then the solutions are straightforward: build as market demand increases. If capacity has to be added in specific increments and there are economic advantages to building larger capacities, the question is how aggressive does the organization want to be in anticipating market growth. The implications have a profound effect on the entire system. The following are some of the most important considerations:

- Unit costs are a function of fixed costs and variable costs; larger systems have the potential to lower fixed cost per unit if the capacity is fully utilized; the negative implication is unabsorbed fixed costs, especially during the early stage of commercialization, contributing to larger negative cash flow requiring additional time to breakeven and a greater investment.
- Purchasing larger systems during the early stages adds to the total investment of the program, requiring greater cash flow to achieve the required rate of return; therefore, the overall program risk is higher.

- Investing in a larger-capacity system early on reduces future flexibility for adapting to an alternative type, especially if the prevailing conditions change dramatically.
- A large system may force management to build inventory to keep the operating system busy; such decisions tend to increase the operating cost of the system making it less lean.
- Larger systems are generally more complicated, reducing agility and flexibility.

Outsourcing may be a strategic option, but there are always additional factors to consider up. If suppliers build the entire product, the information pertaining to its design and construction may become broadly known, inviting competition. Even when the information is protected, especially if there is a patent, there are still significant issues. It is imperative that suppliers have the capabilities to meet quality, cost control, and the other critical goals. Large global companies often have more leverage on key suppliers; therefore, they are more likely to have the ability to exert pressure on outside organizations. Outsourcing some or all of the production or process requirements does not eliminate the necessity for an operating system. Indeed, the system requirements may be more complicated because of the number of transactions necessary to complete the production of the product. The approach should be analytical, not prescriptive.

The operating system includes the choices about the process type, the decision to "make versus buy," equipment selection, and the uses of process tools and their implications on costs and yields. "Make-versus-buy" decisions are difficult, involving economic, strategic, and operational considerations. Simple economic models pertaining to breakeven, as discussed in Chapter 9, suggest that internal production is not financially viable until the volume requirements exceed a breakeven point; after this point it is less expensive to make rather than buy. Although this is a useful first view of the issue, other parameters may also have important impacts. For example, the organization may want to minimize its investment into internal processes and capital equipment. It may wish to maintain a high degree of agility or flexibility or conserve its capital for more-strategic investments.

A product cost-structure model is discussed in Chapter 10. Production costs play a significant role in determining the cost structure. As described above, many cost elements can be shifted depending on the selected process methods. Higher capital intensity translates into higher volume capability and the potential for lower unit costs. However, this is only achieved if capacity utilization is significantly high and the impact of unused capacity is minimal. Conversely, lower capital intensity means more-labor-intensive processes and higher unit costs at a given volume point. These choices have significant impacts on the cost structure and they will be discussed at the end of the chapter.

Yield is a specific concern during the start-up stages. Yield measures the usage factor of the materials or components used to produce the product or the expected number of acceptable finished products from the process. In both cases, costs are higher due to inefficiencies or poor process quality.

To analyze yield, the theoretical condition is a good starting point. What is the best outcome possible? For example, if the process is cutting circular shapes out of a steel plate, in the best case the process will not convert the entire plate into useable pieces. The theoretical best depends on the size of the plate and the size of the shapes, but it can be approximated by determining the optimal way to cut the circular shapes out of the rectangular steel plate. Optimization calculations involve many parameters including the cost of the plate for the various sizes and the cost of the technological sophistication of the equipment. For instance, a simple analysis may suggest that the theoretical yield of the steel plate is approximately 80%. Since it is difficult to exceed that number without changing the underlying processes and operations, the yield of 80% is the target for the new-product situation. If the yield for a new product using a similar process is only 40%, the process achieves only 50% of the potential yield, and the result is a cost element that is 100% higher than the mature (theoretical) process.

The case for product yield is simple to calculate, as discussed in Chapter 10.

$$\begin{aligned}\text{Yield} = {} & (\text{Units produced} \times \%\ \text{acceptable}) \\ & + [\text{Units produced} \times (1 - \%\ \text{Acceptable}) \times \%\ \text{reworked}]\end{aligned}$$

$$\begin{aligned}\text{Product production cost} = {} & [(\text{Units produced} \times \text{Manufacturing costs per unit}) \\ & + (\text{Unit rework costs} \times \text{number of units Reworked})] \\ & \div \text{Yield}\end{aligned}$$

Yield provides a good indication of the cost-effectiveness of the process. It is also an important measure of the potential to lower cost to the theoretical minimum.

Example

1000 units are produced each week; 60% are acceptable; 50% of the defective units can be fixed using rework. Production costs are \$10 per unit. Rework costs are \$4 per unit. Calculate yield and manufacturing costs per unit? What are the implications?

$$\begin{aligned}\text{Yield} &= (1000 \times 0.60) + [1000 \times (1 - 0.60) \times 0.50] \\ &= 600 + 200 = 800\end{aligned}$$

$$\begin{aligned}\text{Product costs per unit} &= [(1000 \times \$10) + (200 \times \$4)] \div 800 \\ &= (\$10{,}000 + \$800) \div 800 = \$13.50\end{aligned}$$

Implications. Unit costs are 35% higher than the theoretical case (at \$10 per unit) if yield was 100%. Output is 20% less than theoretical. The weakness in the process provides a competitor with the opportunity to achieve a superior cost structure.

Operations-program assessment

The best test of an effective process design is how well it satisfies customer specifications and responds to changes in market and business conditions. The assessment of customer satisfaction from a process perspective is relatively simple for a service, especially if the service has direct contact with customers. It is much more difficult to perform for a product. The assessment for a product situation focuses on the capability of the process to respond to customer demand. Does the system have to distort the process elements by building huge quantities of inventory to meet customer expectations or variations in demand structure? Such distortions mean that some of the objectives are taking precedence over others. Large inventory levels make it easier to meet current demand but lean production, flexibility, and possibly low-cost objectives are sacrificed to ensure that the distribution channels have uninterrupted flow of product.

High-volume systems with significant automation may ensure that the product can be built in sufficient quantities to meet demand, but an automated system may not react in a cost-effective way to quality problems that occur during the early stages of commercialization. Conversely, a labor-intensive process with a high level of flexibility may be incapable of keeping up with demand, providing an opportunity for competitors to capture market share. The former case has the potential for lower unit costs, but it has a higher probability of a longer breakeven point and the potential for higher initial cash-flow deficits. The latter case would probably have higher unit costs, but its processes would have a higher probability of being in synchrony with demand during the early stages.

Stakeholder assessment examines the external forces on the production system to ensure that the needs and wants of stakeholders have been considered. Impacts on employees and their families are a primary concern. Occupational safety, and health laws and regulations, are fundamental considerations, in assessing the viability of the operating system for the newproduct. These considerations are particularly important when processes have new or significant changes that are untested in actual operations. Such situations must be validated using the various methods described in previous chapters. If there are significant risks associated with a process, the concepts and techniques used in the FMEA might assure management that the processes are appropriate or highlight the areas that require improvement.

Environmental laws and regulations and other such standards are often perceived as barriers to new-product introduction. Environmental organizations, other special-interest groups, and the public generally advocate cleaner and safer products that avoid wasteful consumption of natural resources or contamination of the environment. The needs of such stakeholders have to be identified and assessed to determine how to address their requirements within the product or the processes.

The enterprise-management model includes processes that use the resources of strategic partners, suppliers, and other external entities to achieve success and to meet new-product objectives. The organization competes based on the enterprise not just its internal capabilities. The assessment of the operational processes includes the capacity and capabilities of the supply networks to meet all of the requirements placed on them. Rapid response to change is an essential part of the equation. Suppliers must be deemed adequate to meet the existing needs, as well as unexpected variations to the demand or changes in the specifications of the product.

The infrastructure provides powerful support structures for the operating system. The flow of goods and services depends on the transportation infrastructure. The flow of information is usually the life-blood of any enterprise that uses the telecommunications system and the Internet. These resources allow for fast, efficient, and effective delivery of the product or service to customers. The infrastructure is often taken for granted with the assumption that sources and capabilities of the infrastructure will be there regardless of the prevailing conditions. That assumption is usually true, but special requirements for a new product may occasionally be unavailable due to a change. The assessment of the infrastructure should determine the organization's vulnerability if the capability was unavailable or changed significantly; the concern is often the latter. For example, companies have assumed that the Internet offers an opportunity to sell their products with minimal expense.

Related industries play a significant role in the success of a product. The availability of supporting products and services may be the difference between success and failure. Complementary products and services are usually accessible for existing products, such as software to support hardware. For new-to-the-world products, the support structure may be unavailable or insufficient to allow customers the full benefits of the new product. For example, digital-camera owners need high-resolution printers to enjoy the full potential of their pictures.

Competition is a primary consideration. As discussed in previous chapters, the competition's capacity and their cost structure have direct impacts on the organization's operating system. They may try to capture and dominate the means of production, such as contracting for a large percentage of the critical raw materials or establishing exclusive relationships with essential service providers.

Operations (process)-program selection

Process selection is often dependent on the existing operating system and capacity of the organization. Leveraging existing assets is typically a primary driver in decision making and often means that the choices are limited by the current operating system. Constantly changing and evolving customer requirements and market opportunities mean that there is no universal formula for selecting the right operating system for a new-product situation. The selection should be based on lean business-management principles and the requirements for flexibility and agility.

Lean business practices ensure that resources are deployed consistent with requirements and that the organization does not commit assets that are unnecessary at a given point in time. Committing to high levels of finished-goods inventory negatively affects the organization's flexibility and often negatively influences cash flow.

The decisions on process selection should be expanded into action plans that provide the details of the implementation process. Action plans include the definitive initiatives and approaches concerning how to build the product or how to provide the service.

Operations-program evaluation

The final step is to evaluate the entire program to determine its feasibility. What is the total capital cost or investment required for executing the program? Is the amount within an acceptable range? If the amount exceeds what is available or reasonable, the program may not be feasible or worth doing. If the required investment is below expectations or the norm, further analysis may be necessary to determine the reasons. A smaller than expected investment may suggest that a critical element was missed or that the approach could be easily duplicated by competitors. The evaluation focuses on the ability to be successful and the probability of achieving a sustainable competitive advantage. The evaluation should include a review of the risks associated with the processes and the likelihood that a significant problem will arise. The evaluation should also include product and process safety measures.

Financial-program development

The financial program requires design and development similar to the technical, marketing, and operational areas. The financial program follows the direction set by strategic management and the financial controllers of the organization. The financial program must be in alignment with the strategic direction of the organization and the analysis of the situation completed during the previous phases.

For most organizations, the fundamental drivers and the requirements are well established. As previously discussed, the cost of capital is a determinant for the goals, metrics, and specifications of the financial program. The basis for evaluating most NPD programs is often the cost of capital plus an incremental adjustment for risk and other considerations. The adjusted cost of capital (usually for risk) serves as the required rate of return or the discounting factor for not present value calculations.

There are standard financial models used to assess and evaluate the projected financial implications of the NPD program. Regardless of the tools, techniques, and methods used during design and development, creative thinking is an essential factor when determining the financial considerations.

Figure 11.9 indicates the key elements of financial-program development. The framework suggested in this chapter provides a discipline for building financial models that are not only comprehensive, but also force practitioners to contemplate the choices they make. The results are less prescriptive and more in line with the actual requirements of the NPD program.

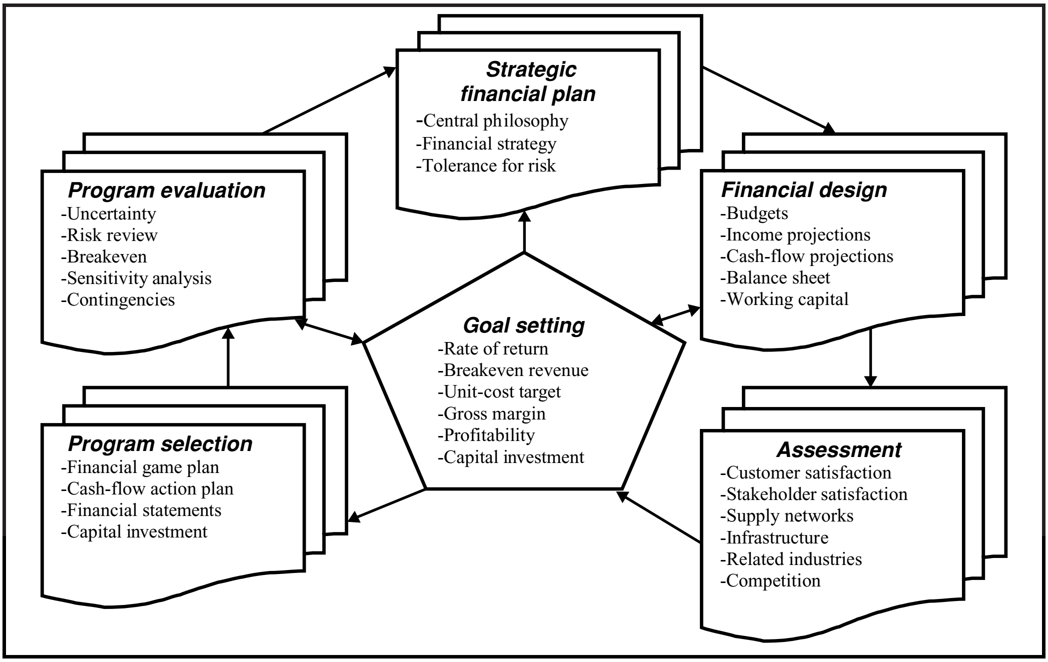


Figure 11.9 Financial-program development

The financial-program development starts with revisiting the financial goals. Based on the technical, marketing, and operations developments, the goals may have to be refined due to the changes made during those activities. The new or revised goals provide the input to complete the financial plan, which serves as the basis for the financial design. The financial design provides the architecture for the ultimate game plan and its implementation. The assessment of the design is a reality check to ensure that the decisions made are valid, considering the constraints of the real world. The assessment provides credibility and confidence in the program, so that management and the NPD team can select action plans for execution. Finally, the overall financial program is evaluated in the light of the entire NPD process.

Goal setting

Goal setting for the financial-program development is a reaffirmation of the financial goals established earlier in the NPD program. The financial-management system or senior management often prescribes the financial goals. A prescribed internal rate of return (IRR) on the total investment is usually the primary goal, because it is directly related to the organization's cost of capital and can be used for a comparative analysis with other programs. The IRR is the discount factor that makes the projected cash flow and the initial cash investment equal zero. The IRR is a very powerful goal, because the target value (the expected value for the goal) can easily be compared with expected value of other projects.

NPV is a related metric that can also serve as a goal. It is the net cash flows of the program, discounted for the time value of money using the required rate of return. It is an alternative to IRR providing a sense of the expected financial benefit of the program in terms of cash flow or money. If the NPV is zero or positive, the NPD program is equal to or greater than a breakeven in terms of cost of capital. With NPV, it is difficult to determine a comparison with other programs. Incorporating the investment index in conjunction with NPV can ameliorate this weakness. The investment index examines the NPV in terms of the total investment. NPV is divided by the total investment to obtain an index. A typical goal is to have an investment index of one or greater.

Other goals include a unit-cost target, gross-margin percentage, and return on sales percentage. A projected unit-cost position close to the target suggests that the competitive situation is favorable. If the target is near the theoretical low for comparable products, then the unit-cost goal provides a sense of what the competitive picture is or might be. A low unit cost with respect to the target gives the organization confidence that its pricing strategy is well positioned versus competitors.

Gross-margin percentage is used to decide the level of margin for supporting the desired level of operating expenses (in particular, the marketing expenses to launch the new product). A high gross margin provides the leverage to allow an aggressive campaign to launch the new product. Return on sales is a simple metric that is used to analyze the product's potential to generate profits in comparison with similar products.

Deciding on a goal for the specific value of total investment is often complicated. The "total-investment" goal is most appropriate for organizations with constrained financial resources. However, it is a metric that can be tracked over the phases of the NPD program. It helps determine whether the program is on track.

Strategic financial plan

The starting point is to revisit the guiding philosophy for the financial aspects of the NPD program. The guiding philosophies and principles help the NPD team to reach an understanding of the financial implications when rendering program decisions. For example, the organization's ability to make certain financial investments is specified and the range of potential financial outcomes is mapped out. The strategic financial implications are reviewed and affirmed, or modified based on the development of the overall NPD program. While the development and analysis of the overall financial plan is part of every phase, the strategic financial plan examines the total picture and ensures that the game plan is internally consistent and that the organization has the necessary resources.

The financial strategy is the big picture in terms of money. It specifies the relative importance of the financial goals. It provides the direction necessary for team members to make appropriate decisions related to the program. The overall financial strategy identifies the sources and applications of the funds. Generally, customers provide the cash flow to sustain the new-product program after launch. The critical questions are how much money is required before customers become the main source of cash flow and when does that breakeven point occur? The organization has to provide funding from internal sources during the pre-launch phases and the early post-launch period. The principal sources of funding for most organizations are the cash flow from internal operations and existing lines of business. The existing product lines generate cash flow that is used for developing improvements, derivatives, replacements, extensions, or entirely new products. A portion of the cash flow provides the seed capital to fund the front-end, design and development, validation, and the pre-commercialization and early commercialization activities and efforts. The sooner the NPD program gets customers to purchase the new product, and thus be a source of cash flow, the better off the organization is in terms of protecting its financial resources.

The tolerance for risk is a particularly critical part of the strategy statement. Risk always has an impact on the financial side of the equation. The financial risk is often stated in terms of the total investment. The risk is often viewed as the loss of the money, and the time and effort, devoted to the NPD program. However, there are other risks that have an impact on the financial equation. Technical risk usually translates into financial risks.

Financial-program design

The financial-management program is designed just like the technical design and the marketing program. The financial design balances any conflicting goals in the system, especially if they involve financial resources. The financial design is developed concurrent with the other major areas. It is a refinement of the financial model developed during the Program Definition Phase. An important step is to ensure that the financial model is strategically aligned with the vision, mission, and strategies of the entire organization. This step is imperative because the linkage with the strategic interest of the organization provides the logic for investing in the NPD program and forms the strategic foundation for all decision making. It provides assurance that the NPD program is in concert with the strategic direction.

The next step is summarizing the budgets developed for each of the essential areas. The overall budget provides input into the income-statement projections and the cash-flow projections. Budget details should be broken down monthly for the first year, quarterly for the second year, and then annually thereafter. Table 11.2 lists some of the budget elements that should be included in the overall program budget.

Table 11.2 *Categories of budget elements*

Major categories	Technical	Marketing	Sales	Operations	Financial
Ongoing (Pre-launch and post-launch)	Refinement Problem solving Consulting	Internet Promotions Advertising Point of sales Trade shows	Travel Entertainment Commissions	Facility expense Supplies packaging Equipment Inventory	Bad debts Depreciation Insurance Legal Taxes
NPD program	R&D Design	Testing market	Training Simulations	Test runs Promotion items	Financial investment
Pre-launch only	Prototyping Engineering	Design Copy	Training	Capital Equipment	Inventory

The standard practice is to summarize the budgeted expenditures by categories and present an overall budget picture. The budget defines the necessary financial commitment to the NPD program. The budget is translated into the pro-forma financial statements that are analyzed and approved before final implementation.

The fourth step is the design and development of the pro-forma financial statements. The financial statements are constructed according to the standard financial-management practices, discussed in Chapter 10.

Assessment of financial implications

The assessment requires an external perspective of the financial implications. The requirements for investments into the new product extend beyond the originator of the new product. The entire enterprise must support the NPD program. Customers must have the financial wherewithal to purchase the product. For simple products, it is a matter of having the disposable income or cash flow to fund the purchase. For example, buying a cellular telephone means that the purchaser incurs a monthly fee of $20 or more for a specified period. The purchase involves immediate payment plus long-term commitment.

Capital equipment is often so expensive that it has to be financed over an extended time period. For example, the airlines usually do not have the cash to pay for aircraft. They may require lease instruments, rental arrangements, or agreements with financial institutions to acquire the products. Such approaches are most important for products with high price tags, like automobiles, homes, machinery, etc. These arrangements may have to be initiated by the selling organization. Indeed, General Motors Acceptance Corporation, when launched in 1923, allowed GM customers to buy an automobile much sooner than if they had to secure their own financial arrangements.

Stakeholders have been included in every facet of the discussions throughout the book. While stakeholders are not normally viewed as significant participants when discussing financial aspects, there are many concerns relating to stakeholders. The most important consideration is the possibility of adverse financial impacts on the broader communities. A new product may cause a significant change to the economy or the social fabric of a country or region. For example, wireless telephones have dramatically changed the telecommunications industry. A new product may increase the social costs associated with pollution and waste streams. It may increase degradation of the natural environment and depletion of resources. A new product may contribute to social ills or problems, resulting in increased taxes. A new cigarette, alcoholic beverage, or gaming facility may deepen social and political problems that have external costs. The assessment of such elements requires a thorough analysis of the organization's social responsibilities to its stakeholders.

Suppliers, like customers, must have the financial means to meet the requirements of their portion of the NPD program. They may have to acquire production equipment, facilities, process mechanisms, and/or build inventory. Suppliers not only provide goods and service, but they may have to design and develop materials, parts, or components that become the supplier's NPD program.

Like suppliers, related industries may have to develop related products to support the needs of the NPD program and potential customers.

The infrastructure may require substantial improvements to accommodate a new product. The automobile companies generally do not think about road construction and repair when they consider a new design – such as when Ford created the Lincoln Navigator which is bigger and heavier than a normal vehicle. It might be more difficult to sell such a product in Europe where the streets and roads are narrower. Companies may assume that governments will solve the problems for the industry and its customers. However, such assumptions occasionally prove to be incorrect.

The infrastructure may have defects in it that are not obvious until the new product is launched, or if there is a significant event that changes everything. The terrorism acts of September 11, 2001 vividly pointed out the weaknesses in security in most areas of the economy. Problems preceded the events of that day, but the seriousness of the defects was not apparent to the managers involved. Another example that is more hypothetical is the potential impacts on the electric-utility industry, and the distribution of power, if electric automobiles were mandated across an entire country like the United States, and if the conversion had to happen within a few years. The generation and distribution capabilities would be stretched. The electric-power infrastructure would be hard pressed to keep up with demand and would require investment of billions of dollars.

Assessing the financial implications of the external dimensions is difficult, given the complexity of the outside forces and the large number of possible scenarios. It is impossible to create a general model to guide practitioners through the process but most entities know the critical factors facing their businesses and NPD programs. They must narrow the field of potential issues, problems, and concerns about financial aspects to a relatively small number of high-priority factors. Table 11.3 identifies a few key questions in each of the categories to highlight the overall approach that might be used to assess the financial implications of selected concerns.

Fuel cells and distributed generation: a bright future for natural gas?

Widespread use of electric vehicles that require daily recharging via household current would increase demand on the electrical-energy infrastructure. However, emerging fuel-cell technology may actually *decrease* demand on the traditional electrical-energy grid, while *increasing* demand for hydrogen-rich fuels such as natural gas. Residential use of fuel cells to generate electricity is part of a distributed generation (DG) strategy that is being pioneered by such companies as GE MicroGen and UTC Fuel Cells. Fuel cells generate electricity through the chemical reaction between hydrogen (or a hydrogen-rich fuel such as natural gas, methanol, or propane) and air. When using pure hydrogen, the preferred feedstock, water and heat are the only two by-products. Natural gas is widely recognized as the practical choice for residential fuel cells because it is a stable, hydrogen-rich fuel with an existing delivery infrastructure. Propane could be used in rural or remote applications.

With significant residential use of fuel cells to generate electricity, the demand for natural gas would be more uniform. Currently, natural-gas suppliers experience a winter demand peak, followed by a drop off to near zero in the summer. A more-uniform demand pattern would allow natural-gas providers to better forecast their loading on an annual, rather than seasonal, basis.

It is difficult to imagine a wide-scale residential adoption of fuel cells until the technology advances to a safe, hassle-free state; as reliable as the current grid, but with a lower cost. Even then, most energy experts feel that the traditional grid system is not going away, but instead feel that DG is a complementary technology which would provide yet another choice for customers. Others feel that DG poses a threat to electric utilities, in the way that PCs initially threatened mainframes. However, it is generally believed that since electric-utility companies have proven themselves to be resourceful, they will find ways of participating, if and when the technology takes off.

Second- or third-generation fuel-cell models offer the promise of integrated systems that would capture and use heat output from the fuel cell year round. The hot exhaust would heat the house as well as the hot water. Furthermore, the excess heat could be used to power an air-conditioning system based on absorption chilling.

The first alkaline-technology fuel-cells used in the space program cost $600,000 per kilowatt. The goal for proton exchange membrane (PEM) fuel cells, preferred for residential and transportation applications, is $50 per kilowatt by 2010.

Source

Johnson, R. R., Fuel cells: white knight for natural gas? *Public Utilities Fortnightly*, March 15 (2000), 22–34.

Table 11.3 *Assessment of the financial implications of the critical dimensions*

Dimension	Financial implications	Assessment
Customers	Purchasing power or discretionary funds. Ability to secure financing.	Do customers have the money to buy the product? Are special purchasing arrangements necessary? Monthly payments? Impacts on cash flow? Revenues?
Stakeholders	Adverse financial impacts. Impacts on the economy. Positive financial implications.	Are there negative financial or social impacts on others? Will others benefit financially from the new product? Will economic stability be affected? Interest rates? What is the availability of money?
Suppliers **Related industries**	Sources of capital to meet the needs of the new product.	Do they have the money to invest in production capacity? Inventories? Accounts receivables? Will their financial wherewithal keep pace with expectations?
Infrastructure	Adverse financial impacts. Positive financial implications.	Are improvements or additions to the infrastructure required and what is the cost? Who will pay? Is it economically feasible to improve the infrastructure?

Financial-program selection

The program selection process is a reaffirmation of the financial-program design based on the assessment step and the concurrent developments, and decisions made in the other principal areas – especially technical design, the creation of the marketing program, and the selection of the means of production and related processes. The selection step is a formality in most cases; however, there are certain situations where it can be a profound step, requiring intricate decision making. The development of a new-to-the-world product necessitates a careful review of all of the financial implications to ensure that there are adequate resources to complete an NPD program, taking into account the high degree of uncertainty involved. NPD programs for new-to-the world products have the potential for unexpected difficulties, resulting in significant overruns. For example, Boeing's decision to build the 777 required a complex series of decisions to ensure that every facet of the program could be completed within the investment envelope. The selection process and program evaluation are often handled on a concurrent basis. In reality, selection and evaluation are directly linked and might be viewed as the same activity. It can be argued that evaluation should precede selection. However, in most cases there are too many design options to evaluate all of them; therefore, a reduction in the number of options is normally the precursor activity.

The important final step is closing the loop, ensuring that the entire game plan for design and development is internally consistent and that there are adequate resources to cover the full development. The main question concerns the goals for the NPD program and the adequacy of the game plan.

From a financial perspective, the cash-flow projection provides the best indication of whether the program can meet expectations. It stipulates the total investment as well as the expected contributions from the NPD program. The total investment includes the required capital to fund all of the elements of the program, based on the budgeted activities, and the expected negative cash flow immediately after launch until breakeven is achieved. The acceptance of the financial program by management and the team is a signal of their confidence.

Financial-program evaluation

Program evaluation is a general review of the financial aspects of the NPD program. It can be done as the overall review at the completion of the Design and Development Phase as a precursor to the management review or during the management review itself. This depends on the degree of formality required due to the nature of the new product. As stated several times, simple incremental innovations generally indicate an informal process, focusing on speed and time to market. On the other hand, a new-to-the-world type of product has a high level of risk, making more formality necessary.

Program evaluation examines the expected results in the light of goals, uncertainty, risks, and financial analysis. Sensitivity analysis as described in Chapter 10 shows the vulnerabilities due to changing conditions or the inability to achieve the desired result. The primary factors are the forces of change on price, volume, unit cost, operating expenses, and investment. The impact of each can be evaluated and its sensitivity can be determined. From the financial evaluation, a clear picture of vulnerabilities emerges, showing which factors are most crucial to manage and guide during the design and development process, and the rest of the NPD program.

Summary and concluding comments

The Design and Development Phase is the pivotal point in the NPD process. It represents the transition from planning, analysis, and conceptual processes, which are more investigative, to more-grounded processes that are based on real-world considerations. Design and development transform the conceptual into the practical. The discussions and analysis tend to evolve toward a final solution as main considerations are revisited and reaffirmed.

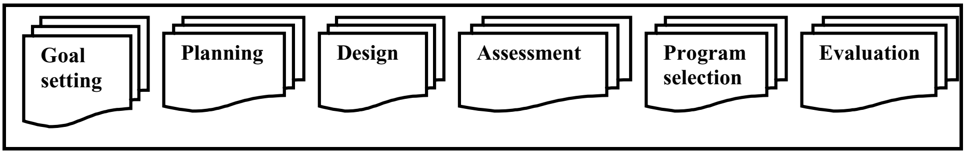


Figure 11.10 Concurrent design and development process elements

The emphasis throughout the chapter has been on innovation through integration. The basic model used through the chapter centered on the convergence of **integration** and **innovation**. An effective business model is a comprehensive framework that forms the basis for analysis, understanding, decision making, and continuous improvement. It is a unifying approach that integrates the people, the processes, the practices and the programs into a comprehensive management system. It ensures that the technical design, marketing, production, and financial decisions are in harmony with each other.

The basic model used for describing the methodology links each of the main facets (technical design, marketing, production, and finance) of the design and development process on a concurrent basis using an identical construct. This approach allows systematic development of the new product using collaboration and coordination between all participants. Figure 11.10 depicts the process elements as discussed throughout the chapter.

While integration of the participants is enhanced through the use of a common methodology, the real power in the process is management's commitment and the concurrent development of the elements. Innovation through integration only works if management is a real-time participant and is committed to the program. Management must have direct knowledge of the NPD program and understand the implications of the decisions as they are being made. This involvement of senior management allows the NPD program to move seamlessly from the conceptual level through design and development without interruption. Linking program management and executive leadership allows a systematic implementation of the program elements.

Successful organizations build enterprise-wide processes based on strategic goals that result in the design, assessment, and selection of proper ingredients for creating a powerful new product. New-product development is about creating new solutions (improvements) that are more effective and elegant than existing ones. It requires understanding metrics like exceeding customer and stakeholder satisfaction, and ensuring that results are linked to the objectives of the organization and the goals of the program.

This model uses the entire NPD program as a mainstream methodology for creating value for everyone. It encourages integration and innovation through effective leadership! Leadership involves creating innovative change, managing the resources of the entire enterprise, and focusing on competitive advantage and value generation. Leadership means linking people, data, information, technologies, and decision making. It provides a more-exciting, fast-paced reality, offering enormous opportunities for creative organizations that want to change the world.

Notes

1. Speed to the market is important, but the implicit aspect of that objective is the development of a high-quality and safe product. There is little point getting to the market first, if the product has inherent defects. Such defects may result in lost revenues, additional costs, and significant liabilities. There are also ethical issues as well; it is inherently unreasonable to bring a new product to the market without an appropriate level of product testing to ensure that customers are not taking unknown risks.
2. K. L. Keller, The brand report card. *Harvard Business Review*, **78**:1, January–February (2000), 147–157.

12 Validation (Phase 5)

Introduction

Validation is an integral part of the new-product development (NPD) process. It is embedded within the NPD process and serves as a mechanism to verify that the decisions are appropriate and in line with objectives and expectations. The reviews at the end of each phase and the Validation Phase itself are the main methods for improving the probability that positive outcomes will be achieved.

During the Validation Phase, decisions made during design and development are evaluated and tested to ensure that the new product meets customer and stakeholder expectations. The validation process includes examining the most significant elements of the NPD program, proving that the product meets specifications, and reducing defects and burdens.

The reduction of uncertainties during the Validation Phase provides management and practitioners with the confidence that critical success factors have been duly considered and that barriers to implementation have been mitigated. The Validation Phase focuses on major risk-reduction methods that require time, effort, and money to complete. Such methods are usually necessary for obtaining management's commitment to fund the Pre-commercialization Phase and Launch. The Validation Phase provides evidence that the potential of the new product is worth the investment and that there are no undue concerns about spending the money to launch the product. This is particularly appropriate where most of the investment is incurred just before commercialization, or if there are significant strategic, market, technical, or financial risks and uncertainties. For example, non-durable consumer products require a significant expenditure in advertising during the Pre-commercialization Phase. In such cases, marketing expenses may represent 80 to 90% of the total investment. Given such situations, a final validation of the product and the marketing program is often well worth the time and money.

Essential questions include: To what extent is the Validation Phase needed and what are the appropriate elements? Since there is considerable variability from program to program in validating the design decisions, every NPD program should consider the requirements for qualifying the attributes of the new product and the outcomes of the NPD program. The scope of the Validation Phase can be significantly decreased if the previous phases of the NPD process included many of the testing and validation methods that might be executed during validation. The main premise of integrated product development (IPD) is to validate the product and decisions on an ongoing basis. Nevertheless, some testing methods are so expensive that it is prudent to wait until the product design has been finalized. This is clearly the case if certification testing is mandated by government agencies and such testing is a major part of the overall NPD process, and if it is extremely expensive. Moreover, given that there is a potential for hidden defects and it is the responsibility of management to ensure that products are safe, *the "precautionary principle" suggests that the Validation Phase is a necessity regardless of the amount of testing during the earlier phases of the NPD program.* It is better to be safe than sorry.

The Validation Phase includes the following topics and learning objectives:

- Testing a prototype of the new product using real-world conditions.
- Determining the potential effectiveness of the marketing program, including testing the advertising copy, pricing, distribution channel(s), and other elements.
- Discovering the potential health, safety, and environmental consequences of the product and the potential impacts of its production processes and their potential impacts.
- Examining the risks and potential liabilities facing customers and stakeholders.
- Exploring the business and financial implications of the risks and liabilities.
- Determining overall NPD-program risk.

The probability of being successful is dependent on validating the decisions made during the Design and Development Phase and ensuring that nothing has been overlooked. The time and money associated with testing have to be balanced with the benefits derived from the activities. The major benefit is that the additional knowledge gained during validation effects changes that reduce the potential for a significant difficulty.

The Validation Phase flow chart

Validation is open-ended; therefore, the generic flow chart does not follow that of the earlier phases. The flow chart for the Validation Phase simply focuses on testing the main considerations and concerns of the internal dimensions, especially the product and the market aspects. Figure 12.1 provides a perspective on how testing the internal and external dimensions fits into the Validation Phase. While the flow chart suggests a sequence, the testing of each external dimension is for the most part independent of each other.

The most important aspects of the Validation Phase are to ensure that the product and the entire system meet the requirements of the market and customers. It also includes ensuring that the product, marketing, production, and financial aspects are suitable and reliable. Validation is about mitigating risks and reducing uncertainty.

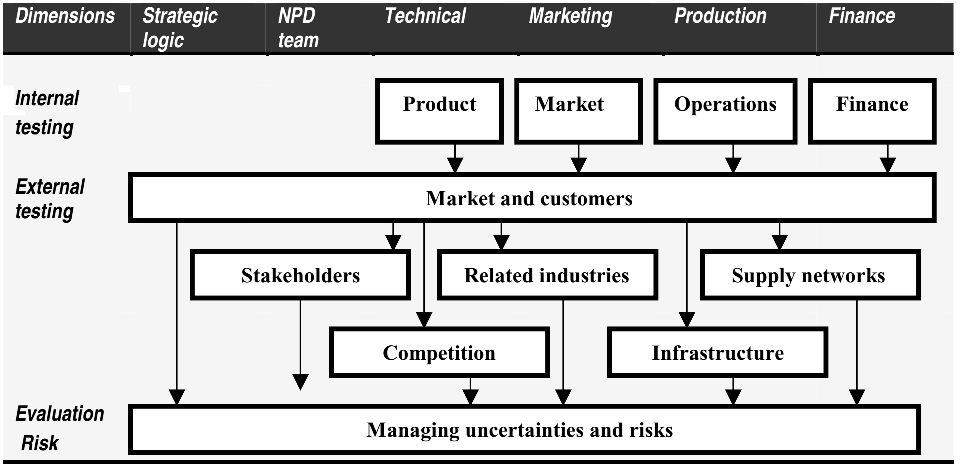


Figure 12.1 Validation Phase flow chart

Product testing

Product-use testing and its applications

Product-use testing determines the strengths and weaknesses of the product in its intended applications. It should be a real-world test of the product characteristics, and how they relate to customer needs. In some cases, product-use testing (alpha testing) occurs during the Design and Development Phase to minimize the time required to complete the testing and to sequence it before customer-use testing (beta testing).

Product-use testing takes many forms, from testing under simulated conditions to accelerating the testing process with intensive customer usage of the product under harsh conditions. The degree of intensity depends upon the uncertainties associated with the new product, and the potential for serious defects and negative consequences. For new products that are improvements on existing products with only minor changes, the amount of testing might be limited to focusing on the changes and the conditions they affect. On the other hand, if the product is a new-to-the-world type or represents a significant departure from conventional methods, materials or components, then serious consideration has to be given to testing all aspects of the product under very stringent conditions.

The testing decision is dependent on the risks and uncertainties involved and the need to balance the major objectives of the overall program. One premise is that testing has to validate that the NPD program can achieve all of its objectives including time to market, development cost (investment), product performance, unit cost, and risk reduction. It is not easy to achieve such difficult and often opposing objectives. In high-risk situations, prudence mandates a high degree of testing intensity. From a customer-safety perspective, mitigating risks often means that high levels of testing are necessary to assure that every reasonable precaution has been taken. Like many NPD questions and considerations, there are no simple answers. Each situation has to be analyzed and carefully thought through before arriving at an appropriate conclusion.

Product-use testing usually requires added time and effort, potentially delaying the new-product entry into the market. However, the lost time can be offset by the gain in confidence that the product has an enhanced probability of being successful, facilitating the launch process. The increased confidence may result in reducing the time to market or accelerating the market penetration rate because the organization can be more aggressive with its marketing campaign and production levels during early commercialization. For instance, the information gained during a month-long product-use test may allow the organization to shave a month off the product introduction cycle. It is difficult to predict the impact of testing, but the simple approach of reducing the amount of testing to save time may not always be the right answer. For example, Microsoft employs product-use testing to find potential defects in the software instructions and packaging. Such testing allows Microsoft to fine-tune the final package design and aggressively market the new product to the entire market.

Often the answer is situational. The following are several scenarios that shed some light on the decision-making process; they are based on two categories. Category 1 indicates that less testing may be appropriate and Category 2 suggests that more testing may be required:

- ***Category 1 (less testing)***
  (1) The competitor has already introduced an identical new product and it is performing extremely well in the market.
  (2) The new product is a derivative of a well-performing existing product that needs to be replaced due to competitive pressures.
  (3) Customers are very familiar with the product and there is little concern about its applications.
  (4) The life cycle for the new product is very short and any lost time in introducing the new product cannot be recovered. Lost time means lost sales and profits, increasing the financial risks.
- ***Category 2 (more testing)***
  (1) There is a significant risk to the reputation and image of the organization and the other products if a failure occurs.
  (2) The product incorporates new technology that may have hidden defects and uncertainties that could influence customer acceptance of the new product.
  (3) Correcting defects in the market place is extremely difficult and costly. Failures or problems could influence both the financial position and future product launches.
  (4) The life cycle of the new product is expected to be considerable and any defects may add to unit costs or reduce the potential market share, especially if the early mistakes seriously tarnish the new product's position in the market. This

is a significant concern if potential customers have many choices from a large number of competitors.

(5) Product-liability issues could have a significant impact on the organization and limited testing could be viewed as an irresponsible choice that has potential risks to customers or stakeholders.

These scenarios are but a few of the many that could influence the decision-making process. In general, if the life cyce of the product is very short, the general tendency is to reduce the amount of product testing to save time. If the life cycle is long and the competitive pressures are not severe, more testing may be the appropriate answer, especially if the risks are high. Nonetheless, if the risks and uncertainties are high, testing is the correct answer.

Types of product-use testing

Customer needs and wants and the related applications vary considerably from customer to customer. It is difficult to stipulate product-use tests that incorporate every conceivable way in which a new product could be used. Some customers may use the product for purposes beyond the intended ones. Many of such uses represent opportunities for extending the legitimate and safe application of the product. However, there are applications that are inappropriate and, in some cases, dangerous. Testing generally focuses on the expected cases, not the unintended. The first step in the testing process is to determine the purpose and objectives of the test. Key questions include: (1) Will the product work as intended? (2) What is its overall quality and expected level of performance? (3) Are there any defects? (4) What are its prospects for success? (5) Does anything have to be changed to improve the new product's probability of being successful?

The following are several of the standard types of product-use tests:

- ***Alpha tests*** – testing done by the producer typically in a laboratory setting to evaluate the characteristics of the product and analyze its quality, performance, and reliability. Such testing often accelerates the time to achieve a given number of cycles or use patterns. For example, a machine may open and close a door on an ongoing basis completing thousands of cycles in a matter of days, while in the real world it might take years to complete the same number of cycles.
- ***Beta tests*** – testing that often follows the producer's in-house testing to assess the perception and real-world applications of the product in the market place. It is an enhancement on the alpha test because it incorporates the customer's perceptions as well as his or her use of the product. For instance, a select number of customers may be given new software to use for a month or two. Because of the diversity of the users, some users may experience situations that are not contemplated by the manufacturer; and if there is a defect in the software code, the customer might find it before the general customer population experiences problems after launch.

Testing methods	Simple improvement	Repositioning	Derivative	New product line	New generation	New-to-the-world product
Alpha	✔				✔	✔
Beta		✔	✔	✔	✔	✔
Gamma				✔	✔	✔

Figure 12.2 Linking product-use testing methodology to new-product type

- ***Gamma tests*** – testing that is conducted for an extensive period of time and determines the product's suitability to meet requirements over time. Such testing is more comprehensive requiring more time and money and may be used for a new-to-the-world product that has a high risk factor. The Food and Drug Administration requires pharmaceutical companies to follow an elaborate protocol for testing new products to ensure safety and efficacy. In the context of testing, the clinical trials and other tests involve all three of the testing mechanisms, including extensive gamma testing.

The type of testing depends on the situation, the uncertainty, and the risk. If the NPD process is straightforward without any significant unresolved issues or questions, then a single method may provide the confidence to proceed without further product-use testing. Indeed, if the situation is not complicated, alpha testing may be sufficient. On the opposite extreme, product-use testing might include all three types to mitigate the risks and improve information about the product. Clearly, the pharmaceutical industry follows such a protocol in developing ethical drugs. While it is difficult to prescribe a general approach, Figure 12.2 provides guidance.

Regardless of the method used, the basic objective is to test the product in the most comprehensive way, requiring the least amount of time and effort. This may sound like an impossibility, but the practical aspects of new-product development demand the desired solution, not a trade-off between the objectives. It is irresponsible to gamble with health and safety, or the value derived by customers and stakeholders because the company chose to save money. Product-use testing does not guarantee that the new product is free from defects, but it does help fulfill the social responsibility to ensure that products meet acceptable standards, and that management has taken reasonable precautions to ensure the efficacy of the product.

Interactive multimedia in testing

Interactive multimedia product-use testing methods provide opportunities to conduct the desired level of testing, using a small fraction of the time and money normally required. According to John Stevenson, "An interactive multimedia research study involves the same components as traditional studies, including stimuli presentation, questionnaire design, and data collection. The primary difference is that the testing is programmed using multimedia software and hardware, therefore turning a paper questionnaire and concept into sight, sound, and computer simulation."[1]

The Internet provides exciting options for product-use testing, and also market testing. It offers the possibility of concurrently achieving multiple objectives. Speed and low costs are the biggest advantages, but there is a major concern on how to validate the information and data. The American Marketing Association, the Advertising Research Foundation, the European Society for Opinion and Marketing Research, and several other organizations are working on guidelines that address issues such as privacy, honesty, security, and validity.

Product testing in the sporting-goods industry: golf balls

Most major golf companies, including Spalding Sports, Titleist, and FootJoy, utilize a mechanical driving machine known as "Iron Byron," to test golf balls and golf clubs. Iron Byron was designed to simulate the swing of golfing legend Byron Nelson. The machine is driven by pneumatic pressure, and is flexible enough to accommodate different types of clubs, including irons, by making adjustments to the backswing, lie angle, swing speed, and grip.

Golf companies take new-product testing very seriously, and testing is therefore conducted under scientific conditions. Club-head speed is measured for each swing, as well as initial ball velocity off the tee. Ball spin rate and launch angle are also measured. Since Iron Byron is typically kept indoors for better environmental control and protection, the balls must exit the building through a small opening in a wall or door. Measurements are then taken by observers in the field, including carry (where the ball lands), total distance (where the ball stops rolling), and deviation from the centerline of the field. Environmental data collected usually include ambient temperature, wind speed, and wind direction. Golf manufacturers select test sites that are warm all year round, with minimal winds and rainfall.

Field tests are performed for a variety of reasons, including evaluation of new designs, competitive comparisons, and regulatory testing. The United States Golf Association (USGA), located in Far Hills, New Jersey has established limits for the total distance a golf ball can travel. Under specific test conditions, a conforming golf ball cannot travel more than a total distance of 280 yards (256 m), with a 6% test tolerance. The USGA also specifies turf conditions required for the test, but has developed turf- and wind-correction factors. These adjustment and correlation factors have always been the subject of much debate and controversy within the golf industry.

Manufacturers attempt to simulate the USGA test-site conditions. In order to monitor production processes as well as the accuracy of their test equipment, balls are periodically sent to the USGA for round-robin testing. Official submissions of product for conformance testing are done twice a year. The USGA then publishes a listing of all balls that have met their test requirements. Manufacturers are not required to seek USGA approval, and small golf-ball manufacturers often do not pursue approval for their products. In any official tournament, however, particularly those on the PGA tour, players are required to use balls from the USGA conforming-ball list.

Manufacturers whose product passes USGA testing are authorized to place the statement "Conforms to USGA specifications" on their packaging. Ball manufacturers themselves typically provide test samples, but the USGA reserves the right to purchase the product at a retail outlet, making it risky for manufacturers to submit specially prepared balls.

Because of some serious drawbacks, the USGA is attempting to replace distance testing using Iron Byron with more-controllable, less-controversial test methods such as the initial velocity (IV) test. The IV test consists of a heavy spinning flywheel with a retractable hammer that hits balls through two ballistic screens. Since the screens are spaced a precisely known distance apart, and the flywheel speed is tightly controlled, a very-accurate velocity measurement is possible.

Market testing

Overview

Market testing and other market-research methods have been employed over the years to determine the viability of the marketing programs for new-product situations. Rather than just testing the product, market testing examines the suitability of the product and the proposed marketing approaches in terms of the realities of the market place. The purpose is to ensure that the marketing plan is appropriate given the prevailing market conditions and trends. The information obtained is used to refine or modify the marketing campaign in the light of customer inputs and perceptions. If market testing is conducted early during the Design and Development Phase, the objectives typically include forecasting the demand for the product, determining what customers actually want, and discovering the best methods for meeting the requirements of the markets and customers. If market testing is conducted during the Validation Phase, the objectives include verifying the effectiveness of the overall program and refining the marketing program based on insights and lessons learned during the testing.

Similar to the discussions on product-use testing, the decision making associated with market testing has to consider time-to-market objectives, the costs of testing, the impacts of competitors, and the benefits of the information and knowledge gained in the process. The potential negative impact on time to market can be minimized if market testing is completed as soon as the design of the marketing program is available. The cost of testing is always a factor, but if market testing provides information and data that lead to substantial improvements in the marketing program, the payback is well worth it.

An important concern about market testing is the potential for competitors to receive advanced notice about the new product and the related marketing program. Such information might allow competitors to develop an identical new product or take countermeasures to reduce the success of the new product or the effectiveness of the marketing campaign. The information obtained from the market place must be sufficient to warrant the exposure to competitive response.

The expected benefits derived from market testing can be determined before testing. The avoidance of mistakes is difficult to quantify but can often result in significant improvements to every objective. Mistakes cost time and money. They also increase the number of activities and reduce the confidence people have about the NPD program. Indeed, the intangible aspect of an improved confidence level enjoyed by the practitioners may justify the expenditures for market testing.

To secure meaningful results, it is imperative that market testing focuses on the target market segment. If the testing is not conducted on the correct market segment, the data and information gleaned about the segment are worthless, or worse if they lead to faulty conclusions.

Why conduct market testing?

The primary reason for market testing is to obtain the market perspective on the product and the marketing program. It is the customer's perceptions that count, not how the producer views the market or the product. Market testing examines the underlying assumptions about the new product and the marketing program, and challenges the assumptions and related decisions using market information and data. It obtains the reactions of the market and customers directly, from those who are theoretically unbiased about the commercial value of the product.

Market testing may also provide information about the product that was not envisioned. Customers may discover new uses that are different from the intended applications. Market testing may reveal product attributes that are superior to the prescribed ones. These insights can enhance the ability to reach potential customers with a value proposition that is truly important to them.

Given the large number of variables involved in developing a marketing campaign, market testing provides comments on how the main parameters relate to each other; and a sense of the interrelationships between the variables. The advertising copy, the pricing scheme, the packaging, the distribution channels, etc., can be evaluated in a real-world setting and analyzed on the basis of their impacts on sales projections. The information may provide a more-realistic view of the potential. For instance, what effect does a higher price have on sales (volume)? With sufficient testing, there should be data to determine the appropriate levels of advertising, the most suitable advertising copy, or the best mix of advertising and promotion, as well as how it relates to the other marketing decisions. For example, Dell Computer was selling "bare-bones," low-price PCs to bolster sales during the 2003 holiday season. The selected model sold for approximately $499 and was designed to meet the needs of the low end of the market. Does the concept fit the Dell business model and will Dell generate new sales potential in the low-end segment? Market testing helps answer whether the concept fits.

Methods of market testing

Market testing methods are similar to the product-use test types, and basically serve similar purposes. The three types of market testing are pseudo-sale, controlled sale, and full sale or test marketing.[2] Each of the three variations provides specific advantages depending on the situation and the new-product type (consumer, industrial, and government).

- ***Pseudo-sale*** – testing to determine if potential customers would buy the new product if it were available. Potential customers have no risks because the product is not actually sold. The testing assesses the marketing messages to get the customer to buy the product and evaluates the perceptions of the customers about the attributes of the new product.
- ***Controlled sales*** – testing that includes the actual sale of the new product. The sales situation is controlled, but there is a sense of reality and more of the marketing campaign is tested. The distribution aspects of the product are limited and often difficult to measure because artificial mechanisms are used to control the selling situation.
- ***Full testing*** – testing that is conducted under normal conditions limited only by scope. The new product is actually launched in one or two geographic markets. The number of areas selected limits the market reach, but in each area the new product is tested on a fully integrated basis. All aspects of the product and the marketing program are tested.

The pseudo-sale method can be used early in the NPD process, because the actual product does not have to be available for sale. It is advantageous for obtaining a head start on validating the selected marketing approaches for new-product launch. There are several different techniques that can be used for a pseudo-sale. In most cases, the transaction with the potential customer is hypothetical. The product is described and the marketing program is presented to potential customers. There are various approaches used to determine the customers' response. Typically, a questionnaire helps to gauge the respondent's interest and attitude. The presentation of the new product includes the proposed advertising campaign, the promotional package, the pricing, and other marketing elements. The participant is observed and his or her responses are noted.

One variation uses a mathematical algorithm to simulate the market place in order to estimate trial purchases and the effects of subsequent repeat purchases. A statistical model is built to predict sales volume and buyer behavior.

The controlled-sale method is more sophisticated and costly than the pseudo-sale method. Although the situation may be contrived, there is an attempt to ensure that the process is as valid as possible. Often it is the setting that is contrived or the typical location for a transaction that is fabricated. For example, the transaction might take place at a trade show or in a specially designed facility. The customer (or participant) engages in the process as if the entire event was the standard sales situation. The participant's decision-making processes and behaviors are as authentic as possible; therefore, the process provides valid insights on the product and the marketing program.

The full-sale method is often called test marketing. The typical set-up is the utilization of a relatively small metropolitan area to introduce the product and determine its potential sales in the test market. Test marketing provides valuable insights about how an actual market responds to the product and the marketing program under actual conditions. The results are genuine and the situation has all of the "noise" or confusion found in real-world markets. The entire product delivery system has to support the new product including the production processes and the distribution channels. The situation is definitely not contrived and competitors may try to confound the results by taking aggressive actions via their product lines or marketing programs. For example, a competitor may significantly reduce the price of its products to draw customers away from the new product. Even a very-attractive new product may have a difficult time competing against a similar product at half the regular price.

Test marketing can require a considerable investment of time and money. There are many variations of test marketing. The most popular version is the planned roll-out method. The planned-roll-out method is based on the NPD philosophy that is central to the construct of the NPD process described in this book. In essence, the new-product launch is based on market segments that are discernible and achievable. The new product is individually introduced to each segment. The lessons learned during the introduction of the new product in one segment (geographical area or otherwise) are used to modify the overall program so that as additional segments are targeted, the implementation can be suitably enhanced. The roll-out may focus on market segments that are based on demographics, distribution channels, geographical schemes, or psychographic factors.

As with product-use testing, the type of testing depends on the situation, the uncertainties, and the risks. If the new product is a simple improvement or replacement of an existing product, the marketing program would potentially be the same as for the existing products. In such cases, the amount of market testing would be minimal. If the new product is the repositioning of an existing product into a new market, there may be a high level of uncertainty pertaining to the new market. Such a situation may require considerable testing before launch. A derivative of an existing product line or product platform might exhibit many characteristics that are similar to the previous products; therefore, the marketing issues are straightforward. In such cases, market testing may not be critical. At the opposite extreme, market testing might be extremely important for new product lines, and new-generation and new-to-the-world types of products. Sophisticated market testing might be necessary to ensure that marketing decisions are based on reality, not assumptions. If there is a high risk of failure, then additional testing may be prudent given the complexities involved with new products that represent significant changes to the prevailing situation. Although it is difficult to prescribe a general approach, Figure 12.3 provides some guidance.

Testing methods	Simple improvement	Repositioning	Derivative	New product line	New generation	New-to-the-world product
Pseudo	✔	✔	✔		✔	✔
Controlled		✔	✔	✔	✔	✔
Full				✔	✔	✔
Roll-out				✔	✔	✔

Figure 12.3 Linking market-testing methodology to new-product type

The criteria for selecting the best approach are not easily determined. Each NPD program has different risks, levels of uncertainty, and barriers to success. In some cases, competitive pressures are of paramount importance. In other cases, economic or social conditions and trends are the important determinants. However, there are several generalizations. In every situation, the market size or potential is a critical factor that requires real-world validation. The effectiveness of the product positioning is also an important factor. In addition, the appropriateness of the marketing program is an essential question that should be validated by market testing as well.

The market testing method depends on the situation. For simple changes to the product, the pseudo-sales techniques may be adequate to meet the testing requirements, saving time and money. Simple changes to a product that targets the same market may not necessitate sophisticated means of validating the marketing program. For example, Proctor & Gamble (P&G) has almost continuously introduced a “new Tide” that is directly related to the “old Tide.” P&G has a significant amount of information on its product and the market it serves. It is unlikely that the “new Tide” requires any testing given that normally only minor changes are made. P&G has a well-honed marketing strategy for Tide which needs only minor modifications.

For new or existing products targeted for new markets, the degree of marketing uncertainty is relatively high. Market testing techniques have to provide a higher degree of assurance that the selected marketing program fits the conditions and trends of the market. In such situations, controlled-sale techniques or a combination of controlled-sale and roll-out techniques may be necessary.

Replacement products require extensive market testing. For example, Microsoft conducted a two-year study of selected customers to measure the appeal and value proposition of “Windows 98.” In the high-stakes game of capturing or retaining its number-one market-share position, continuous market research and market testing were warranted. With the high-level objectives at stake, every technique was deployed.

New-generation and new-to-the-world products have many factors requiring extensive information gathering to develop effective marketing programs. Every technique may have to be used to reduce uncertainty.

In general, testing improves the prospects of making good choices and enhances the probability of success. Too much testing may delay commercialization; too little testing may also lead to disaster because of too many open-ended issues or incorrect assumptions.

Pilot and trial production

Introduction

It is difficult to generalize the specific methods for validating the production or operations areas during the Validation Phase. The initial step is to build a relatively small number of the new product as prototypes. The validation of the production process can be conducted using either job-shop or batch-type operational methods to obtain a sense of the flow requirements of the intended processes to determine their suitability in an actual situation.

Prototypes are not only built to test the design, but are also constructed to validate the manufacturing processes and procedures. The entire production system is often tested during the Validation Phase to ascertain its capability to perform all of the required functions. A missing link or flaw in one part of the system may create a flow problem restricting the capability and capacity of the whole process. The problem could lead to an inability to produce the product, or deliver the service, thereby reducing the output or yield of the system so that the marketing or financial objectives are impossible to achieve. The purpose of validating the production system is to ensure that everything is linked together and that the production plan and program are obtainable.

The fundamental goal of such testing is to determine that the operating system can meet and exceed expectations. The review covers an analysis of the quality aspects, demand management, capacity planning, layout issues, production planning, inventory management, scheduling, etc. The review focuses on:

(1) ***Discovering potential problems and concerns*** – What is not in accordance with the game plan?
(2) ***Deducing the causes of the problems*** – What are the elements that are not under control and why?
(3) ***Determining possible solutions*** – What are the theoretical or proven methods for getting at the root cause?
(4) ***Developing action plans for implementation*** – What tasks are required to get the proper results?

Lean manufacturing techniques facilitate the integration of the product delivery system by linking suppliers with the production processes. They encourage interaction and communication among suppliers in subsystem designs because each supplier knows that it is an essential part of the system and has primary responsibility for its part of the product. In addition, cost targets can be set and included in the overall design effort, and validated upon receipt of the initial supply and production of the first products. The initial manufacturing or operational process may be effective on a small scale, but it is imperative that the information is gleaned in a way that the full-scale operations are tested. For example, it may be easy to handle 1, 10 or 100 products, but can the system handle 1,000 or even 100,000 units?

Pilot or trial production techniques are similar to product-use testing or market testing. The determination of the best approach for testing the production system is highly dependent on the situation. A mini-scale test may be sufficient for a well-honed system that requires very few changes for the new product. This is similar to alpha or pseudo-testing. On the other hand, if there are significant changes necessary to the operating system or there is a new system for producing the product, full-scale testing may be a necessity. This is similar to gamma testing or full-scale market testing.

The critical concern is that problems may not be discovered until much later during early commercialization – creating cost, quality, and market-related difficulties. The expected outcome from pilot or production testing is the assurance that the right parts for the right schedule are being received at the right time, and that problems are found quickly and can be traced to their sources and cured. This is part of total quality management (TQM) thinking. It is doing the job right the first time. The best solution for handling problems is prevention or early detection. In TQM thinking, it is essential to recognize and eliminate problems before they occur. Focusing attention on the causes of potential problems instead of curing them during commercialization reduces costs associated with poor production, minimizes the lost time due to time-consuming corrective actions, and enhances value to customers by providing defect-free products. By investing in prevention, an organization can save on expenses and resources in the short term and unplanned product-liability issues in the long term.

Organizations with effective concurrent-engineering efforts have been able to improve time-to-market objectives and reduce direct costs and scrap costs. The cost to change a design is lowest early in the design and development process. *The critical aspect of testing is to discover any potential problems before the product design and production processes are frozen or the product goes into actual production.* The cost of change after such significant events is significantly higher than when there is flexibility to incorporate additional changes.

Changes tend to occur late in the design process, in pilot production, or even after the first shipments reach the customers. By that time, the cost to correct the problem is magnified 10 to 100 times or more, and the impact of design defects may have already affected schedules as well as customer satisfaction.[3] Figure 12.4 provides a sense of the deployment of funds during the NPD process to correct problems or defects.

Scrap, rework, and vendor returns are the classic dispositions when defective materials or production problems are found. Such events cause the product to be more expensive than it should be, making it less attractive to customers, and have an impact on the viability of the NPD program.

Outstanding potential can be negated by poor execution. The end result of the testing is to discover potential problems, conduct a root-cause analysis to find the underlying reasons for the problems, and initiate corrective action to preclude a recurrence.

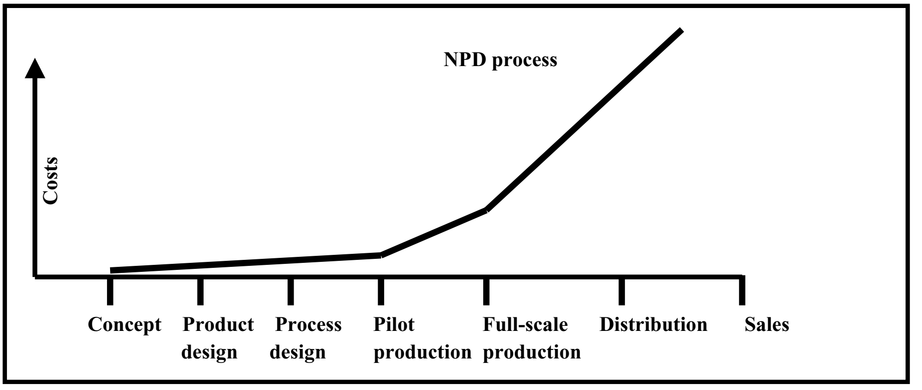


Figure 12.4 Cost implications of design changes (theoretical perspective)

An uncorrected problem propagates through and across the production process. A two-minute problem on a single machine or operation can become a two-hour, or even a two-day rework at a later stage in the operation.

Rework, added machine set-up, paperwork, expediting, or transportation activities do not add any incremental value to a product or the processes. To the degree that these burdens can be eliminated, the cost of the product will decline, the process will accelerate and quality will improve. Every possible source of higher cost or defects has to be reviewed and analyzed for potential improvements. The flow of the operating systems has to be seamless from the customer's perspective.

Testing the reliability of the production system

The three main reliability tests include: validation of the product quality and performance as produced by the operating system; the assurance that the system operates reliably; and confirming that the people have the knowledge to perform their roles and responsibilities. The testing of the production examines the system's ability to produce defect-free products from the selected processes. It determines the system's ability to produce products that exceed customer expectations and meet the quality and performance objectives of the specifications.

The primary goal of the operating system is to produce the appropriate level of output without major disruptions or excessive amounts of inventory, scrap, or operating expenses.[4] The main purpose of testing the reliability of the system is to increase the confidence that the system can perform and meet the expectations of the new-product program and all of its objectives. The objectives typically include meeting cost targets, production outputs or throughput levels, and the prescribed interactions between the major elements of the system. The testing focuses on the ability to produce the required outputs in terms of the acceptable input parameters.

Thus, the testing examines the efficiency, effectiveness, and productivity of the operating system. *Efficiency* measures the economic viability of the system. It examines the production based on the effective use of resources and ensures that the system capability is in line with expectations for costs and throughput. *Effectiveness* explores the options available and ensures that the most beneficial means are used to produce the end results. *Productivity* measures the ability to translate inputs into outputs and to meet the resource-utilization objectives of the NPD program. However, these measurements do not ensure that the operating system is performing well, if the output simply goes into inventory. Testing not only evaluates the capability of the production process, it determines that the system is capable of cost-effective and sustainable production.

Eliminating non-value-added activities is the overarching objective of lean business practices and a significant focus of the operating system. Any non-value-added activity costs money and creates waste. Both lead to a sub-optimal system that is vulnerable to attack by competitors.

The testing also relates to the people and their ability to perform. It examines their knowledge, and their ability to complete the work within the time and costs specified in the NPD plans.

Testing the financial aspects

During the Validation Phase, the financial plan is often re-examined to ensure that the financial implications of the plan fit the existing realities of the NPD program. The most important elements are the product cost structure and the cash-flow projections. Given that the design is essentially complete, and most revisions have become effective, the cost structure for the product is almost entirely locked-in toward the end of the Validation Phase. The expected costs of the product are compared with the estimates or the targeted cost to ascertain the fit. The analysis is dependent on the situation. In some cases, $\pm 10\%$ variation from the target would be acceptable, but in a highly competitive product arena 10% may be too high. If the number is significantly lower than the targeted value, then an analysis should be conducted to ensure that nothing was missed.

Likewise, the same analysis should be performed on the other critical financial elements. Cash flow is the essential projection for most of the crucial metrics. Projected cash flow is the main variable in calculating the expected internal rate of return. The analysis examines the main elements of the cash-flow projections and determines their vulnerability to shift toward less-favorable values.

Testing the external dimensions

Overview

Testing of the external dimensions beyond the market dimension is not usually done. The time and cost involved are the standard reasons given for the lack of attention to the other external dimensions. However, there may be more to the question than time and money. The answer may also lie in the fact that there is not a standard methodology for testing the external dimensions. It is an evolving field. The approach is to examine potential problems or issues beyond the directly related aspects of the primary dimensions of the value system. While it is difficult to ascertain the consequences of present and future impacts, it is imperative that the testing extends beyond the obvious implications of customers and markets. Such testing examines the broader dimensions of the new product to ensure that it is in harmony with the realities of the world.

However, there is logic in the suggestion that testing of the internal dimensions should precede the testing of the non-market-related external dimensions. The reason is simply time and money. There is little point testing the external dimensions if serious problems exist within the product structure and the market, production, or financial aspects of the NPD program; these problems will require significant time and effort to solve. Furthermore, testing of the external dimensions may involve certain disclosures that preferably should occur toward the end of the NPD program. The sequence of testing is based on the degree of importance of each dimension, as determined during early phases of the program.

As discussed in previous chapters, the critical external dimensions beyond the markets and customers are stakeholders, supply networks, related industries, infrastructure, and competition. The initial step is to determine the vulnerabilities with respect to each dimension and determine which, if any, require testing. The issue of testing the external dimensions centers on the uncertainties involved and the need for additional information or analysis. The considerations for testing focus on the same main considerations; time, money, and risk.

The perspective should also focus on the positive. The purpose is to gain insights into how the external dimensions will respond to the new product and what role they will play during the early commercialization. The added insights may provide solutions to problems or opportunities to enhance the program elements so that the process is completely integrated, both internally and externally.

Stakeholder issues

Stakeholder issues are extremely broad and very difficult to define unless there is a long history of involvement in the market, the industry, and the business environment. Fortunately for most NPD situations, the organization does have knowledge of and information about the stakeholders, because the new product is often related to the existing product lines and activities. This is particularly the case if the new product is an improvement, a replacement, or a derivative. However, there are situations in which the new product is being positioned in a new market or new territory where the stakeholders and their impacts may be unfamiliar to the organization. In such situations, a careful examination of stakeholder impacts is necessary.

The first step is to outline the critical stakeholder issues and how they would have an impact on the new product. This information was developed during earlier phases, and this step is simply a reaffirmation of the previous effort. Once the most important issues have been identified, they should be prioritized in order of importance or potential impact.

The next step is to select the issues that could have a large potential impact on the success of the new product and establish a mechanism for testing what role they might play during the launch and the life-cycle of the new product. This assumes that such choices have to be made. As previously stated, for organizations with existing product lines and operations, most of the stakeholder issues are well known and are established as part of the management system. For the new-product situation, the key issues and choices are driven by the new-product program; thus, complex requirements become feasible because there is focus on the implications for the new product.

The third step is to formulate a test plan that includes the important questions pertaining to stakeholders and related issues. Similar to product and market testing, the objectives are to assess the views of the essential stakeholders and ensure that the new product incorporates appropriate solutions, addressing the stakeholder concerns. If it is impossible to address every critical question, the focus should be on the dominant issues and the principal vulnerabilities. The testing instrument should address the following:

- Identification of important stakeholder needs and the organization's ability to satisfy and manage those needs.
- Assessment of the constraints that might limit the potential of the new product due to stakeholder issues.
- Evaluation of the potential impacts of the new product on society, the business environment, and stakeholders.
- Risk assessment of the potential impacts and vulnerability to those impacts.
- Mitigation approaches for reducing or eliminating the most significant real or perceived problems.

Testing stakeholder responses is often the domain of specialists who support the NPD team. Whereas it is highly desirable to assess stakeholder reactions to a new product formally, such testing is more of an ad-hoc process than a systematic part of the NPD process. Unfortunately, the data to support the argument that stakeholder testing is a good idea are based on episodic evidence from catastrophic events. In such cases, the situations are complex and it is difficult to point to a single mode of failure.

The Exxon Valdez oil spill is an example. The company's operating system for designing and managing supertankers was based on customers' need for petroleum products and the economic drivers of the industry. Stakeholder interests and perspectives were seemingly not high on the priority list, even though there had been evidence at the time that environmental issues and spills from tankers were critical issues. What would have been the results if the system accommodated the stakeholder concerns? It could be argued that properly managing such issues would have been a huge benefit to the company as well as to the stakeholders and shareholders.

Supply-networks testing

The supply-networks implications are another difficult testing situation. The construct and logic for such testing is similar to the above discussions on stakeholders. The main vulnerabilities include the following:

- Disruptions in the flow of inputs to the operating system.
- Unavailability of a strategic material.
- Dramatic increase in the cost of critical materials and parts, or ones that have a major influence on the total cost of the new product.
- Profound impact on the quality or yield of the purchased materials.
- Significant shifts in the assumptions about the supply and logistics.

Testing for such problems tends to be ongoing, rather than at a distinct point in the NPD process. There may be situations where it is useful to have a final check of the supply network to ensure that any assumptions about the supply of materials and parts are valid. The organization might test the most complicated or vulnerable part of its supply chain and distribution channels. For example, if the new product is to be shipped via rail cars, the test might include shipping the new product using the assumed routes and methods to determine if there are any problems or barriers. An unforeseen barrier might include the requirement to have a specific permit to transport the product through a residential area of a given city. Trends in the transportation industry might also be assessed.

Supply-networks implications are generally well established, and there is usually abundant information pertaining to the requirements. Nevertheless, there is always the potential for a problem. If the uncertainty about a requirement is relatively high, it makes good sense to mitigate the risks by spending time and money on discovering the potential problems and taking corrective action to cure those problems. Again, the implications of September 11, 2001 provide insights. The assumption that goods can be easily and quickly shipped from point A to B using air or motor freight has to be examined based on the new security checks. Nothing should be assumed.

Related-industries testing and infrastructure testing

The complexity of testing aspects of related industries is even higher than that of the supply networks. The success of a new product may depend on the organization's external relationships with providers of related products and services. It is the combination of the new product and the related products and services that leads to success. An automobile without gasoline is not worth much; nor is a new software technology that has requirements for advanced hardware that the customer may not be ready to purchase. Testing generally focuses on clarifying and validating roles, responsibilities, and requirements. The ultimate goal of the process is to achieve sustainable outcomes that provide win–win relationships.

Infrastructure testing is not common place; however, there are more and more cases where it is important to determine the ability of the infrastructure to respond to the needs of the new product. For example, a new automobile design that uses compressed natural gas is dependent on the distribution channel and infrastructure for natural gas. Thus, if there are questions about the availability of that fuel, the infrastructure aspects should be tested. The testing instrument should address the following:

- Identification of the related industries or infrastructure requirements and the availability of the required solution.
- Assessment of the constraints that might limit the effectiveness of the related industries or the infrastructure.
- Risk assessment of the potential impacts and the vulnerability to those impacts.
- Mitigating approaches for reducing or eliminating the most significant real or perceived problems.

Testing may be a critical element in determining the timing of the support. The new product may reach the market ahead of the necessary support structure of related industries or the infrastructure. The actual elements of such testing are dependent on the specifics of the situation.

Competition

Competitive analysis is a well-known method for understanding the competitive landscape and capabilities. Competitive intelligence and determining competitive responses are well-established methodologies. The purpose of such testing would be to ascertain, as far as is possible, the expected responses of the most critical competitors. To some extent, such testing would be part of test marketing. If test marketing is done and the methods include competitor responses, then separate competitor testing is unnecessary.

The objectives are to determine, as soon as possible, the potential impacts of key competitors. The questions relate to their expected strategies. The following are a few sample questions:

- Which competitors are the most likely to respond negatively to the new product?
- How will they respond? Possibly by: introducing a similar new product; cutting prices of existing products that are related to the product area; increasing advertising and promotion of their other products; limiting access to the distribution channels or other critical resources in the supply chain.
- How will they change their marketing strategies?
- How long can our new product enjoy an advantage in the market given the expected competitors' response? Consider its uniqueness, newness, cost, image, etc.

The bottom line is to determine whether the opportunity is sufficient to cover the investment and make an adequate return on the effort. The answer depends on the analysis, the window of opportunity, and the value of the rewards.

Managing uncertainty and risk

Managing uncertainty in new-product development

An inherent focus of the NPD process is on managing uncertainty and risk. NPD programs that stretch the envelope are fraught with questions and unknowns. However, the NPD process includes mechanisms for converting unknowns and issues into reliable information and data, and resolvable situations. The various means of testing and evaluation from concept to validation provide powerful solutions to the uncertainty that is part of anything that is new.

If the uncertainty is relatively low, it may suggest that the challenge is low, as might be the potential reward. Uncertainty is expected to be relatively high at the beginning and to diminish over time, if the NPD process is managed properly.

In the beginning, there is an idea or, in some cases, a well-defined concept. However, the details required to make informed decisions are typically lacking. The power of the NPD process is the systematic growth of information and knowledge over the course of a program, thus, reducing the unknowns and potential problems associated with the external and internal factors. The following are a few of the most important considerations when exploring the impacts of uncertainty and their influences on decision making:

- Is the new-product opportunity **strategically aligned** with the mission and direction of the organization and does the organization have the competencies and capabilities?
- Does the organization truly **understand the needs and wants** of potential customers; both the tangible and intangible aspects?
- Is the product **positioned** in the market so that it offers distinctive benefits and is it unique in providing customer value? Is there a **well-defined value proposition**?
- Are the **market and technical requirements** for achieving success identified properly and dealt with?
- Are there **well-established channels** to deliver the product (or service) to the market using means and mechanisms that are both efficient and effective?
- Have **important stakeholders** and their key concerns and issues pertaining to the impacts of the product been handled appropriately? (Have government laws and regulations been identified, assessed and complied with?)
- Have influential **competitors** and their expected responses to the new product been adequately addressed and have counter-actions been prepared?
- Are the most important other **external dimensions and their impacts** on the product considered correctly and handled?

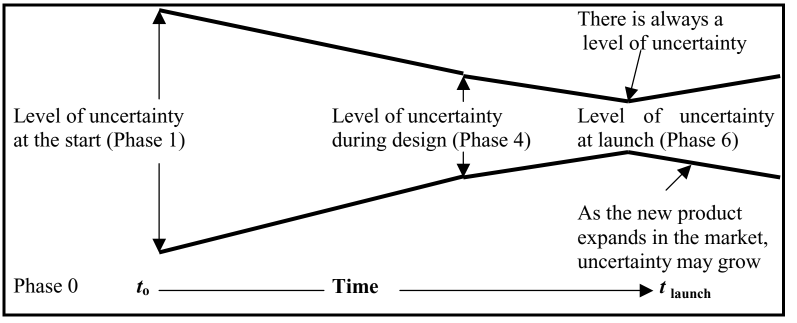


Figure 12.5 Relative view of decreasing uncertainty over the life of the NPD program (ideal condition based on full benefits of IPD)

- Are the total **resource requirements** to complete the program identified?
- Are the **market**, **technical**, and **business risks** mitigated?

This list of concerns just highlights the most crucial factors that have to be addressed and monitored through an NPD program. The fundamental approach is one of reducing uncertainty through information and knowledge. Although uncertainty is high at the beginning, it is usually mitigated during the NPD process by systematically obtaining, analyzing, and understanding information, and making informed decisions about the new product and its consequences on the internal and external dimensions.

An effective NPD program leads to convergence of the availability of information and knowledge with the needs for analysis and decision making. During the first phase of a program, the information need is high, but the resources and the time available are also high. The investment in the program should reduce the gap between the need and the availability of information and knowledge.

Whereas perfect information and knowledge never exist, Figure 12.5 suggests that over time the remaining level of uncertainty should be falling toward zero.

An increasing level of uncertainty suggests that the activities and resources (investments) are not producing a commensurate improvement in the understanding of the essential aspects of the NPD process and program. Such a situation may signal a significant problem, requiring remedial action. The investment of time, effort, and money should produce tangible evidence that the uncertainty is diminishing. With such improvements in information, knowledge, and confidence, management and the participants are willing to assume the risks and continue developing the NPD program.

In the ideal case, uncertainty decreases from a relatively high level during Phase 1 to close to zero at the beginning of Phase 6. Even with the best efforts, there are always uncertainties. It is recognized that the uncertainty may increase after launch as competition responds to the new product. Moreover, early success may invite new competitors, making the business environment more challenging and difficult to interpret. The business environment can change from stable to turbulent, requiring new strategies and new solutions.

A basic premise of IPD is to minimize the level of uncertainty by investing in testing and validation activities. Again, such activities are performed throughout the NPD program in various degrees during each of the phases. The tests and evaluation methods often provide the input for management and the NPD team to make critical decisions, especially those pertaining to proceeding to the next phase. The Validation Phase is typically the most significant step in the NPD process for reducing uncertainty to an acceptable level. There will always be uncertainty due to changing external dimensions. One of the reasons for “speed” is to offset the potential negative impacts of changes in the business environment.

Understanding and evaluating risks

Risk is an ever-present part of new-product development. It is to be managed and reduced; however, eliminating all risks may open the door to more (new) competitors, who ordinarily would not have the capacity to take advantage of the opportunity, given the prevailing level of presumed risk. The key is to understand the elements of risks and to mitigate risks whenever possible.

There are market-related risks, technical risks, program-related risks, stakeholder risks, financial risks, and business risks. Each one has to be analyzed and evaluated to determine the level of risk and the ability of the organization to manage and deal with the potential impacts. The types and areas of risks may be independent of each other or may be combined in some fashion to pose a more-substantial threat. For example, the Firestone tire problems present product-liability questions as well as market impacts pertaining to all of the product lines, and corporate concerns about the reputation of the company. Can the company sustain all of these risks? The ability to determine the impacts and consequences of the risk elements becomes more difficult as the potential for significant interactions increases. In an attempt to keep the analysis easy to follow, this discussion examines stand-alone risk.

Market-related risk explores the potential of a significant unexpected event occurring or a failure to understand one or more of the essential market requirements. For example, the market size may only be half of its projected size. Such a situation could have a dramatic effect on the ability to use a high-volume channel for the distribution of the product. Alternative means would have to be obtained in order to secure outlets to reach customers; it could affect the decisions about the capacity of the operating system. The biggest market-related risk is the product failing in the market due to a defect, causing product-liability claims or a loss of reputation.

Technical risks are often a function of the internal design and development processes. It includes the failure to develop an essential component of the product or the inability to secure the appropriate resources to build the product. There are many forms of technical risks. They include the failure of the product to work as required or to miss its performance envelope, lack of reliability of the product, inability to meet quality standards, lack of compliance with government regulations, the inability to meet cost expectations, and many others. The risks vary depending on the type of new-product opportunity and its complexity.

New products that require significant breakthroughs in new technologies tend to be more risky than those using well-proven technologies. If the new technology fails to materialize, then the product itself may be impossible to create. The Iridium System that Motorola and its partners developed is an example of the failure of the technology to meet the needs of potential customers. While the global wireless communication system was achieved with 66 satellites, plus spares, the product was not successful because of the size of the telephone sets, their limitations, and the costs. The technical problems and high unit cost significantly reduced the market potential for the product.

Program-related risks center on the failure of the program elements to meet their objectives. One of the most crucial risks is the failure to meet the schedule and the target launch date. Program-related risks are often difficult to manage, but their implications are actually the simplest to understand. The management system and the NPD process should provide the means to control the program elements. However, management and the NPD team often fail to maintain control, and technical or market-related problems cause a disruption in the timing so that the overall program falls behind schedule. This affects time-to-market objectives, as well as the financial objectives, since revenue streams are delayed. The solution is embedded in the NPD process and the notion of concurrent engineering (processing). Even with technical or marketing problems, such difficulties should become readily apparent and solutions can be found to cure the problems before there are major impacts.

Stakeholder risk is a relatively new area for risk assessment; however, there are many examples where the new product failed to meet the requirements or expectations of stakeholders. For example, cellular-telephone technology requires the construction of towers for the transmission of signals. Such towers are often viewed as unsightly intrusions in the community. Local citizens enjoin the political powers to prevent additions to the system. Such failures do not always have a large impact on the success of the new product immediately after launch, but the number of cases in which it does have an impact is growing. Stakeholder problems usually arise during the growth period of the product life cycle, making risk assessment difficult unless there is a concerted effort to understand the potential impacts and risks.

Financial risks are the most frequently discussed and analyzed risks in a new-product situation. The focus is on the ability or inability to meet the expected results, especially the financial rewards. This risk is often one of the metrics used to determine the potential for the overall program, since failing to achieve the financial requirements usually means that the program has failed, regardless of technical or market successes. Given that the financial aspects have been covered extensively in Chapter 10, further discussion is not necessary.

Business risks address potential negative impacts on the entire enterprise. The analysis examines the possibly of a serious or even catastrophic failure that would significantly damage the strategic position and reputation of the organization. This type of risk is difficult to quantify and predict. However, due to the seriousness of what is at stake, business risk should always be given a high level of consideration. The key question is: What negative impacts could affect the entire company, if the product fails severely and the consequences have extreme negative implications?

A company might be capable of paying for the product-liability claims and the related law suits, but can it withstand the loss of revenue in its other product categories? The effects of the product failure are much broader than just the products involved.

Managing risks during the NPD process

One of the most important attributes of IPD is the ability to moderate risk. The NPD process includes **phases and reviews** that allow the NPD team and management to determine whether or not all of the elements within a phase have been completed, and are acceptable, before continuing to the next phase. The approach also provides the mechanisms for understanding the entire new-product picture at any given point in time so that a comprehensive view is always available and a determination to continue or not is based on all of the elements. For example, during the Concept Development and Selection Phase there is an understanding not just of the product aspects, but the marketing, financial, and operational aspects as well. This is powerful because it allows management to make informed decisions throughout the NPD process and program about the prospects for success. It means that risks can be moderated on a continuous basis since all elements are being developed on a parallel track. The ability to modify, correct, or terminate the process is a critical advantage of IPD, since informed and astute management has excellent knowledge of the proceedings and can take appropriate actions immediately.

Typically, at the beginning of the NPD process, the assumed probability of success at that point is low due to the high level of uncertainty. However, that is generally not a concern because the investment is negligible; therefore, the level of risk is low. The purpose of the phases and reviews is to keep the level of risks low even though the investment level continues to increase over time. By managing the process, the team and management mitigate the risks.

Figure 12.6 depicts the traditional view of managing risk. In simple terms, the level of risk is the product of risk and the level of uncertainty. If the level of uncertainty declines over time because the NPD process provides the assurances that all elements are on track, then increasing risks can be tolerated.

This graphic display depicts the expected case. Risk increases over the phases of the NPD process, but because the level of uncertainty decreases, the "level of risk" stays relatively flat. In large and complex technology-driven programs, increases in the level

Phase	Risk (r)	Level of uncertainty (p)	Level of risk ($r \times p$)
1	1	0.9	0.9
2	1.5	0.8	1.2
3	2	0.7	1.4
4	4	0.4	1.6
5	6	0.3	1.8
6	8	0.2	1.6
	8	0.3	2.4

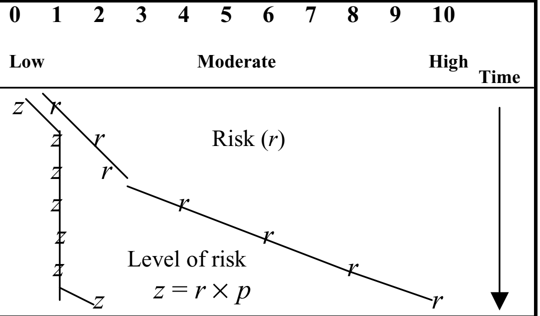


Figure 12.6 Model of level of risk over the phases of the NPD process (relative risk)

of risk are inherent in the process. It is impossible to keep the level of risk within a relatively low range for such programs.

The major strength of IPD is the ability to terminate the program at any point, particularly during the review at the end of a phase. If the level of risk exceeds a predetermined limit, the program can be corrected, modified, or cancelled. These actions tend to reduce the overall risks, especially the total risks associated with a large portfolio of many new-product opportunities. This is a powerful construct for larger companies, who are developing many new products simultaneously.

Establishing criteria

The overall objective is to manage the level of risk and to keep it within an acceptable range. The acceptable level of risk varies from company to company and program to program. Well-endowed companies with vast resources may have the ability to tolerate higher levels of risks. However, even these companies often examine the question in terms of risk-to-reward ratio rather than affordability criteria.

The approach is simple. There is a relationship between the level of risk and the expected reward. It is difficult to generalize on the exact values that are appropriate, but the concept is easy to portray.

Figure 12.7 presents the construct in its simplest form. It examines the relative level of risk to the relative level of reward. Figure 12.7 is a variation of Figure 10.5. The relative level is measured based on factors of a relevant base. For instance, the factor of one for the relative level of reward might be equivalent to the required rate of return from a financial perspective. If the required rate of return is 15%, then factors of two and three equal 30 and 45%, respectively. Similarly, a relative level of risk of one might equate to the total investment into the NPD program. In a simple view of the risk profile, the relative level of risk would be expressed in multiples of the total investment. While such a view may not fully characterize the risk, the concept is accurate.

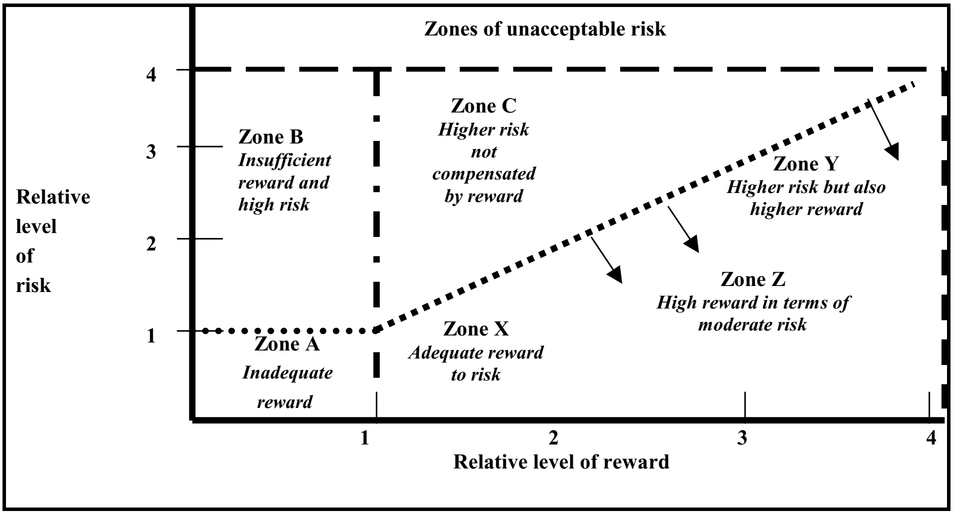


Figure 12.7 Relative levels of risk-to-reward matrix

Zones A to C are areas of unacceptable risk based on the potential reward. Zones A and B simply do not meet expectations. Zone C has an acceptable reward, but the risks are too high for the relatively low level of reward. Zones X, Y, and Z are acceptable based on the level of risk. In particular, Zone Z represents an area where the reward is substantial relative to the level of risk.

This methodology is simply a means of delineating and understanding the level of risk versus reward. It is intended to provide guidance in making determinations about risk-to-reward ratio. It is not to be construed as an absolute sense of acceptability.

Summary

Validation is a complex topic that has to be determined in the context of the NPD program. The discussion in this chapter provides a broad overview of the concepts and theories pertaining to the validation of the decisions made during the upstream phases of the NPD program. It is the validation that is important, not the testing.

Validation is an empirically derived outcome that is grounded in the real world as closely as possible. The purpose for demonstration and testing is to gain insights into the dynamics of the variables in design and development and to obtain evidence that appropriate decisions have been made. Objective data are obtained directly from the situation being studied. The analysis follows scientific methodology, incorporating inductive and deductive reasoning. Demonstration and testing is analogous to obtaining results for an experiment. It uses scientific principles to improve the knowledge about the questions pertaining to the new-product development.

A primary benefit of the Validation Phase is the gain in confidence about the new product and the NPD program. Confidence is enhanced through the discovery of real-world phenomena that support the propositions and decisions of the underlying construct of the new product.

Notes

1. J. Stevenson, Interactive research can enhance new design. *Marketing News*, **32**:7, March (1998), 12.
2. C. Crawford, Merle, and C. Antony Di Benedetto, *New Products Management*, 6th edn, (New York: Irwin McGraw-Hill, 2001, pp. 406–445). While the terminology may vary depending on the author, I used the basic construct in the aforementioned text and others as well. I have selected the text for my managing NPD course over the years.
3. Anon. A smarter way to manufacture. *Business Week*, April 30 (1990), 110.
4. Operating expenses include production costs (such as direct labor, indirect labor, inventory carrying costs, equipment depreciation, and materials and supplies used in production) and administrative costs.

Supplement to Chapter 12
Rapid prototyping and stereolithography

By Edward D. Arnheiter

Introduction

A critical consideration during new-product development (NPD) is the question of prototyping. Developers must consider the extent of the development of prototypes, for example, how many will be needed, when they will be needed, and the method of producing the prototypes. Prototypes of individual components might be needed in order to test aspects of the product's overall design, or to serve as visual aids for product designers. At the end of the product design period there are typically no tools or dies, no machinery, and no assembly facilities to produce the product. If a working model of the finished product were created during the design process, it might be crude or cosmetically unappealing, and therefore not suitable for demonstration at trade shows, sales meetings, etc. Developers may not even know if there is a viable market for the product, and high-quality prototypes can provide valuable market feedback. Because of the need to produce prototypes quickly and cheaply, *rapid-prototyping* (RP) technology has become an indispensable tool in many industries.

The ability to build physical prototypes has long been a weak link in the product-development process. Using traditional machining and fabrication methods, physical prototypes are very expensive and time consuming to build. Because building them is expensive, there are often too few prototypes available for the marketing department or others that would benefit from having working models available to them. A prototype should mirror as closely as possible the key attributes of the final product, especially if marketing plans to utilize the prototype when visiting prospective customers.

Using RP, design errors are caught early, before production begins. The design concept can be verified before expensive hard tooling is manufactured. It even allows the creation of low-volume production parts in some cases, without the need for hard tooling. Exciting new applications in medical modeling, building construction, and aerospace parts are proving that RP is no longer just about building prototypes.

RP technology is still in the early stages of its development, being only around 15 years old. The RP pioneer, 3D Systems introduced its first stereolithography machine in November 1987. Developments have been very rapid since that time, and much progress has been made toward the development of systems that can produce stronger, more-accurate parts in less time.

Traditionally, once the design engineer had completed a design, there was very little flexibility for changes. As soon as a final design was submitted to a draftsman to be made into a blueprint, changes were discouraged because they were very time consuming and costly. Today, computer-aided design (CAD) methods allow unlimited design-change flexibility. All drawings are done electronically and can be changed with a few clicks of the mouse. Prior to RP, tooling had to be designed and developed in order to make a part; today it is possible not to make any part-specific tooling for the production of a prototype. Using RP it is possible to make prototypes very quickly, relatively inexpensively, and with great detail.

Conventional prototyping techniques such as computerized numerical control (CNC) machining begin with a piece of raw material such as block of steel, and through the machining process material is progressively removed until the desired object emerges. RP is essentially the opposite of this conventional-machining approach to production. It is an additive process that adds material in thin layers to gradually build up and form a part with the desired geometry.

RP can be used to improve or optimize the design of a part very efficiently and effectively. It allows designers to view three-dimensional models of components so that design errors can be detected early in the process. RP also allows tool designs and concepts to be verified before any hard tooling is created. Therefore, RP improves the speed, and quality, and reduces the cost, for both engineering and manufacturing processes in the product development cycle. The most common type of RP is stereolithography (SLA).

One of the original obstacles associated with stereolithography was the conversion of CAD files to STL files, a form that SLA machines can read. The STL (STereo Lithography) file format was developed primarily by the Albert Consulting Group and is the main file standard for RP systems. Software has recently improved greatly, making the conversion to STL file format much easier. However, program developers still envision eventually achieving "push-button" simplicity.[1]

The success of RP spawned interest in rapid-manufacturing (RM) research, and rapid-tooling (RT) technology. Most experts envision RP, RM, and RT ultimately taking two separate paths, each path serving a different need. The first need (mainly through RP) is the need for models to facilitate communications regarding product design, to provide design-concept validation and measurement, and to give engineers and others a visual representation of what a part will look like. This niche will be for low-cost, faster technologies, with less emphasis on component strength. The second aspect focuses on using RP concepts for manufactured parts that are stronger and more precise than RP typically yields, so that the parts produced can be used as actual production parts (mainly using RM and RT). So eventually, "prototype" parts will be quickly produced at low cost for validation, measurement, and, in some cases, actual use.[2]

New materials that produce stronger, usable prototypes are now the focus of RP research. Producing usable prototypes using RM is in its early stages of development and successful applications have been limited to low-volume, niche markets, such as medical devices or space-related items. The main factor driving RM research is the increasing demand for low-volume, customized products. It is also now possible to produce usable tooling with RP techniques. RT techniques have been developed that can produce fully dense molds that may be capable of producing 100,000 molded parts.[3]

Prototypes produced using SLA have traditionally been colored with a commercial, aqueous-based dye. However, this method requires prolonged soaking in hot aqueous solutions that often did not color uniformly on all resins, and the hot dye would actually deform the model. DSM Somos developed a new coloring method that provides more consistent coverage. Parts are colored by applying aniline-based dyes in non-aqueous solutions (also known as leather dyes).[4]

A few companies are using RP techniques to manufacture parts that would usually be injection molded. Among the many challenges of approximating the properties of thermoplastics are improving impact strength and tensile elongation, which measure the ability of a material to resist shock. When toughness and rigidity are improved, it usually reduces the material's heat resistance, and vice versa. The grade of SLA resin that is most similar to polypropylene has a flexural modulus of 180,000 pounds per square inch (12,655 kg per cm^2), heat-deflection temperature of about 180 °F (82 °C), and an impact strength of 0.8 feet-pounds per inch (43 joules per meter). Despite the fact that these properties still fall short of polypropylene, SLA resins have come a long way in a short period of time, and research efforts continue.[5]

SLA resins are also being used to produce end-use products. For example, in the manufacture of teeth aligners, a clear plastic replacement for wire braces, SLA is being used as a method to achieve mass customization. Polycarbonate prototypes created using SLA and ABS plastic resin can withstand functional testing, and have 80 to 90% of the strength of a comparable injection-molded part. In the medical-device industry, SLA is being used to produce hearing-aid shells.[6]

One new process now under development may bring RP and RM into the composites arena. OptoForm LLC is developing a RP process called *direct composite manufacturing*, which builds parts utilizing photosensitive paste. Direct composite manufacturing differs in some key aspects from conventional SLA systems. Because a viscous paste is used, there is no tank of liquid resin in which the part forms. The paste is slowing pushed up through a cylinder, where a special coating system smoothes out the paste to form a solid layer. Unlike traditional SLA, there is no waiting for liquid resin to settle before the next layer can be formed; so direct composite manufacturing is a very quick process.[7]

Producing large parts using RP has been a chronic problem. Typically, the production of oversize parts requires digitally cutting the CAD drawing into several sections, imaging each section separately, and then gluing the parts together, but the large, glued

Table 12S.1 *Summary of rapid-prototyping techniques*

Rapid-prototyping technique	Process description
Stereolithography (SLA)	Ultra-violet laser traces cross-sections of object onto surface of liquid resin. Resin hardens upon contact by laser beam. Platform then moves lower in vat of resin and process is repeated.
Ballistic-particle manufacturing (BPM)	High-pressure stream shoots millions of identical microscopic particles of molten resin that freeze upon contact. No material supports or post-curing required.
Drop-on-demand inkjet plotting technology	Inkjet system traveling on x–y drive carriage deposits thermoplastic and wax materials onto a build substrate. Cutters maintain precise z-axis dimensions by removing excess vertical height of build layer.
Fused deposition modeling (FDM)	Thermoplastic modeling material is pushed through temperature-controlled extrusion head where it is heated to semi-liquid state. Material is deposited in thin layers and solidifies, laminating to preceding layer.
Laminated-object manufacturing (LOM)	Laser cuts cross-sectional outline in top layer, then cross-hatches excess material for later removal. New layer is then bonded to previous layer and process is repeated. When all layers have been laminated and cut, excess material is removed to expose finished model.
Multi-jet modeling (MJM)	Uses print head with 96 jets in a linear array. Each jet dispenses thermopolymer material on demand. Head speeds back and forth, building layer upon layer of material to form part.
Selective laser sintering (SLS)	Laser beam is applied to a thin layer of powder.

assemblies often warp and deform in the process. A new epoxy photopolymer manufactured by DSM Somos can be used to build large parts that are both mechanically stronger and more dimensionally stable than those made of traditional SLA materials. Using this material, a 5-ft-long (1.52 m) prototype dashboard was built in one piece in only 50 hours.[8]

The stereolithography process

In the SLA process, cross-sectional data regarding part geometry are fed to an ultraviolet laser. The laser, either a helium–cadmium or argon type, then traces successive cross-sections of the part onto a thin surface layer of photosensitive resin. These passes solidify the resin. The platform on which the part rests is then lowered a few thousandths of an inch, so that a new layer of liquid resin can cover the section just hardened. The computer then receives its next set of planar coordinates and repeats the outlining. This process is continued until the final planar section is completed. The prototype is then removed from the machine and post-cured in a controlled furnace, or an ultra-violet curing apparatus.

Therefore, SLA consists of two primary steps: the scanning and curing step, and the recoating step that provides a new layer of liquid resin. Since the recoating step is the most time-consuming part of the process, much SLA research is focused on new and faster recoating techniques.

Compared with traditional prototype production using standard machine tools, which can take six months or more to produce a prototype, stereolithography and other RP techniques offer several significant benefits:

- They reduce the time and expense of new-product development.
- They can rapidly produce prototypes suitable for fit and function testing.
- They can produce die castings, investment castings, and spray-metal modeling patterns and molds.

Working models can serve several important purposes:

- They allow design engineers to see their part in three dimensions.
- Engineers developing adjoining parts can use the prototype part to facilitate their own design efforts.
- The RP model, in some cases, may be used as the pattern for a casting process of a subsequent investment.

There are some important design points to consider when developing a design that will be prototyped using SLA. First, parts cannot contain hollow areas that may trap the liquid resin. Additionally, cantilevered sections need to be supported during the build-up process. Supports are then mechanically removed after creation of the prototype is complete. A technique to remove supports of ABS models by simply immersing them in a water-based solution, leaving a clean model with smooth surfaces, has recently been developed.[9] A third consideration is that distortion or shrinkage may occur during the build that can affect the dimensional characteristics of the part.

In addition to SLA, there are many other types of RP techniques, including ballistic particle manufacturing (BPM), drop-on-demand inkjet plotting technology, fused deposition modeling (FDM), laminated-object manufacturing (LOM), multi-jet modeling (MJM), and selective laser sintering (SLS). Table 12S.1 summarizes the characteristics of each of these RP techniques.

There have been numerous highly successful applications of SLA. Mattel used SLA to quickly produce new Hot Wheels cars for the American International Toy Fair. The high-tech *Top Speed Pipejammers* were to be introduced at the fair and there was not enough time to make working prototypes using conventional methods. Conventional methods would have required $15,000 and three weeks to create. Instead, Mattel produced new models suitable for display at the toy fair in just 24 hours.[10]

Black & Decker designers relied on SLA when they had only 100 days to transform their concepts for an improved shearer/shrub-trimmer power tool into an attractive, functioning prototype. Thirty working copies were desired in that time frame, which would not have been possible to produce using traditional prototyping techniques.[11]

Notes

1. R. B. Aronson, M. Burns, and K. Johnson, It's not just RP anymore. *Manufacturing Engineering*, **124**:5 (2000), 98–112.
2. *Ibid*.
3. *Ibid*.
4. Anon., Add color to SLA parts. *Manufacturing Engineering*, **128**:5 (2002), 46.
5. J. DeGaspari, Rapid evolution. *Mechanical Engineering*, **124**:3 (2002), 48–52.
6. *Ibid*.
7. *Ibid*.
8. J. M. Hoffman, Big, tough prototypes in two days. *Machine Design*, **73**:11 (2001), 43.
9. Aronson, *et al.*, It's not just RP anymore, 98–112.
10. http://www.3dsystems.com/atwork/casestudies/atwork_mattel.asp.
11. http://www.3dsystems.com/atwork_black_and_decker.asp.

13 Pre-commercialization (Phase 6) and the launch

Introduction

This chapter discusses and analyzes the pre-commercialization and launch of the new product. The Pre-commercialization Phase ensures that the required resources are available and that the commercialization game plan is ready to roll. The actual elements of the Pre-commercialization Phase vary from situation to situation; however, it generally involves finalizing the specific means to bring the product or service to the market. The major requirements typically include producing sufficient levels of the product so that it is available for distribution to the channels or directly to the customers, completing the marketing program elements, and committing the financial resources to the product delivery system and marketing communications plans. The Pre-commercialization Phase involves the transition from design and development, and validation, to the execution of the launch.

Not every new-product development (NPD) program needs an extensive Pre-commercialization Phase. In some cases the new product is ready for commercialization immediately after the Validation Phase. This is particularly true for services or software products that do not require significant production or inventory requirements. Similarly, it may not be required when the NPD program is rolled out in simple stages that minimize large commitments for inventory, marketing communications, or other longer-lead-time activities. Likewise, it is often not necessary if the introduction of the new product is being bootstrapped one stage at a time. However, the Pre-commercialization Phase is critical for large, complex programs with many elements that have to be timed perfectly at launch.

Commercialization of a new product varies considerably as well. In large programs with a national launch there is often a preset launch date when the product has to be available to all customers. If the new product is rolled out in stages, there may not be an official launch date. In such cases, the product simply becomes available to customers as the marketing programs and distribution channels reach them. The launch is simply aligned with the implementation scheme and products are sold to the first customers reached by the programs. In such cases, without an official launch date, the point at which product is actually introduced is blurred.

The essence of pre-commercialization and the launch is the convergence of the program elements, the people, and resources into a fully integrated management system that creates a pathway to success. The convergence of all of the parallel development elements into a cohesive launch plan provides an integrated perspective about the effects and implications of customers and markets, supply networks, stakeholders, related industries, the infrastructure, and the potential impacts from competition. It provides a high level of awareness of what has to happen to achieve the new-product goals and corporate objectives. Customers and markets are the primary focus during the later phases of an NPD program.

Chapter 13 includes the following topics and learning objectives:

- Understanding the essential framework for preparing the launch.
- Developing the launch mechanisms.
- Thinking about commercialization and beyond, and the post-commercialization reviews.

Pre-commercialization Phase

Technical design and quality-related decisions

Final design and development – making the last changes

The transition from the testing steps conducted during the Validation Phase and the completion and finalization of the design and development aspects should be seamless. Unless serious design problems exist, the final product design, the marketing program, and production should proceed without significant change.

Best practices suggest that design changes occur as soon in the design process as possible. Changes at the end of the NPD process should be minimized.[1] However, it is impossible to stipulate that there will be no changes after a certain point in the design process. Management might freeze the design after the Validation Phase – or even earlier – to reduce the potential of delaying commercialization because the design team is still making changes. Such a mandate works for standard features or adding "bells and whistles." However, if there are safety concerns or issues pertaining to product defects, then action must be taken to ensure that the company is not exposed to product-liability risks. Practices associated with freezing the design involve ongoing debates that do not have simple answers. Indeed, the NPD process with its "phases and reviews" provides the formal mechanism that simplifies these complicated questions. A fundamental premise of integrated product development (IPD) is that continuous review and testing throughout the NPD process minimizes uncertainties and reduces the potential for last-minute problems.

Finalizing the design is an arduous task that takes enormous discipline for obtaining agreement about the adequacy of the work performed and the implications of moving toward launch. There is always a hesitancy that something is missing or that more time and effort are required. It is useful to have guidelines that help practitioners decide when the design is finished. For example, Boeing used a multi-step approach during the design of the Boeing 777 with defined exit criteria for each phase. This permitted designers to know precisely where they were in the process, and when they finished the final step, they knew they were done.[2]

Freezing the design allows operations to finalize their methods for producing the product or delivering the service. The final design is transferred to the other areas of responsibility within the organization via many mechanisms including electronic data, computer files, standard engineering drawings, etc. The information includes manufacturing engineering details and production instructions that were produced in concert with the operations personnel. It also provides the final input to the marketing groups for the completion of the promotion and communications programs. The marketing team uses the information for ensuring that its messages are consistent with the technical specifications of the product.

Strategic alignment with internal and external dimensions provides the integration for linking the technical design with the all of the other elements, including supply networks, marketing, business partners, alliances, and customers. Integration means that everyone understands the technical design and how it relates to his or her functions.

The final quality plans

Quality is designed and built into the product. The final step of checking the quality plans is to assure that the customer will receive what is promised. The design has to be translated into work processes that are logical, efficient, and complete. Work processes should be standardized using best practices for ensuring consistency and high quality of outputs. A total quality management (TQM) approach is based on the product, the processes, and the people.

Individuals in the production process must know how they fit into the management system and how their work influences upstream and downstream outcomes. Training and education of all the participants in the launch becomes a priority after the design has been completed. This is not to say that training does not occur before this point in the NPD process. However, it becomes imperative that all such training has been provided before the entire organization becomes involved in the commercialization of the new product.

The bottom line is that everyone throughout the organization has to understand what the new product is and what is expected during the launch. This includes instilling and supporting the concept of continuous improvement. It is understood that a new product will evolve over its life cycle into a more-powerful performer if the entire organization contributes everything it can to make it the best possible product.

Leadership is an essential role for management during the Pre-commercialization Phase. Inspirational leadership focuses on generating dedication and enthusiasm. This is a new perspective on the role of functional management and its responsibility for integrating the new product into the product delivery system. As the expression suggests, inspirational leadership addresses how to motivate practitioners and management within the system to achieve excellence. Inspirational leadership invokes a spirit to become the best and to build new capabilities and competencies. Motivating people means getting them to work effectively and efficiently. Inspiring people means engendering within people the enthusiasm and willingness to achieve extraordinary results.

Ramping-up the operating system and the supply networks

Operating-systems integration

During the Pre-commercialization Phase, product and service requirements are translated into production targets, methods and organizational responsibilities. This includes integrating the requirements into the planning and control systems for forecasting, inventory planning, production scheduling, production and quality control, and systems maintenance.

The commitment to the production of the product or delivery of the service is typically made during the Pre-commercialization Phase. If the production resources exist and are being leveraged for the new product, this step is simply allocating production capabilities to the new product. Under such conditions, the cost and time implications may be minor. However, if new resources are required, the steps involved in the process may have significant implications. The investment of resources into the NPD program might increase dramatically at the point in time when management commits to and builds the production capacity for the new product. The timing of these decisions and activities shows wide variation, ranging from commitments during the Design and Development Phase to waiting as long as possible to invest the funds to secure the means of producing the product or delivering the service. Generally, the decision-making process is based on the confidence that management has in the new product. A high confidence level often translates into aggressive actions with respect to capital investments. Low confidence levels usually cause hesitation and delays. Such conditions may be a signal that management needs to make a thorough review of the NPD program and make a determination about the underlying difficulties. Problems should be addressed and cured before the final commitments are made.

For most incremental innovations, the Pre-commercialization Phase ensures that the capacity is in place, the operating system is capable, and production can start. An important question involves the level of production and the amount of product to be produced just prior to the launch. The answer depends on the operating system and the management philosophy pertaining to inventory. In a lean business-management situation, the level of inventory is kept minimal.

Lean thinking is consistent with the NPD goal of managing risk. Building inventory adds to the investment and risk involved in the NPD process. Regardless of the philosophy, there is always a level of inventory (product) necessary to fill the distribution channel. If there is a specific launch date, the product has to be in the channel in advance. There has to be sufficient product available so that customers can make a purchase decision.

The level of inventory in the channel depends on the overall program. If the initial marketing campaign is very aggressive and anticipates that initial sales will be high, then the product has to be available in sufficient quantities. On the other hand, a gradual roll-out of the product means that inventory can be synchronized at reduced levels to coincide with the expected demand. In all cases, a determination has to be made about the quantity of product required before launch.

Strategic alignment of the supply networks

The strategic alignment of the supply networks requires simultaneous coordination of all of the resources and capabilities of the entire enterprise. Strategic alignment means ensuring that suppliers and distributors are seamlessly linked with the operating system so that materials, products, and people interface automatically as a single system.

Contributions from suppliers have to be linked to the planned production schedule and the flows of materials commence well in advance of the start of production. This essential need reinforces the notion of the enterprise and the strategic alignment between the organization and its suppliers. Similarly, the links to the customer have to be in place before launch so that the new product can flow from production to purchaser. This means that the channel has to be geared for delivering the product to customers without disruption, and in an efficient and timely manner.

Systems integration aims to select and integrate processes, methods, and tools used by the supply networks to create a structure that relentlessly seeks excellence and moves faster than the competition. The goal is to create relationships between people, and product-related partnerships, that maximize efficiency and effectiveness to out-perform competing enterprises. The basic approach toward building a sustainable enterprise is the creation of value streams that focus on delighting customers and building an enduring foundation for launching and sustaining the new product.

A "world-class" enterprise understands its constituents and creates processes that provide innovative solutions. Electronic commerce provides the means for increasing the speed at which information and transactions can be performed. It also reduces the cost of such exchanges so that the increased complexity and volume of interactions can be managed efficiently and effectively. Communications integration via the Internet provides an enterprise-based system for carrying out activities regardless of location or the involvement of players. The number of purchasing transactions made business to business using electronic commerce is expanding dramatically as poor security and other problems are being solved. Order tracking, funds transfer, and other related activities make electronic commerce the preferred vehicle for managing such operations.

Initiating marketing promotion and communications

Market drivers and marketing messages

Reaffirming the market conditions is one of the first steps during the Pre-commercialization Phase. Regardless of the speed of the NPD process, time elapses between the initial phases and the Pre-commercialization Phase, and the world changes. Anticipating change and responding to the dynamics of the business environment are important precursors to launching a new product. The NPD program requires continuous updating to ensure that the program elements are in concert with the expectations of customers and stakeholders. Understanding of the prevailing market, business conditions, and trends has to be fine-tuned to capture the complexities of the business environment and the implications of change on the new product. The Pre-commercialization Phase includes a final assessment and review of all of the essential elements. The review typically includes the critical factors for success and the market-attractiveness elements. While the assessment is based on the same factors developed earlier in the NPD program, it is important that a final check be made to ensure success. The checks are similar to those made by airplane pilots before they take-off. The aim is to make sure that nothing has been overlooked.

Some of the most important questions are:

- ***Projected revenue***. Is the size of the targeted market segment more than sufficient to provide the revenue streams required for success?
- ***Market growth***. Is the potential growth rate of the market in line with the expectations for sales, cash flow, and return?
- ***Customer base***. Are there adequate numbers of customers over the long term to sustain the success of the new product?
- ***Customer needs***. Does marketing understand the critical needs and wants of customers and has the program captured the correct perspectives? Have the needs and wants of customers changed in any significant way?
- ***Selling the benefits***. Do the benefits of the new product meet or exceed the expectations of customers? Does the marketing program focus on selling the most important benefits?
- ***Clarity of the message***. Does the marketing program articulate a powerful message that will reach potential customers?
- ***Predicting competitor response***. What are the expected responses of competitors and their position vis-à-vis the new product? Have they significantly changed?
- ***Shifting barriers***. Are there any new barriers to success or have the existing barriers shifted so that success is more difficult?

These are some of the most important review questions, but there are more that could be, and possibly should be, assessed for determining the state of affairs prior to making the major commitments for launch or prior to the launch itself. They represent the final step in reducing uncertainty and gaining the confidence that all elements are ready.

Fine-tuning the marketing campaign

The marketing campaign is normally developed during the early phases and initiated during the Pre-commercialization Phase. The promotional messages and mechanisms are finalized, and the brochures and other printed materials are completed and distributed across the enterprise. The advertising campaign is activated, and advertising spots for television, radio, newspaper, magazines, and others are signed, sealed, and committed. Such commitments involve a significant monetary outlay and often represent a critical point after which it is extremely difficult to make changes. It is often the "point of no return" or at least the juncture where changes have considerable cost and time implications.

In addition to releasing the advertising, the sales literature, and the other promotional support elements, the activities include training the sales force and the channel participants, initiating press releases, encouraging publicity, and distributing the product to the distribution channel. The situation is similar to assembling the logistical requirements and the communications methods prior to a military operation. It involves an enormous amount of preparation and coordination. All elements of the marketing plan must be ready for simultaneous commercialization.

The launch

The implementation process

Launch is a term that has many meanings depending on the industry and the business situation. For very-large NPD programs focusing on an entire market with a broad geographic perspective, a launch can be a single event on a given date. Every aspect of the entire NPD program is initiated at the same time. For smaller programs or for those with modest roll-out strategies, the actual launch is less definitive and may take place over a considerable period of time. In such cases, the launch becomes a series of steps that culminate in the NPD program reaching a critical mass. Having achieved critical mass, the NPD program can be viewed as obtaining full commercialization.

The question of full commercialization has become more important with the advent of web-based launch programs. It is often difficult to ascertain the difference between the precursor activities of market testing and the actual commercial approaches of selling the product to mainstream customers. The Internet allows NPD programs to make the transition smoothly from phase to phase without worrying about the precise definition of the actual point in the NPD process. This may be an advantage for small companies or for small NPD programs that are easier to manage, but large NPD programs require enormous levels of coordination between diverse groups having limited interactions. Theoretically, difficulties in communications should be minimized by the modern information technologies and computerized systems, but the availability of the means to communicate does not guarantee seamless and consistent coordination, or effective outcomes.

Implementation is embedded within the NPD process. It is determined by the requirements of the situation. As discussed throughout this book, the advantage of IPD is the flexibility to handle numerous variations. It is both prescriptive, in terms of the flow of the process and the generic elements, and flexible with respect to the actual elements covered during the analyses of the specific requirements and the execution of the game plan.

The objective of the launch is to commercialize the new product and achieve success in the market. Success is the criteria, not the path taken to get to it. Whereas there may be better ways to accomplish the end result, the aim is to achieve the goals of the NPD program and sustain the product in the market. Such goals include building upon the success to achieve higher levels of market position and recognition.

Flexibility means that activities must be organized in a way that the implementers can thrive on change and are able to adapt to new conditions as they develop. The structure cannot be so rigid that it can only meet the requirements of the defined case without variation. The structure has to allow rapid reconfiguration of human and physical resources to accommodate change.

Depending on the organizational structure and style, the implementation process for a new product includes a transition from the more-open-ended approaches of the typical NPD process to the more-defined requirements of the product delivery system of the organization. In many cases, the number of participants expands significantly as the broader (typically functional) organization replaces the NPD team during commercialization. It is imperative that the new product fits into the general scheme of the existing management system. The organizational construct has to make the transition from the more-independent, innovative, and initiative-driven style of the NPD team to the more-structured approach of established lines of control, responsibility, and authority of the enterprise. In many organizations, the NPD team gives way during the launch to the product-delivery organization that has the full responsibility of ensuring the success of the product in the long term.

Management control

Management control of the launch process is essential for achieving success over the longer term. Initial success can be negated by failures to manage the entire process. A single mistake can produce unexpected consequences. For example, the floating-point defect in Intel’s first-generation Pentium chip was not significant from an application perspective, but it did introduce issues of trust that extended beyond the specific product to corporate values. Such a defect might have seriously eroded the market potential for the new product and could have had an impact on the short-term and long-term viability of the product and future products. Even if the effects are only short term, the lost cash flow during the launch period might have a significant influence on the net present value (NPV) calculation of the program or the ability to invest money into other NPD programs.

The market place and the business environment determine success and failure. The driving force for the management control process is the need to minimize the time for creating and exploiting customer awareness, and building a demand structure sufficient to sustain the new product.

These requirements are more important in those cases where others in the organization take over the responsibilities for the new product after launch. Momentum has to build rapidly after launch, as market growth demands more from the organization. There is little time to rest on the gains made during the early stages. Successful implementation depends on the following:

- Monitoring the progressive attainment of the essential performance targets and time objectives.
- Identifying and diagnosing variations in achieving the targets and time objectives so that deviations from the game plan are minimized and the expected outcomes are realized.
- Reviewing and revising the plans and objectives in order to keep up to date with the realities of the world.

Monitoring results is an ongoing process. It becomes especially important after the launch to ascertain the direction of the program. Monitoring usually focuses on leading indicators to detect the general trend. If the program is proceeding on track, the confidence in the NPD program is enhanced and management can continue with the game plan established during the NPD process. If the process is moving off track, early detection allows for corrective actions that can be initiated before serious problems occur.

The sensitivity analysis used during the financial evaluation step of the NPD process provides powerful input to determine what moving *off track* means and what its implications are for the program. For example, most sensitivity analyses examine the effects of exceeding the cost target for the product. In a specific analysis, the cost overruns are examined based on their impact on pricing, profitability, and return on the investment. Assuming that the cost is 10% higher than expected, sensitivity analysis provides an indication of the impact on the bottom line. Using the results of the sensitivity analysis, management has a means to determine how far off target a given parameter can get before significant corrective action is required. The knowledge gained from the sensitivity analysis and other methods used throughout the NPD process allow for better definition of what an unacceptable variance is and how to manage the situation.

The outcomes from the analyses conducted during the phases of the NPD program should be made available to the critical participants of the product delivery system so that they understand the implications of the metrics.

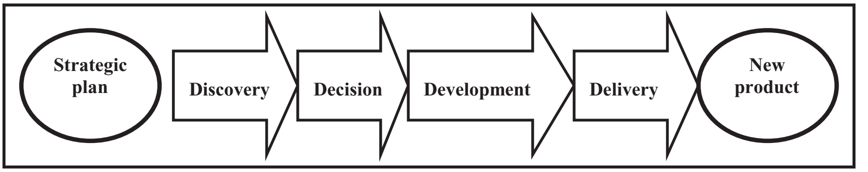


Figure 13.1 Four steps in product innovation (Goebeli and Brown, 1993)

Commercialization and beyond

Delivering value

As suggested throughout the book, new-product development is about creating and delivering value. The value proposition is one of the most powerful methods in managing the enterprise. Everyone seeks value! And it is value that generates wealth.

Product innovation is one of the most important mechanisms in enterprise management. Newer, better, cheaper, faster, cleaner, safer, and better-performing products are the mantra of businesses and their customers and stakeholders. The combination of these facets provides the mechanisms for achieving success. Just focusing on one, such as faster (speed), may skew the results. Getting to the market first, but with an inferior product, is a prescription for failure. New-product development is concerned with adding new value, and deliverying value is the benchmark used by the market place.

Connecting the NPD process with the product delivery system

Decision making is the essence of new-product development. Product innovation is all about the orderly transition from the Strategic Logic and Alignment Phase to product delivery system. Goebeli and Brown suggest that the transition flows through four basic stages, as depicted in Figure 13.1. While their model is a simple model of a complex topic, it does focus on the critical steps embodied in the NPD process.

The authors point out that each step must be completed in a timely and efficient manner and that, in practice, the most significant problem is "inadequate resources."[3] Their research indicated that the overall incidences of such problems were exacerbated during delivery (commercialization).[4] Post-launch activities and processes require the same diligent attention as mapped-out during the NPD process. Often, there is insufficient articulation of the ongoing processes associated with full commercialization.

The Quality Director's Network of the Industrial Research Institute (IRI) carried out a survey of member companies to determine how successful their members were at adapting the "stage–gate" model. It was determined that most companies used the basic structure, but only a few were deemed totally successful.[5] Davidson, *et al*. (1999) identified five principles used by the successful companies: clarity, ownership, leadership, integration, and flexibility.[6] Clarity means that everyone understands the process and his or her responsibilities. Ownership suggests that the people are the pivotal instruments for success. Leadership provides the guidance and inspiration for obtaining the desired results. Integration means that everything is aligned within the NPD process and across the entire enterprise. Flexibility provides the means to change with the dynamics of the business environment. These items have been discussed throughout the book.

While Goebeli and Brown's construct and comments could have been introduced earlier in the book, they are most appropriate as the NPD program reaches the point of integration with the product delivery system and becomes a part of the operating system. Indeed, each of the points has been addressed in detail throughout the book. Staying focused on the goals of the NPD program is essential for meeting expectations in the longer term.

Thinking about commercialization

Product life-cycle thinking

After launch, new products typically follow the product life-cycle concept. The commercialization of a product proceeds through four stages: introduction, growth, maturity, and decline. The introduction stage is the initial period following launch. Demand and sales during the early-commercialization stage are low due to the lack of awareness of the new product and, possibly, customers' concerns about the product. Additionally, the marketing program has to have time to build to a critical mass. For instance, advertising requires a considerable number of repetitions before the market receives the marketing communications and has time to understand and act on the messages. Production capabilities may also require time to reach a volume sufficient in size to have a significant impact on reducing the unit cost of the product. Moreover, there may be hidden product or manufacturing defects that have to be resolved before benefits of the new product outweigh the perceived risks to customers. There are many reasons why the market needs an extended amount of time before growth increases at a high rate. Indeed, a fundamental mistake in estimating demand during introduction is assuming that sales will accelerate quickly because customers will "fall in love" with the new product.

As market success is achieved, more resources are allocated to the product delivery system to increase output in anticipation of higher rates of growth. At the point of inflexion, the life cycle moves into the growth stage and demand moves into high gear. During the growth stage, volume increases and profitability generally improves. The experience curve starts to approach the optimal point and the yield problems, if any, are solved. Additional production capacity often has to be acquired and the outputs of the product delivery system have to be expanded. Such expansions typically lead to an improved cost structure with improved profitability. Some of the cost savings are passed on to the customer in the form of lower prices helping to simulate additional demand. Eventually, customer awareness and acceptance get close to reaching the full market potential. While there are many positive aspects of the growth stage, success usually encourages additional competition and gross margins are put under pressure by the more-aggressive competitive situation.

Ultimately, most products reach a level of full maturity. Demand stabilizes, but margins generally fall. The product reaches its potential and there are limited means available to stimulate additional demand. Moreover, other new products may have entered the market that also dampen the demand curve.

As new products and even new technologies make their way into the markets and customers migrate toward the more-innovative products, the mature product starts to decline, entering the last stage. Decline could continue for a considerable period, but the product is often replaced during the late mature stage or early decline stage with a new product. The replacement starts the process over again.

The flow of the product life cycle follows an "S" -shaped curve. While it is not possible to use the function of the curve to predict the actual demand, the generalized concept does help management think about the implications of the dynamics of demand and change over time. The length of the cycle, the duration of each stage, and the precise shape of the curve are difficult to predict. There is a wide range of variability from product to product.

Most products make a transition over their the life cycle from an exciting innovative product to basic commodity status. The Kano principles, as discussed in Chapter 4, suggest that every product has a life cycle that influences the product's power and position over time. The process may be akin to a new product that has been launched into space and time, having gravity pulling on it to bring it back to the common base of Earth. Organizations have to spend an enormous amount of time and money to keep their satellites (products) in space. Without a concerted effort, they fall back to Earth, suffering damage or worse. Of course, one way to maintain the power of the product in the market is through product innovation. Incremental innovations on an ongoing basis can prolong the attractiveness of the product and inhibit obsolescence (decline and fall).

Impacts on the potential of the new product

During commercialization, many changes occur as the impacts of the new product reach the market place. The most crucial factor is obtaining acceptance, both in the market and by stakeholders. Customers may fail to respond favorably to a new product, especially one that represents radical changes from the prevailing views of customers' expectations. For example, the Internet traces its origin to the 1960s. However, it did not expand and gain widespread consumer use until the mid 1990s after the first user-friendly interface was created at the University of Minnesota. The number of Internet hosts as of December 1994 was under 5 million.[7] Internet usage accelerated between 1995 and 1997 as web servers increased dramatically and the number of Internet hosts increased

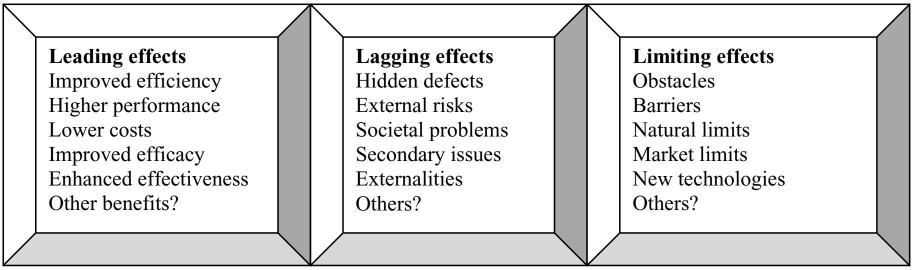


Figure 13.2 Impacts on the potential of the new product

by more than 15 million in just two years.[8] Internet use expanded exponentially after a critical mass of web domains became available.

The commercialization of new products is based on their projected benefits for customers and markets. As discussed in Chapter 2, a product has leading, lagging, and limiting effects. A new product has leading effects that are the drivers for the development program. The leading effects are the positive attributes (projected benefits) that become the selling points for the new product. The lagging effects are the impacts that are not always apparent at launch, but may show up at later stages of commercialization. For instance, the ozone-depleting properties of chlorofluorocarbons (CFCs) took many decades to discover and validate. CFCs were viewed as some of the most successful products of the twentieth century. As refrigerants, they changed the quality of life by providing the means for indoor refrigeration. However, during the 1980s and 1990s powerful forces converged to prohibit the production and use of CFCs. The lagging effects of ozone depletion and expanded applications of CFCs reversed society's acceptance of CFCs and ultimately caused their demise. Limiting effects are similar. They are obstacles and barriers, or the natural phenomenon, that constrain the potential of the new product. For instance, the speed at which personal computers operate is limited by the laws of physics. The market potential will be constrained by the number of users and the replacement cycle in the future.

The potential of a new product in the long term is basically described by the following formula:

$$\begin{aligned}\text{Potential} = {} & \Sigma\text{Leading effects} \pm \Sigma\text{Lagging effects} \\ & \pm \Sigma\text{Limiting effects}\end{aligned}$$

Lagging effects may be positive or negative. Negative effects tend to be the hidden defects in the product or the structure. Positive effects are conditions or attributes that allow the product to be expanded into new arenas. For example, the introduction of the Windows operating system with its graphical user interface allowed many more individuals to become computer literate because Windows made using the personal computer significantly easier. Figure 13.2 shows some of the essential areas pertaining to each of the effects.

From the perspective of the product life cycle, leading effects are the reasons why the product is successful and why sales expand during the growth stage. Positive lagging effects accelerate demand and kick it into high gear. The negative lagging effects may explain why the growth of the product demand starts decelerating or levels off. The limiting effects are often the precursors to reaching the "high-water" mark and the beginnings of the decline.

While there is a general relationship with life-cycle thinking, the effects can be manifested at any time. The limiting effects may occur very early in the introductory stage as customers find the limitations of the product. Success or failure often depends on the aggressive actions of operational or product management to mitigate the negative effects and/or add to the positive ones.

Look before you launch a new product

It is often argued that by being first to market with a new technology, a company can reap a host of financial benefits. In 1989, a Fortune magazine article showcased companies that were well-known ultra-fast innovators, and described the benefits reaped by US companies that bring new technology to the market sooner. For example, Honda slashed its NPD time from 5 years to 2 years, and Hewlett-Packard cut their time from 4.5 years to 22 months. While in general it is true that a "first mover" can charge a premium price, premature product introduction can also compromise quality and increase the risk of defects.

When companies hastily introduce products to market, it can hurt the long-term development of a new application. For instance, early handheld computers, because they could do only half the things that standard desktop PCs could do, disappointed lead users. With the arrival of the PalmPilot personal digital assistant (PDA) and other similar products, the market for handheld devices has improved. However, because many manufacturers previously jumped into an emerging handheld computer market with substandard offerings, the overall business for PDAs suffered.

There were many reasons for the sluggish sales of early handheld devices. The usefulness of handheld personal organizers was never initially demonstrated, so businesses were lukewarm about the concept from the beginning. To address this problem, manufacturers began packaging the devices with applications from desktop and laptop PCs, to give corporations a better idea of how to use them. For example, Packard Bell NEC bundled its MobilePro with desktops and notebooks. In the beginning, there was also a fluctuating product supply, with some products actually becoming out of stock. For instance, a shortage of modems and 4-Mb models of the PC Companion slowed down sales for Compaq. Finally, since handheld computers were a totally new item in terms of technology, many potential users simply waited to determine which direction the technology was headed.

Initially, handheld computers possessed limited power and functioned more as personal organizers rather than PC companions. Suppliers needed to correct flaws with data synchronization, to enable the devices to exchange information with larger computers. In addition, manufacturers discovered that users wanted improved communications ability, so they added integrated modems and wireless connections. There were slow early sales of handheld computers running Windows CE, a stripped-down version of the Windows operating system, because inadequate marketing channels for promotion and education hurt the introduction. Apple Computer experienced similar problems, which affected the sales of its highly publicized Newton.

Since the introduction of the first, limited-capability handheld computers, many new applications for the devices have developed. The application builder PulseGroup of Bryn Mawr, Pennsylvania developed an application called PulsePilot that runs on 3COM's PalmPilot, which makes it easier for patients to input and provide information to doctors, and the data can even been entered via a Web browser. The capability of PDA devices has improved greatly. Financial traders often use handheld devices to examine desk-top data when on the trading floor, and most PDAs now provide wireless access to the Internet.

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Post-launch review and continuous improvement

Initial post-launch review

The initial post-launch review examines the results achieved to that point with respect to the metrics used for the NPD program. The purpose of the review is to determine whether the new product is on track with the game plan and whether corrective actions are required. While there is always a concern about the success of the new product immediately after launch, the assessment of the situation may suggest that more-aggressive action is appropriate because the demand for the new product is stronger than anticipated. If the review is conducted within 30 to 60 days after commercialization, the implications and insights gleaned allow management and the product delivery system to allocate the resources necessary for improving potential outcomes. Such reviews are the domain of the NPD team and management, since the goal is to reflect on what has happened relative to the expectations and metrics.

The outcome of the review may be a closer scrutiny of one or more metrics that indicate that there may be a problem. Management may track those metrics on an ongoing basis to ensure that the product does not falter during the early going. For example, customers may misinterpret marketing communications and fail to comprehend the benefits associated with the product. Gillette's Mach III has become a great success because the company's new advertising focused on both a superior shave and "no nicks." The message is clear and easily understood.

Moreover, the initial post-launch review provides immediate feedback to the senior management and product innovation personnel so that the NPD process can be improved based on the lessons learned during the phases of the program and the post-launch situation. The lessons learned should include all facets of the program, the product development, the NPD process, and the people! Most importantly, it should identify any changes that may be necessary to improve the process or enhance the skills, knowledge, and capabilities of participants. The cornerstone of IPD is that success is achieved through customer and stakeholder satisfaction and the integration of the effort. All reviews are intended to ensure that best practices are being used and that the management system is focused on achieving the objectives based on continuous improvement.

The post-launch review should also assess the business environment using the methods developed during the NPD program to ascertain whether any significant changes occurred. Such changes may provide additional opportunities for the potential of the new product that should be exploited immediately. The demand for the new product might be greater than expected or there may be certain geographical regions where the new product is significantly exceeding expectations. In such cases, the additional action plans should be initiated to take advantage of the situation. The technological capabilities of the supply networks may have improved more dramatically than expected. For example, PC technology exploded during the early 1990s providing faster and more-capable machines with a significantly higher performance-to-price ratio. As newer generations become available, the cost-effectiveness of the older product offerings quickly disappeared. According to the *Computer Industry Almanac*, the "386" had the largest market share in 1991 to 1992, to be replaced by the "486" in 1993 to 1994, and the "586" in 1995 to 1996. The evolution of the technology forced users to establish an ongoing assessment of their needs and resources, and equipment manufacturers like Compaq had to continuously revamp their product lines. Compaq suffered severe difficulties in the early 1990s due to the slow introduction of its "486" product line and Intel's launch of its Pentium microprocessor technology; problems arose again in 1999 when, according to CEO Michael Capellas, "Compaq's slowness in developing an Internet strategy" cost the company its leadership position.[9]

The review should also examine the negative implications of change. There may be additional barriers to the full implementation of the launch. Competitor responses may be more aggressive than expected. The notion that there is limited competition or that there are no competitors quickly evaporates if the new product makes a big splash and enjoys tremendous cash flow.

The next stage in the development

Given that the new product is successful, the next stage in its ongoing development is to seek additional opportunities for exploiting the strategic, market, and financial advantages created after the launch. As potential customers become aware of the benefits of the new product, other market segments can be analyzed to determine the suitablility of penetrating additional market targets. Such actions might be an extension of the original program, may be viewed as a related NPD program, or become the responsibilities of the operating units. It depends on the amount of leveraging from the program elements and the required changes for the additional market segments. If the changes are modest and the market-related elements are similar, the initiatives to expand into other segments can be done in the context of the product delivery system. On the other hand, if the external dimensions necessitate profound changes to the product delivery system, then the initiatives should be viewed as derivative NPD programs, mandating a more-formal structure to the process.

The first-year review

A first-year review may not be standard practice, but it represents an opportunity to obtain an objective view of the new product based on the actual history. The first-year review may be a formal audit or a quick assessment of the results and their implications. The purpose is the same, to obtain a valid overview of the achievements and challenges. In most cases, the review is based on the objectives and expectations of the original game plan. The format depends on the situation and the objectives of the review. A simple approach is to follow the elements of the NPD program and examine the dimensions.

The first-year review takes a "total systems approach" to assessing the entire flow of information, materials, products, and services, from raw materials obtained from suppliers, to production, then through distribution to customers. It includes analyzing resource utilization, materials management, purchasing, supplier relationships, quality aspects, cost implications, standardization, outsourcing, and electronic-information flow.

The assessment/audit should include an examination of the main elements of the plan, obtaining and assessing market and customer feedback, determining the level of quality, inspecting and qualifying the operations, validating the cost structure and the other financial aspects, and re-examining the technical details. The assessment can be comprehensive, including every impact that the new product has on the product delivery system, or it can take the form of a sampling of the essential elements based on the key metrics to determine whether a thorough analysis is warranted. Table 13.1 provides a summary of The Stanley Works' approach.[10]

The two overarching concerns are: (1) the required changes to the program elements to correct deficiencies in the game plan; and (2) significant drifts from the desired direction for the new product due to undesirable revisions within the product delivery system. The former is an inherent part of enterprise management, IPD, and total quality management (TQM). It is the relentless pursuit of excellence. The aim is to stay focused on the objectives and desired outcomes of the NPD program as it matures in the market place. The latter include the unintended changes that often occur as new participants

Table 13.1 *Stanley's one-year project review*

Major activities	Responsibility
Review of actual sales data versus plan, and assessment of customer feedback • Measure actual first-year sales versus product forecast • Evaluate customer feedback • Evaluate service and warranty results • Evaluate competitor reaction • Determine activities to increase sales (promotion, etc.)	**Marketing/product management**
Review quality and process capabilities versus plan • In-house retest and re-certify product • Safety review • Process capabilities versus plan review • Outside vendor component review • Review/revise instructions/service manuals	**Manufacturing/quality assurance**
Financial review versus plan • Actual product cost versus estimate • Actual capital expenditure versus plan	**Finance**
Cost-down plan • Determine major cost-down activities/timing • Supplier cost-down activities/timing	**Engineering/purchasing/ manufacturing**

and management assume roles and responsibilities and have views that may not be in concert with the original plans.

A successful management system creates a close fit between what is needed and required by customers and stakeholders and what the system does and is capable of doing. Performance evaluation is the ongoing effort of assessing and maintaining the strategic alignment between all of the constituents involved in the NPD process, particularly after launch.

Continuous process improvement

The success of the new product depends on the ability to manage and improve internal processes and external relationships over time. Continuous process improvement includes reflecting on the entire NPD program and ascertaining the process elements that can be (should be) improved for the next program. Continuous improvement of the NPD process focuses on achieving speed with thoroughness, understanding needs and wants, reducing risks and liabilities, decreasing the costs (investment) associated with the NPD process, identifying new business opportunities, and positioning the organization to meet the needs of the future. It examines the tools and techniques used for planning, analysis, decision making, and evaluation. The review should focus on improving the following:

- Integrated product and process design and development to provide future participants with qualitative and quantitative assessment and knowledge gained during the NPD program.
- Techniques and practices for assessing the needs and requirements of customers and markets, product/market attributes, stakeholder implications, and the impacts of the other dimensions.
- Methods, tools, and procedures to improve the ability to evaluate product/market requirements and the risks associated with problems and issues and the cost/benefits of eliminating or reducing them.

The rapid growth of best practices, globalization, technological developments (information technologies, CAD/CAM, and virtual product development), NPD methodologies, and changing customer expectations and intense competition, have made staying ahead both challenging and essential. It is imperative that people within and outside the organization collaborate with each other to make substantial gains in the design, development, and delivery of new products.

Leading corporations are constantly working to make product innovation a core competence and an area of excellence. Such capabilities provide the means to achieve a sustainable competitive advantage that will enable them to reinvigorate growth and reduce the vulnerabilities associated with turbulence in the business environment.

The continuous improvement efforts are exploratory. The emphasis is on the development of new or refined methods, practices, and approaches to guide businesses in the management of new-product development. The continuous improvement efforts investigate the way in which the organization develops innovative processes for managing NPD programs, and for creating the tools to facilitate the related activities. The expected results of such efforts are insights and lessons learned that can be applied in the future. Continuous improvement efforts are empirical inquiries that investigate phenomena within the real-world context using multiple sources of evidence.

Summary

The Pre-commercialization Phase is open-ended and depends on the nature of the new product and the complexities facing the product delivery system during launch. For simple changes to existing products, the Pre-commercialization Phase is straightforward requiring very few activities since the new product leverages existing resources and methods. For more-radical changes, the preparations for launch require incredible amounts of time and money. The former is similar to a professional baseball player being traded to a new team. He knows the game, the rules, the skills requirements, and the other teams; he just has to learn the nuances of his new team and its game plan. The latter is akin to Michael Jordan, a superstar at basketball, trying to become a professional baseball star. Everything is new. He has to learn the game, acquire the skills, become part of the process, and understand and work with the people.

The challenge facing managers and participants is how to deal with the wide spectrum of preparations and practices. The implementation of a new product involves linking the operational practices and transforming the product delivery system to richer levels of sophistication and knowledge. It prepares the organization for achieving a sustainable launch, mitigating risks, reducing liabilities, earning profits, and satisfying customers and stakeholders.

Launch is the culmination of the NPD process and the transition of the responsibilities to the domain of the product delivery system and product management. It represents the end of the gestation period, as measured in "phases and reviews," and the birth of the new product, which develops and grows over its product life cycle into a mature and successful adult. The launch is often more symbolic than real. Regardless of whether the NPD process was virtual, whether it was a modification of IPD or traditional, the launch is a milestone that signifies the genesis of a new creation to contribute to wealth and the betterment of humankind.

Notes

1. J. Hauser, and D. Clausing, The house of quality. *Harvard Business Review*, May–June (1988), 64. The authors present the case of a Japanese automobile manufacturer who made changes early in the design process.
2. D. Dimancescu, *The Seamless Enterprise: Making Cross-functional Management Work* (New York: Harper Business, 1992, p. 151).
3. D. H. Goebeli and D. J. Brown, Improving the process of product innovation. *Research Technology Management*, **36**:2, March–April, 1993.
4. *Ibid*. Approximately 40% of the incidences pertained to lack of resources.
5. J. M. Davidson, A. Clamen, and R. A. Karol, Learning from the best new product developers. *Research Technology Management*, **42**:4, July–August (1999), 12–18. The use of the this comment is not to suggest that R. C. Cooper's "stage–gate" process does not work, but to reinforce the notion that the process requires continuous management commitment, especially after launch.
6. *Ibid*.
7. R. Zakon, Hobbes' Internet Timeline, http://www.isoc.org/zakon/Internet/History/HIT.html, 1999. The actual number varies depending on the survey instrument cited. For the purpose of this discussion, only a relative order of magnitude is important, since it is the growth based on customer acceptance that is pivotal.
8. *Ibid*.
9. C. Hill and G. Jones, *Strategic Management: An Integrated Approach,* 5th edn (Boston, MA, and New York: Houghton Mifflin Company, 2001, p. 450).
10. The Stanley Works, *Product Development Process*. September 1999, p. P-19.

14 Concluding remarks and insights about product innovation in the twenty-first century

Introduction

This chapter adds insights on how leading organizations are improving their processes and techniques for developing high-quality, superior-performance, and low-cost products having superior reliability and durability. The demands are not only on the products, but also on the processes and the people involved. Effective companies have to create and launch new products with outstanding attributes and in record times. They have to create a positive climate for being the best and achieving superior outcomes.

Product innovation has evolved dramatically over the latter part of the twentieth century. Leading corporations have integrated product development into their organizational constructs and have progressed from the linear flow of project-management thinking to a more-dynamic and interactive process-management framework, attempting to maximize synchronization of the activities and speed to market. On a global basis, most large companies are using some form of integrated product development (IPD) and are incorporating contributions of their customers, stakeholders, supply networks, strategic partnerships, related industries, and stakeholders into the new-product development (NPD) process.

Product innovation in the twenty-first century continues to evolve as new methods and techniques become available. Nevertheless, the near-term challenges include how to maintain continuous improvement and to discover even better ways of leading and managing product innovation. Leading companies are exploring the means to develop products virtually and to improve further the effectiveness of their NPD programs. While many companies are trying to reduce time to market, enhance quality and performance, and increase the probabilities of being successful, innovative companies are also expanding the thoroughness of their assessments and perfecting their outcomes through sustainable development.

Product innovation and IPD provide a strategic-management methodology for solving business problems, meeting the expectations of the business environment, and sustaining the organization over the long term. They are broad management constructs focusing on creativity and innovation to create better products and processes for improved outcomes. The primary drivers include the social, economic, market, environmental, and business conditions and trends; the consequences and impacts of technologies, products, processes, and operations; and the pressing need for sustaining competitive advantages and successful strategic positions over the long term.

Product innovation requires creativity, knowledge, experience, and learning. The stakeholder-based (principle-based as well) methodology described throughout the book provides a balanced approach for everyone involved in the NPD process and all of the related constituents. Leading corporations continue to enhance their product-innovation constructs, to reach for new heights, and to become sustainable and enriched through innovation.

The enterprise-management model and product innovation provide the logic, the systems, the processes, and the mechanisms for leading change, dealing with the consequences and impacts of products, processes, and operations during their life cycles, and creating innovative ways of sustaining the future. This includes improving every facet of the enterprise from the small detail to the most significant NPD program.

The changing world of product innovation

Intense global competition necessitates finding more-effective ways for developing new products on an accelerated basis that meet the needs of the entire enterprise. Moreover, leadership in product innovation not only means using sophisticated development methods and cutting-edge technologies, it engenders a sense of compatibility with respect to competing forces in society, the political milieu, the economy in general, and the business environment. Products and processes are becoming more refined as the participants in the global business community learn how create more-sustainable methods for achieving business, economic, and societal goals.

The synthesis of the driving forces of social–technological–business changes will continue to shape the future of product innovation as leading organizations become more adept at creating sustainable enterprises that embody all of the dimensions involved in the prevailing conditions and forces of change. The ultimate objective is to achieve every facet of the new-product development and its process without having to make any trade-off. The most important needs and wants of such processes are to:

- Ensure full integration, with all internal participants and external customers and stakeholders playing their roles and providing contributions and analyses on a concurrent basis.
- Minimize the time and effort required for developing the new product; thereby achieving reduced time to market.
- Reduce the resources deployed during the process, minimizing the total investment and financial risk and at the same time maintaining a high probability of achieving success.

- Enhance the quality and performance of the product so that it has a differential competitive advantage in the market, which is also sustainable.
- Make choices that are based on a solid foundation of insights, analyses, design options, testing, evaluation, validation, and informed decision making in order to reduce the probability of failure, and solve problems or difficulties before they arise.
- Build sustainability into the product through comprehensive assessment and review so that the product will have a reasonably long life cycle.

The more effective the process, the more effective the results

Historically, the fundamental difficulty has been balancing the critical requirements of the NPD process. The basic questions involve: What are most important driving forces in the business environment? What do customers and stakeholders need and expect? How can the company achieve a balance between all of the goals and objectives? For example, an accelerated process often means reducing the amount of testing done to validate decisions. While time to market is improved, thoroughness may be significantly jeopardized, making the process and the results more risky. Poor quality and performance might endanger the overall advantage gained by speed.

Rapid advances in technology, innovative business practices, and stakeholder-based business models (for instance, the enterprise-management model) offer new solutions for the integration, acceleration, and perfection of product-innovation methods and techniques. In a fast-paced world of global competition and sophisticated management systems, leading change is essential for survival and success. The path toward success is rarely clear; however, in the ever-changing landscape of demanding customers and concerned stakeholders, there has to be a relentless search for improving the development processes and creating innovative solutions. The capability to conceptualize, position, design, develop, validate, and commercialize new products is a strategic factor in achieving a sustainable future (the more effective the process, the more effective the results).

The basic coverage of the book pertains to the principal aspects of the prevailing methods and techniques used by industry in the context of developing new products. The trends are to expand and enrich those methods for more-creative and more-productive approaches. While there are many innovative methods for new products being developed and it is impossible to discuss every one of them, virtual product development and design for sustainability are frequently mentioned in the literature and are approaches used by several global corporations like Siemens AG of Germany and IBM. Other derivatives of IPD include Design for Six-Sigma (DFSS) as practiced by Honeywell, General Electric, and others, and Lean Product Development developed by Toyota and used by Wiremold, Inc.

Table 14.1 provides a broad overview and assessment of such methods. Each of the methodologies has several major benefits for the practitioners. Each has significant

Table 14.1 *A description and assessment of leading new-product methodologies*

Methodology	Main attributes	Potential concerns
Design for Six-Sigma ***Quality and customer satisfaction*** **Example** • General Electric	• Highly focused on quality and identifying the needs of customers • Reduces redundancy using the fundamental elements of the process – define, measure, analyze, design, and validate • Identifies the essential requirements • Eliminates defects and negative consequences	• The basic approach is useful for improvements to existing products and derivatives thereof but may lack the sophistication for new-to-the-world products. • The process lacks specific pathways that offer reductions in time because well-defined processes are used.
Virtual product development ***Speed and integration*** **Example** • Siemens AG	• Reduces cycle time • Minimizes resources and moves toward lean design • Integrates participants using technology • Uses partners and alliances on a concurrent basis • Expands the contributions of diverse locations with different (more-global) insights • Uses CAD/CAM as a vehicle for communications and design methodologies	• Lack of true validation steps • Requires large computerized system that is complex and expensive (CATIA) • Requires a significant amount of training • Requires a totally integrated system • May have conflicts due to cultural differences
Design for sustainability ***Reduced risks and enhanced long-term viability*** **Example** • P&G	• Comprehensive life-cycle analysis of potential impacts • Improves longevity • Balances social, economic, environmental, and business considerations • Balanced solutions for stakeholders and customers • Examines the full impact of decisions from cradle to grave • Mitigates defects, burdens, and risks during design • Reduces liabilities	• Time-consuming activities for such analysis • Inadequate databases to do analysis • Lack of trained personnel • An evolving methodology which lacks widespread agreement on the specifics
Fully articulated IPD (Lean management) ***Cost effective NPD with process quality and design, production, and marketing fully integrated with suppliers and customers*** **Example** • Toyota	• Established principles for decision making; rapid decisions • Fully mapped out process; participants don't waste time figuring out process elements • Minimizes discontinuities between functions and groups • Easy to add new players to the groups • Leads to standardization and good interfaces • Saves money by using common or existing parts • Links past designs with future designs	• Needs a stable work force that is integrated • Could be seen as rigid; one method has to fit all • May stifle creativity • Requires sufficient training • Could constrain design options; thinking out of the box • Requires significant investment into linkages with suppliers

similarities with the others. As derivatives of IPD, they are related to each other. Yet, each has subtle differences that are tailored for the specific requirements of the organization.

DFSS was covered extensively in Chapter 3. Many leading corporations are adapting it. DFSS focuses on quality and performance metrics. It is the combination of total quality management (TQM) thinking and IPD approaches. While DFSS belongs to the list of innovative NPD processes, the details of DFSS are not discussed in this chapter because of the coverage in previous chapters.

Virtual product development is gaining prominence as more global companies attempt to link their far-flung development centers and integrate their capabilities into a management system. For most of the companies using virtual development it is impossible to co-locate their development organizations because of the diversity of the people involved and their geographic separation. However, the benefits of having insights from different perspectives (American, European, Asian, etc.) are significant and offer insights and contributions that are not possible if the team was co-located.

Design for sustainability (DFS) is also referred to as design for the environment (DFE) in some industries. It depends on the principles, focus, and scope. DFE is the older of the two, and it had its origin in environmental management. It focuses on design strategies that enhance the environmental quality of new products and processes. DFS is a recent new-product methodology which incorporates the social, economic, and environmental considerations and consequences, and life-cycle thinking, during design and development using a comprehensive model. It attempts to increase all of the positive aspects of products, and at the same time reduce all of the negative aspects, in an attempt to move closer to the ideal solutions (Quite frankly, the method discussed in this book follow many of the precepts of DFS.).

Fully articulated IPD (lean management) is the combination of total quality management (TQM), lean business-management practices, and stakeholder-based assessment with IPD. It is the model discussed throughout the book. In essence, it is the prevailing methodology. Even though, IPD has been in use for more than a decade, only recently have the corporations in general adapted process-management principles and techniques and started to enjoy the benefits of a fully integrated NPD process that flows seamlessly because practitioners are following a prescribed pathway.

However, there is not a single approach that incorporates all of the desirable benefits. Given the potential benefits for long-term success, the evolutionary track of IPD toward an all-encompassing methodology will continue.

The most important contribution of IPD has been the integration of the major functional areas of the organization during the development process. The sense of integration means that cross-functional teams play an essential role in facilitating the activities and processes. Advanced techniques such as quality function deployment (QFD), computer-aided design and computer-aided manufacturing (CAD/CAM) and computer design packages (virtual product development) have allowed easy access and sharing of data and information, and design and other process details, so that new products can be designed and validated quickly. Automated design and development tools and techniques have significantly contributed to improvements in speed, performance, quality, reliability, and cost structures. When speed is essential for achieving market success, particularly in fast-paced industries like electronics, the cycle-time metric is the driver. Clark and Wheelwright argue that cycle time is more important than program expenditures if the market opportunity has limited duration and missing the introduction date has serious negative financial implications. On the other hand, if the new product has a long expected life cycle, then unit cost and product performance have a greater impact on success.

Yet, with all of the sophistication, companies are still having difficulties with the coordination and timing of getting new products to market and improving the processes for doing so. The ongoing challenges are the continuous improvements in the processes for developing new products to exploit the technological capabilities of the organization. The superior NPD approach will possibly be a combination of the methods summarized in Table 14.1.

Virtual product development

Virtual product development is a highly specialized field of new-product development that uses automation, computerization, and electronic communications to facilitate the development process that employs NPD teams at remote locations. Many large (global) corporations are embracing virtual product development as the means to increase speed to market and improve effectiveness of the product innovation process. Companies like Siemens AG have evolved process capabilities to create new products using CAD/CAM systems, simulations, digital networks, rapid prototyping, and advanced telecommunications; these processes enable them to work on their development programs continuously, 24 hours a day. While such companies are still in the minority, the trend toward virtual development is growing.

Virtual reality and the conception of virtual product development are on the leading edge of change. They enhance an organization's ability to obtain speed, quality, performance, and high value. Virtual product development incorporates significant improvements to the underlying premises of IPD by using computer and information technologies for streamlining the development process. Siemens AG calls their methodology "Streamlined Development" (time-optimized processes). The approach is to get new products to the market sooner with the same high-quality and cost-effective designs as in the past through the elimination of barriers that impede the work flow; the following are some of the techniques used to achieve a 1.8-fold increase in process speed:[1]

- Spatial merging of team members with different tasks (e.g. design, production, test laboratories, controlling).
- Maintenance of direct contact between developers and suppliers, including topic-related joint workshop.
- Enhanced consideration of customer-oriented solutions during the product planning stage.
- Early involvement of workshop and assembly personnel in the drawing up of concepts and designing of products.

While most of these points are really the underpinnings of IPD, the complete integration using virtual reality and related computer-based methodologies is a significant modification to the prevailing approaches. The notion of “time-optimized” product development has been the underlying consideration during the 1990s as IPD made the transition from being a radical change in the development of new products to the mainstream of business practices. Streamlining new-product development is the ongoing challenge that is central to the discussions within industry and the academic communities. The main question is: What are the appropriate mechanisms and methods for improving the processes?

Again, integration is the essential term. The evolutionary track suggests that a model that is fully integrated with the time dimension is pivotal. The transformation to virtual product-development methodology will occur naturally over time as global companies improve their capabilities to link elements within the NPD process. More importantly, it will evolve as more companies use information technologies to integrate their management systems. The integration of the supply network is critical for effective new-product development. The Mercedes plant in Stuttgart, Germany is developing an information-management system that links the entire supply chain (seven tiers deep) in its product delivery system.

Virtual product development may eliminate the need for formal review steps. Planning and implementation are embedded within the overall framework and directly linked within the process, which will have fewer distinct phases. There will be reviews but they will be embedded into a seamless process. Figure 14.1 provides a rough outline of the flow of activities from phase to phase using virtual product-development methodology.

The phases flow seamlessly from one to the other. To accelerate the process, certain activities in a subsequent phase begin before the preceding phase has been completed. The reason for such action is to provide the continuity of flow at a low cost under the premise that the program will proceed. As with most approaches, there are advantages and disadvantages to the methodology. The main advantages are the reduction in time and money spent on the program along with the full integration of the process over time as upstream and downstream activities are linked directly with each other. Indeed, the downstream activities flow immediately from the upstream, eliminating the start and

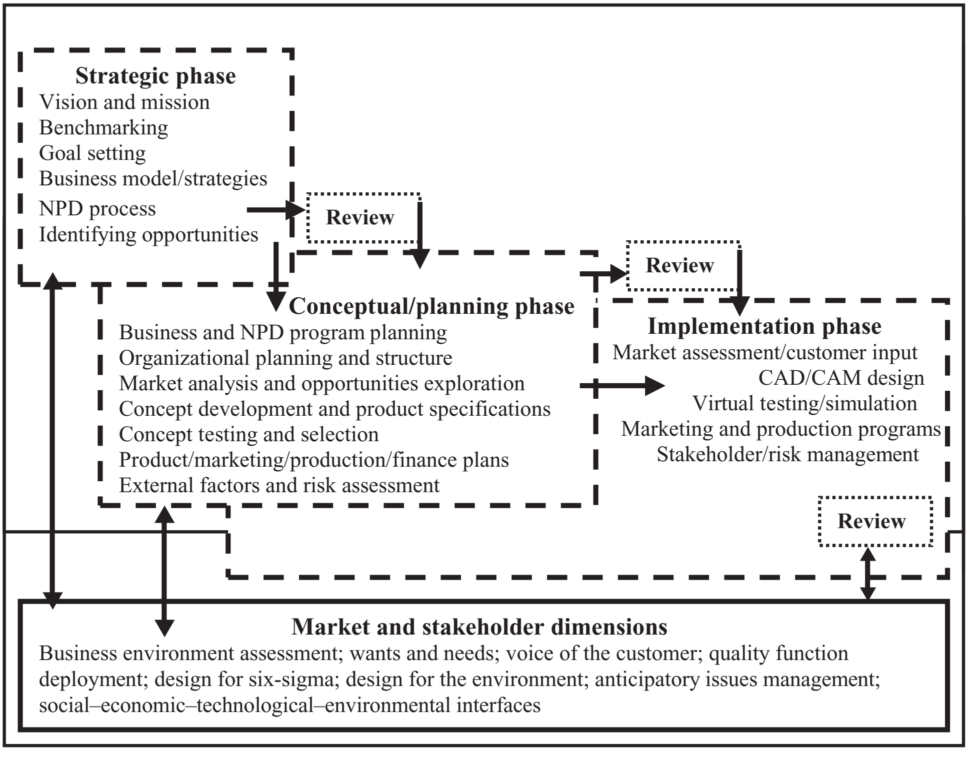

Figure 14.1 A simplified schematic of a seamless version of virtual product development

stop aspects of the conventional NPD process. The most significant disadvantages are the dependency on the information technology system (CAD/CAM or virtual) to ensure the proper linkages with all of the participants and the flow of data and information. There are also the potential difficulties of misinterpreting information that could lead to faulty conclusions. While the reliance on information technology is not a major concern, the automation of the creative process where people are not engaged face to face may limit the flow of diverse views and out-of-the-box thinking. Resource allocation may be a concern since teams of people are dependent on the outputs of others for their inputs. If one of the teams cannot fulfill its responsibilities, it may have negative effects on the entire endeavor. If the main objectives (advantages sought) are the savings of time and money, then the NPD process does not have any slack or resources in reserve to solve an unexpected difficulty. The overwhelming concern is the possibility of not being as thorough as the world expects. The focus on speed and time may subordinate the other objectives.

The most critical facet of full integration is the potential to discover defects very early in the overall process and to cure them or make appropriate adjustments as quickly as possible. Indeed, solutions can be built into the process.

Sustainable development and environmentally conscious product development

Moving toward design for sustainability (DFS)

The underpinnings of "sustainable development" are discovering and curing hidden defects and burdens that may seriously affect the viability of the new product. Sustainable development focuses on creating products that are more capable and attractive from social, economic, environmental, technological, and legal perspectives. The approach focuses on minimizing the risks and liabilities and improving the longevity of the new product. The emphasis is on maximizing the value derived by all of the constituents of the enterprise.

Sustainable development is the complete synthesis of conventional compliance-based systems with new forms of corporate, social, economic, and environmental strategies that link market, customer, stakeholder, and environmental needs with product development and the product delivery system. This third stage of environmental management focuses on creating new products with built-in social, technical, economic, and environmental solutions.

Business leadership in the twenty-first century requires creative methods and technological innovations to solve existing problems and manage emerging issues. Leadership means being on the leading edge of proactive changes to the management system and the enterprise, dealing with the negative consequences of every product and process from cradle to grave, and producing significant improvements from every facet of the enterprise. Everyone shares the responsibility to make the products and processes more successful and sustainable. Social, economic, and environmental sustainability will be as powerful in the vocabulary of business as quality, efficiency, and productivity.

The responsibility for developing environmental solutions is no longer the sole function of environment, health and safety professionals. The new players include product designers, design and development engineers, R&D engineers, and marketing professionals.

During the 1970s, environmental management was in its infancy. Organizations desperately tried to stay abreast of the mandates for environmental protection. These included mandates for reducing air emissions, improving water effluents, managing and reducing hazardous waste, preventing accidents and spills, and dealing with legacies of improperly disposed wastes. These challenges required significant investments into improved practices and pollution-abatement equipment. The prevailing philosophy was to comply with the rules and regulations, but only to the extent necessary. The majority of companies either resisted the encroachment of the federal or state governments into their domain, or simply followed the rules and regulations minimizing the impact on their operations and businesses. Changes were made to accommodate the requirements, but there was resistance to making more-fundamental changes.

The 1980s were pivotal. Environmental, health and safety concerns began to be considered by a wider number of business functions. In the United States, the enactment of the Emergency Planning and Community Right-to-Know Act (ECRA) in 1986 forced businesses to disclose information about their operations and the waste generated. ECRA expanded customers' and stakeholders' right to know about the specifics of environmental issues. Business philosophies pertaining to environmental issues were transformed from compliance thinking to waste minimization and pollution prevention. Regulatory compliance became a two-dimensional approach dealing with laws and regulations, and managing stakeholder and customer satisfaction. Although this represented a significant change, organizations were still responding to threats rather than discovering opportunities.

Market-driven mandates became the important drivers in the 1990s. "Pollution prevention" (P2) rather than waste management became the prevailing methodology for solving environmental problems. P2 was not necessarily new; 3M had started its program in 1975. With the passage of the Pollution Prevention Act in 1990, P2 was formalized and became pervasive, albeit voluntary. By embracing P2, environmental management reached a higher level of growth and maturity. The emphasis on having an environmental-management system became an essential part of achieving significant results. For example, United Technologies Corporation (UTC) reduced its waste streams by 80% during the 1990s. Therefore, UTC's CEO George David established a program calling for a 10-fold improvement in 1997.

The environmental decision-making process has changed from a simple construct based on compliance and pollution prevention to an elegant management system for creating environmentally conscious new products. Such a system examines all of the implications and impacts of business decisions and provides a balanced solution for all stakeholders and customers. According to Kaplan and Norton, an organization must use a balanced scorecard when making decisions.[2] They suggest that business organizations must balance their objectives by including financial, customer satisfaction, organizational learning, and internal factors.

DFS requires problem solving based on environmental and business metrics, while fostering the development of programs and initiatives which not only exceed compliance, but create competitive advantages through reduced costs, increased brand image, and the enhancement of market share. It also expands the scope of environmental management from the domain of operations management and environmental professionals to product designers, R&D personnel, and marketing professionals.

Linking product development with environmental-management considerations

Environmentally conscious product development combines the concepts and techniques of IPD with the principles and methods of design for the environment. The convergence of IPD and DFS is intended to produce cost-effective designs that meet or exceed customer and stakeholder expectations, while maximizing the performance of the system and minimizing the negative impacts on the external environment. A primary focus is on the identification and analysis of the ingredients and energy used to create and produce a product and the environmental implications of its production. The linkage of environmental strategy with product development extends IPD and concurrent engineering to the next logical stage by ensuring that all aspects of design analysis and decision making have been thoroughly explored. The bottom line is to contribute to making products and processes more environmentally acceptable to customers and stakeholders.

Linking environmental-management strategy to product development necessitates an enterprise view of all of the participants, their needs and contributions, the consequences of processes used to create products, and the opportunities for improvements. This includes defining the strategic tasks, collecting information about opportunities and challenges, developing a vision of the future situation, and managing changes over time.

Environmentally conscious design and marketing play significant roles in developing and introducing new products by addressing key stakeholder needs at an early stage in the NPD process. By building key stakeholder relationships with government, non-government organizations, and consumer entities, a firm can not only anticipate issues it would otherwise not have been aware of, but can build trust among these key constituents. Through this process, a firm can enhance product-brand reputation as well as the reputation of the firm.

DFS: an integrated model (simplified view)[3]

DFS is a relatively new product-innovation construct dealing with a "cradle-to-grave" evaluation of: (1) raw material acquisition; (2) materials processing; (3) materials production; (4) manufacturing and assembly; (5) use and service; (6) retirement and disposal. It includes life-cycle considerations and analysis of all of the upstream implications of supply-chain management and manufacturing, and the downstream aspects of product use and retirement. It includes the perspectives, stakeholders, and other entities that play an important role in developing new products.

Life-cycle assessment is a systematic method used to analyze and evaluate the resources, outcomes, and environmental burdens associated with a product, the related processes, distribution requirements, and applications. The analysis is undertaken to identify, quantify, and evaluate the materials and energy used to produce and use the product over its entire life cycle. The approach is a multi-stage input–output model that examines all of the inputs and outputs and their impacts, including materials, products, wastes, and emissions. The model examines the existing situation and explores the possibilities for systematic improvements through product design aspects.

The implementation of design strategies for reducing environmental impacts is based on analysis of product requirements and the selection of the most economic, technical and environmentally conscious approaches. Appropriate strategies satisfy not only the economic and functional objectives of the product design but include the environmental, health and safety aspects as well. An appropriate design is one that satisfies the entire set of product requirements, thus creating a sustainable design for every perspective. It includes strategies associated with managing re-manufacturing, reuse and recycling and using design for disassembly, design for reuse, design for recovery, and design for maintainability.

The model follows the construct of the generic IPD process with an overlay of DFS. The essential requirement for effective convergence of the two methodologies is that DFS considerations have to be embedded on a concurrent basis. The NPD process cannot be interrupted to do life-cycle assessments or to determine the impacts of the design after the process elements have been completed. Integration of Design for Sustainability and concurrent engineering provide a more-comprehensive solution for achieving outstanding new products. It may not be perfection, but it is moving in the right direction. Figure 14.2 indicates how some of the DFS elements fit within the generic IPD process.

The suggested approach is one of many ways in which the two methodologies can be integrated into a single system. The actual methodology used in any specific situation is dependent of the context of the business environment and the approach has to be modified accordingly. Unfortunately, the more-comprehensive approach requires a more-complicated structure. However, there is a huge potential advantage of having an all-encompassing business (NPD) model that includes every aspects of the design and development process, regardless of the driving force.

Fully articulated IPD methodology

This book covers a generic model and the basic variations of IPD methodologies. These are the prevailing models at the beginning of the twenty-first century. Most of the concepts, constructs, and techniques have been explained and evaluated throughout the text. Fully articulated IPD means that all of the details associated with an NPD program are fully established early on, so that all participants are aware of the requirements and their roles in the process.

IPD continues to evolve as companies seek competitive advantages over their competitors, and practitioners attempt to improve new-product successes and minimize the failures.

IPD has had a profound effect on the ability to commercialize new products. The total time required to introduce a new product has been reduced dramatically in recent years. For example, the time to launch a new automobile has been cut in half from

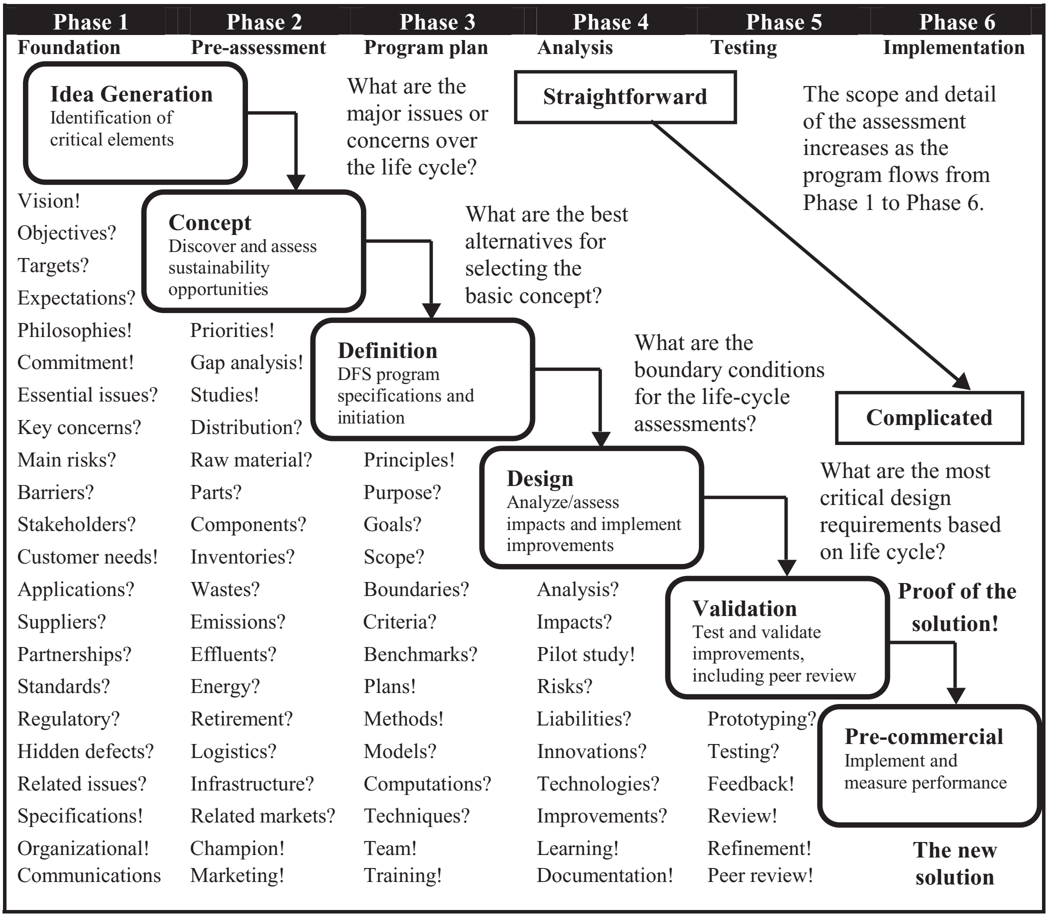

Figure 14.2 Embedding DFS and design for six-sigma within IPD

five years to less than two and a half years. General Motors is trying to reduce its cycle time to 24 months, while Toyota's new target is 18 months.

The overall IPD process has become more systematic and the sequence of activities is more predictable. The leading organizations have also made their processes more lean, eliminating wasteful activities that cost time and money. The following are some of the major aspects of IPD that have lead to such dramatic improvements:

- Using cross-functional teams facilitates coordination and communication between the participants, across disciplines and time, and within an NPD program so that fewer mistakes are made. Activities are completed correctly the first time because the inputs for good decision making are readily available, and upstream and downstream participants collaborate in the decision-making process.
- Concurrent design and development means that every functional aspect of an NPD program is being developed simultaneously so that the feasibility and potential value

of the program can be ascertained on an ongoing basis; go/no-go decisions can be made theoretical at any point, not just at selected points (reviews) or worse yet at the end of the process.
- IPD means that each participant has the appropriate information and data when making decisions. This approach tends to minimize errors due to inadequate communications since everyone is linked.
- The financial investment into all of the new-product programs can be effectively managed using a common methodology, allowing management to discern good opportunities from weaker ones. Early termination of a questionable NPD program saves time and money, providing resources for opportunities that are more attractive.

Concluding insights

Summarizing the implications of product innovation

Product innovation is about leading change. It is a subset of the broad perspectives of managing change, which includes technological innovation and business-concept innovation. All three are essential for success and each focuses on different needs for managing a business enterprise from an innovation perspective.
- Product innovation focuses on developing new products for the prevailing business conditions and trends. Product innovation is most effective when the business environment is stable, and incremental changes are practical ways for keeping pace with evolving customer and stakeholder needs.
- Technological innovation concentrates on managing new technologies and radical innovations based on R&D or new sources of technologies. It is most effective when the business environment is turbulent and when customers and stakeholders require revolutionary solutions for their problems.
- Business-concept innovation involves changing the business model when the business environment has shifted dramatically and the old enterprise model is no longer acceptable.

The prime application of the methods used for product innovation is the creation of new products, services, and processes that can be integrated into the business enterprise to improve, update, or replace existing versions or to create new opportunities. The methods may also apply when technological innovation becomes an important part of the approach, especially for new-generation products or new-to-the-world products.

Table 14.2 summarizes some of the essential aspects of the types of product innovations and their implications from internal and external perspectives. The concepts, methods, and techniques described have focused on the simpler types of product innovation that are usually more appropriate for stable business environments.

Table 14.2 *The logic of product innovation (internal and external views)*

Product type	External perspectives	Internal perspectives
Turbulent business environment	Uncertainty in customer demand	Strategic direction and leadership
	Vulnerabilities in markets	Disruptive technologies and products
Radical innovation	New types of competition	Value relationships and networks
New technologies	New pressures from stakeholders	R&D
New to the world	Technological changes/ inventions	Uncertainty, risks, rewards, concerns!
New generation		Opportunities and threats
	Changes in business environment	
Stable business environment	Customer and stakeholder needs	Leveraging core capabilities
	Market conditions and trends	Marketing, sales, technical, production
Derivatives	Value creation and benefits	Availability of finances and resources
New markets	Suppliers and partnerships	Quality, performance, speed, timing
Varieties/versions	Competitive forces and actions	Financial implications
Improvements	Linear changes in economics	Metrics
Cost reductions	Infrastructure	Investments
	Related industries	Risks versus rewards
		Standardization, costs, productivity

Product innovation is most suitable for the stable business environment, while technological innovation is most suitable for the more-turbulent situations. Process management is more appropriate for the former, and project management is more pertinent for the latter. However, practitioners and their organizations have to decide on the most effective methods for developing new products. There may be generic approaches, but there is not a single answer for every situation. It is dependent on the actual business environment and the resources and capabilities of the organization.

The ongoing evolution of IPD

Given the dynamics of the global business environment and the rapidity of change, IPD will continue to evolve into an even more comprehensive methodology, incorporating the salient elements of the innovative approaches being developed by leading corporations. It can be envisioned that future NPD methods will combine the critical features of the main variants of IPD into a single management system. Organizations will not have the luxury of either failing to discover all of the potential hidden defects or taking a piecemeal approach for developing new products. IPD will merge the aspects of virtual product development and design for sustainability into a comprehensive model that includes the notions of speed, customer and stakeholder satisfaction, value, thoroughness, performance, reliability, quality, zero defects, and business success.

Just as IPD evolved during the 1990s to include concurrent engineering, total quality management, supply-chain management, E-business, and other leading constructs, it will incorporate the prevailing methods of the twenty-first century and become an even more dynamic process for developing new products. The most significant trends for the improvement of the NPD processes may include the following:

- Continued declining cycle time to develop new products because the longevity of existing products will continue to be eroded by competition and the demand for better solutions. Technology and innovations will likewise reduce the opportunity available in the market for the new products.
- Demands for improved quality and performance will increase as leading producers move toward six-sigma quality making the prevailing quality appear to be inferior if not obsolete. This trend has been proceeding for more than 20 years.
- Value will continue to be a critical factor for success. Customers expect high quality and low prices. The trend toward improved cost structure will become even more crucial as global competition makes it more difficult to sell high-cost products.
- Due to the high costs of litigation and product-liability problems, sustainability and life-cycle assessment will become more important during the development of a new product. Corporations will have to discover all potential defects and burdens, and solve such problems during the development process. The liability of a defective design will be extremely great, making the conventional approach of letting customers find hidden defects unacceptable.
- Information technologies will facilitate the rapid development of new products as participants are linked via telecommunications and advanced computer software programs to carry out the development process on a 24-hours-a-day basis. Teams in remote locations will be linked electronically and will work seamlessly together although they may never meet each other.
- Advanced prototyping technologies and other such methods will allow for the rapid testing of the new product so that validation and speed can coexist. These technologies will provide the means to ensure accelerated development and thorough analysis of the design and production elements.
- The concept of sustainability will become prevalent as organizations seek the means to reduce risks and eliminate liabilities. The notion of having a rapid and comprehensive NPD model will gain prominence.
- NPD models will continue to integrate all facets of the development, including linkages with customers, stakeholders, suppliers, related industries, the infrastructure, and even competitors.

The essence of IPD

Managing the fundamentals is critical for achieving success in the NPD arena. Regardless of the situation, the **People**, the **Process**, the **Plan**, the **Program**, and the **Product** are the essence of new-product development. Success is obtained through the intellectual contributions of people and their dedication to the process. The people are the heroes through teamwork, and their commitment to the NPD process and the new

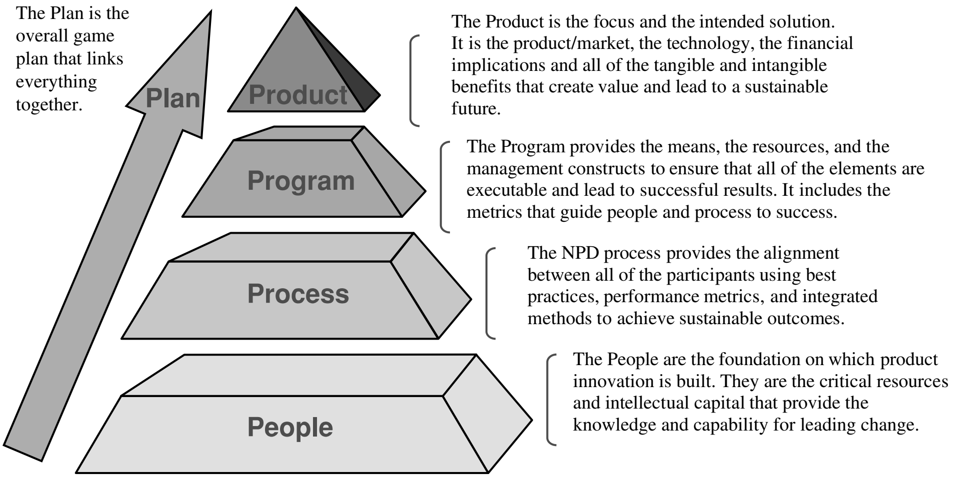

Figure 14.3 The essence of new-product development

products and services created. The secrets to success are effective communications, a well-trained team, effective coordination, balanced decision making, and, most importantly, the pursuit of excellence. The attitude of the participants is one of the most important parts of achieving success. Confident outlooks and positive attitudes are essential for minimizing conflicts and achieving effective coordination.

A synchronized process is likewise crucial for success, especially in the long term. The process has to link all activities so that all of the essential elements at any given point in the process are developed on a concurrent basis. Success is achieved by using proven methods and practices as well as by improving the process and its elements during and after the NPD program. It is important to realize that NPD is a continuum and that the process goes on. For most corporations and participants there will be a similar new-product opportunity immediately upon completion of the current program. The NPD program is the structure that gives life to the new product.

The new product is the means to a sustainable competitive advantage. It provides the mechanism to achieve customer satisfaction and to ensure customer loyalty. It is the result or tangible outcome of the process and program. The product is the link to the future as well as the legacy of the past. A new product offers the enterprise new opportunities for success and the ability to sustain the positive outcomes for another generation. Figure 14.3 provides a graphic presentation of the NPD perspectives.

Concluding comments

NPD thinking follows scientific methods. The book uses a multi-dimensional approach for describing, analyzing, and explaining the concepts, methods, and techniques used for developing new products in an environment of rapid change and demanding standards. The basic framework incorporates an integrated perspective, pertaining to the linkages between the external dimensions and the internal capabilities, for formulating and implementing the most agile and effective game plan given the existing conditions and trends.

The NPD framework describes the way businesses develop innovative processes for managing product design and development programs, and for creating tools and techniques to facilitate the related activities. It offers generic approaches for managing the processes. The central focus is on the "why" and "how" questions. The methods and techniques provide insights that can be applied to many NPD situations. It is important to understand that the constructs are presented as generic approaches. In dealing with complex, diverse, and innovative situations, it is imperative that the practitioners understand the dynamics of their system and determine or discover theories and insights pertaining to the realities of the actual business environment. It is incumbent upon the practitioner using the premises and approaches in the book to modify the elements to fit his or her situation.

Notes

1. H. Knobloch, Time-optimized processes in development. http://w4.siemens.de/FuI/archiv/zeitschrift/heft2_97/artike109/ index.html, p. 1.
2. R. Kaplan and D. Norton, *The Balanced Scorecard: Translating Strategy into Action*. Boston, MA: Harvard Business School Press, 1996, pp. 7–8.
3. It is not practical to describe in detail all of the facets and implications of Design for Sustainability. The author plans to publish a book entitled: *Environmental Leadership and Business Integration: Moving toward Sustainability through Product and Technological Innovation,* during 2006.

Glossary

Term/concept	Definition or use of the term or concept
After-market considerations	After-market considerations include the ongoing solutions for the customer and the required support services. Such services include installation, assembly instructions, guidelines, manuals, information on the Internet, help desk, etc.
A–T–A–R model	The A–T–A–R model suggests that the market potential for a new product equals the percentage of customers who become aware (A) of the new product multiplied by the percentage who try (T) the new product multiplied by the percentage who have the product available (A) to them multiplied by the percentage who repeat (R) using the product.
Attributes	The sum of the benefits, features, and functions of a product deployed to meet the needs of customers.
Axiomatic design	Axiomatic design focuses on dramatically improving the means to achieve a systematic design with the full integration of the enterprise. Axioms are fundamental truths that are embedded in the design process. The underpinning of axioms is scientific thinking pertaining to superior designs.
Batch flow	Product batches are produced on a limited number of identifiable paths or routings through the plant, or the product is produced in definitive quantities.
Brainstorming	Brainstorming is an open exchange of ideas without negative feedback or adverse consequences, attempting to create “out-of-the-box” thinking about new-product possibilities.
Brand equity or branding	Brand equity is the term used for creating awareness and acceptance of the company’s product as a “unique” position, with its own attributes and value proposition.

Term/concept	Definition or use of the term or concept
Bullwhip or whiplash effect	A phenomenon that illustrates the dynamic nature of supply chains because a small variance in actual demand grows as it moves upstream and therefore "cracks the whip" for upstream suppliers.
Business environment	The external forces impinging upon the organization. They include the social, economic, political, technological, environmental, and market forces. The business environment includes the external dimensions of markets, competition, related industries, supply networks, and the infrastructure.
Capability index (C_p)	The capability index is the measure of the capability of a process to meet customer requirements.
Capacity utilization	Capacity utilization measures how much of the design capacity is utilized at a specific time.
Computer-aided design (CAD)	CAD is information technology incorporating software and hardware into a computerized design system that links all of the participants and design elements, and integrates the design and the work flow.
Computer-aided engineering (CAE)	CAE approaches are computerized tools and techniques used to improve the productivity of the NPD process, especially the design aspects. Generally, CAE involves software programs that facilitate the gathering, handling, and management of data and information.
Computer-aided manufacturing (CAM)	CAM links the design elements to the manufacturing requirements and production processes, eliminating the steps to convert information on drawings into details used for producing a prototype or manufacturing the product.
Concept	A concept is a new-product candidate that is fully articulated into a defined opportunity and expressed in terms of the targeted product/market, and described based on its marketability, producibility, and feasibility perspectives.
Concurrent engineering	A systematic approach to the integrated, concurrent development of a product and its related processes that emphasizes response to customer expectations and embodies team values of cooperation, trust, and sharing.
Continuous flow	A production method where the materials being processed flow continuously, rather than in discrete units. Continuous-flow operations produce large-volume products that are often commodities.

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Term/concept	Definition or use of the term or concept
Continuous improvement	Continuous improvement is a broad concept that implies that products and processes are never perfect and require ongoing improvements.
Core capabilities	Core capabilities are the fundamental strengths that the organization enjoys, but they are not necessarily unique to the organization.
Core competencies	Core competencies are the capabilities of the organization that it uniquely possesses and are difficult for others to emulate. C. K. Prahalad and Gary Hamel define core competencies as "the collective learning in an organization."
Cross-functional team	A group (team) of individuals from various disciplines who are organized into a temporary work arrangement to perform selected tasks concurrently.
Derivative	A variation to a technology platform that results in a product form that is different from its predecessors. It offers different attributes.
Design capacity	Design capacity is defined as the level at which the facility can operate for long periods without major breakdowns.
Design for manufacture (DFM)	The DFM philosophy emphasizes reducing the total number of parts contained in a design and reducing the total number of different parts. It also includes the notion of simplification.
Design for reliability (DFR)	Design for reliability focuses on improving product longevity and minimizing failures by increasing component reliability and using redundant parts and components at critical points in the design.
Design for six-sigma (DFSS)	DFSS provides a systematic means of achieving higher quality and world-class performance with a high degree of customer and stakeholder satisfaction.
Design for the environment (DFE)	DFE is a systematic approach for evaluating the consequences of products and processes and their impact on human health and the natural environment. DFE is an environmental management construct based on cradle-to-grave assessments of products and processes.
Distribution channels	Distribution channels include intermediaries, wholesalers, retailers, and other organizations such as value-added resellers who play a role interfacing with the customer.
Differentiation	A position with one or more attributes that are significantly different from those offered by others.

Term/concept	Definition or use of the term or concept
Effects	Effects are the impacts or consequences on the downstream processes, operations, or customers if the failure mode is not prevented or corrected. They are also the outcomes of upstream actions at some time in the future.
Enterprise	The enterprise is the entire organization (corporation) with all of its external relationships and linkages. It is a high-level strategic-management system of the corporation and all of its strategic business units and their product delivery systems along with the all of the virtual relationships with supply networks, partnerships, alliances, and other value networks.
Enterprise management	The full integration of the internal functional areas and strategic position of the organization with all of the external factors influencing the business.
Enterprise-management model (EMM)	The EMM presents a holistic, multi-dimensional view of the business environment confronting NPD opportunities. It is an embedded management system that includes the strategic-management systems and the product delivery systems. EMM provides a framework for ensuring that all of the essential dimensions and elements therein are covered in the NPD process. The model sets the stage for a descriptive, analytical, and structural understanding of the needs, opportunities, challenges, requirements, specifications, and flow of the NPD process.
Entrepreneur	A business person who aims to create or take advantage of opportunities, and acquire and build the capabilities, resources, systems, processes, and methods necessary to formulate and implement business strategies, and achieve positive outcomes.
Evolutionary innovation	Evolutionary innovation focuses on incremental improvements to existing products to enhance their value for existing markets and customers. It is generally a response to short-term pressures by customers, stakeholders, and competitors, or a concerted effort to stay ahead of the driving forces of change.
Failure mode	Failure mode is the mechanism causing the product or process, or any part thereof, to fail to meet specifications.
Failure mode and effects analysis (FMEA)	FMEA is an analytical tool used to determine the robustness and safety of product and process designs and to understand the underlying risks. FMEA is a quantitative approach used to identify the mechanisms in a product or process that can fail, to determine the severity and the likelihood of the potential problem or failure, and to establish the means of preventing those failures.

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Term/concept	Definition or use of the term or concept
Financial risk	Financial risks include the failure to achieve an acceptable financial reward, the damage to the corporate reputation and its ability to generate future cash flow, and the costs to mitigate defective products and/or deficiencies of the NPD program.
Focus	The concentration of time, effort, and money on a given geographical area or group of customers where a competitive advantage can be achieved.
Framework	A management system that includes the interrelated dimensions and the elements thereof, and defines the boundaries and scope of the system from a spatial and temporal perspective.
Fusion	Two or more technologies are combined to create a new product having enhanced attributes and expanded potential.
Globalization	The notion that the world economies are shifting toward a borderless economic structure in which nation states are less relevant and global corporations vie to satisfy customer demand based on standardized (globalized) products and more-homogenized approaches. Space and time are compressed and geography is not a critical factor.
Idea	An idea is simply a new-product possibility that requires further definition before it can be converted into an opportunity.
Incremental change	Incremental change focuses on proportional improvements in products and technologies, typically measured in terms of 5 to 20% improvement. It is also viewed as evolutionary change.
Industry structure	The industry dimensions include the producer, its competitors, and related industries.
Innovation	A change or improvement that has a positive outcome(s) with respect to customers, stakeholders, and the organization.
Intangibles	Intangibles include psychological and other less-apparent aspects that may be important to customers and stakeholders.
Integrated product design	Integrated product design involves selecting technologies and technical functions, and determining the product configuration based on the requirements of the entire enterprise. It examines the elements of the creative activities performed to translate the conceptual aspects into a definitive product/market form.

Term/concept	Definition or use of the term or concept
Integrated product development (IPD)	A powerful management construct that systematically links the external business environment and its needs, wants, opportunities, and challenges with the internal dimensions of the organization, and its capabilities and resources, to create innovative solutions based on improved products and services. It is the concurrent development of new products using cross-functional teams that are aligned strategically and tactically. It is the prevailing form of product innovation.
Job shops	Job shops are production methods that are characterized by a jumbled product flow where "*n*" jobs must be processed through "*m*" machines.
Lean production	A manufacturing system that minimizes inventory and other resources and produces, from the customer's perspective, exactly what is required, when it is required.
Learning curve or experience effects	The learning-curve effect suggests that the cost of the materials, parts, components, and therefore the product, decline with increases in volume. The experience curve suggests that production costs and the time to complete work activities decline with cumulative volume based on knowledge of the process.
Management system	The management system is the integration of all of the processes and activities, the relationships and people, and the leadership and organizational capabilities, knowledge, skills, and methods.
Manufacturability	A term used to describe the philosophy and practice of designing products that are easier to manufacture; the term also indicates that production requirements have been contemplated during design.
Market risks	Market risks include uncertainties about market conditions and trends, or unknown factors that negatively affect the design and decisions made about the new product. They also include changes in the market(s) during the NPD process that have adverse consequences on the new product.
Market segmentation	Market segmentation is the categorization of the market into definitive segments that exhibit homogeneous characteristics. Market segmentation is used to target a group of customers having common needs that are identifiable and clustered by behavioristic, geographic, demographic, psychographic, and other patterns.

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Term/concept	Definition or use of the term or concept
Market testing	Market testing involves validating the product via customers based on market conditions and the implications of the business environment.
Mean time between failures (MTBF)	MTBF is the average time between failures of a product. It is a measure of reliability. MTBF = Total time of use ÷ Total number of failures.
Methodology	The processes, procedures, practices, and guidelines used by practitioners and management to formulate and execute strategies, programs, and action plans. It includes the methods, techniques, and analysis used to understand the prevailing situation and to determine appropriate actions.
Mission	The mission defines the long-term direction of the organization and how new-product opportunities fit the strategic direction. It defines opportunities and fuels the passion for achieving outstanding results.
New-product development	The overarching term used to describe the processes, programs, and practices used to identify, conceptualize, design, develop, validate, and commercialize new products and services.
New-to-the-world products	Products that are new creations not based on previous product lines or technology platforms. They are normally the results of technological development.
Outsourcing	Outsourcing is the use of outside suppliers to provide services or products, frequently offering a cost-competitive alternative to performing the required activities in-house.
Pathway	A notion taken from organic chemistry that represents one of several ways of achieving an end result(s). It has the connotation of being a defined route with flexibility built in.
Penetration pricing	Penetration pricing establishes a relatively low price at launch to stimulate market development and growth. It is used to build market demand quickly and obtain market share.
Performance-to-price ratio	A metric that measures the value or benefits derived from the new product in relation to the cost or price the customer has to pay.
Pilot and trial production	Production-oriented testing that includes validation of the product quality and performance as produced by the operating system, the assurance that the system operates reliably, and the determination that the people have the knowledge to perform their roles and responsibilities.

Term/concept	Definition or use of the term or concept
"Plan–Do–Study–Act" (PDSA)	The "Plan" provides for customer needs in the product characteristics. The "Do" integrates the technical features and functions of the product into a viable design. The "Study" includes analysis and testing that verify the efficacy and safety of the design. The "Act" is the incorporation of the design element and the continuation of the process.
Platform	The technology base that a series of products are built upon. The platform is the basic architecture of the technology.
Pre-commercialization	Pre-commercialization includes all of the activities required to prepare for the launch of the new product. It includes initiating the marketing campaign, building production facility(s) and/or inventory, and distributing the product.
Process-flow diagram	The process-flow diagram provides a graphical representation of how parts and materials flow through the process, and depicts the overall behavior of the operating system. Tasks are represented as small rectangles, flows (both physical as well as informational) are represented using arrows, inverted triangles represent inventory storage (incoming material as well as work-in-process), and circles represent the storage of information.
Process management	Process management is a horizontal construct that links activities and actions for converting inputs into outputs in a systematic way.
Product architecture	Product architecture involves product characteristics, material selection, packaging options, resource utilization, and market considerations. It involves the determination of the features, functions, benefits, and detailed specifications of the product.
Product delivery system	The operating system involved in the marketing and production of existing products and the related services. It focuses on near-term results and the operational requirements to meet expectations.
Product engineering	Product engineering is the creative activities of defining the product in the light of all of the internal dimensions and external forces of the business environment. It translates the product architecture into design specifications that give specificity to the product.

(*cont.*)

Term/concept	Definition or use of the term or concept
Product innovation	A broad management construct that includes the initiatives, methods, techniques, and processes for making incremental changes and improvements to existing products and services. It involves making evolutionary changes to the products and product lines, employing the prevailing technologies and organizational capabilities. It represents superior improvements for meeting the needs of customers and stakeholders.
Product liability	The legal construct and requirement that products are designed and produced to ensure safe and functional applications. The failure to provide such outcomes can lead to legal claims against the producer and agents.
Product life-cycle thinking	Product life-cycle thinking includes planning for the requirements necessary to assure the success of the product after launch and during its life in the market(s).
Product/market	The product/market construct combines the essence of the product in a market segment and defines the product attributes based on market position.
Product portfolio	The product portfolio includes the core products, related products, services, after-market products and services, and their relationship to new products.
Product testing	Product testing involves validating the design and production qualities of the product to ensure that it meets design requirements and specifications.
Product-structure diagrams	Product-structure diagrams (or assembly charts) depict the relationships between components at adjacent levels in the system. They are essentially graphical representations of the bill of materials (BOM) of the product, showing the order of assembly and how parts fit together in the assembly process.
Profit maximization	An unproven theory that suggests the sole purpose of a for-profit corporation is to maximize profits.
Project management	A management construct that is used to manage one-of-a-kind programs, especially those involving technological innovation.
Quality function deployment (QFD)	QFD is a sophisticated technique used to identify, prioritize, and translate customer needs into design (product) characteristics and manufacturing requirements, and build them into the product.
Quantum change	Quantum change represents stepwise improvements that have significant consequences on the value equation, typically measured in terms of factors ($+2\times$) of improvement.

Term/concept	Definition or use of the term or concept
Radical change	Radical change focuses on creating a new reality. It is difficult to articulate precisely the implications, but often the results lead to improvements that are 10× to 100× or more. It also involves eliminating significant barriers or burdens associated with the prevailing technologies
Related industries	Related industries provide complementary and support products and services that make the new product more valuable or even feasible.
Reliability	Reliability is defined as the probability that the product will perform its specified functions under the anticipated conditions of the design for a specified length of time.
Review process	The steps or events generally at the end of each phase to assure that the process is on track and that the necessary steps have been completed. It affirms or rejects decisions made.
Revolutionary innovation	Revolutionary innovation involves radical changes to the underlying technologies and the management system. They are often disruptive to the existing system, necessitating new capabilities, assets, and resources.
Seasonal effects	Seasonal effects influence the demand of the product. Seasonality is a critical concern when analyzing market demand and the flow of revenue.
Situation analysis	The situation analysis provides an understanding of the current business situation in light of new-product opportunities and challenges, and a determination of the most advantageous avenues for new products.
Skimming pricing	Skimming pricing establishes a high initial price during the launch of the product. This mechanism provides customers with a sense of high quality and high value. It attempts to obtain a high cash flow per unit sold.
Specifications	The requirements that customers seek in the product and what the producer has to provide as attributes.
Stakeholder	Any individual or group that is directly or indirectly affected by the products, programs, processes, and/or systems, but does not directly benefit as an economic participant such as a customer or supplier. Stakeholders include government agencies, interest groups, communities, society in general, and other constituents.
Stakeholder-based model	A model that includes stakeholders as coequal to customers and suppliers as participants in the system or process.

(*cont.*)

Term/concept	Definition or use of the term or concept
"Standardized" NPD process	An NPD process that consists of six phases and reviews. It is similar in content and flow to many of the NPD processes used by leading corporations.
Steering committee	In large corporations, executives are designated as a "review and approval" (steering committee) authority for making decisions about NPD programs and the activities thereof.
Strategic alignment	Strategic alignment is the process of ensuring that the internal dimensions are consistent with the strategies, and properly positioned with respect to the external dimensions.
Strategic management	Strategic management provides the direction and strategic logic for developing new products. It includes the upstream planning and analysis of strategic business issues and opportunities, and sets the stage for establishing the criteria for selecting opportunities.
Strategic-management system (SMS)	The SMS integrates the organization's processes and resources into a comprehensive framework for managing and directing business strategies including those related to new-product development. It includes the organization's philosophies, positions, and strategies with respect to the enterprise-management model and the NPD process.
Strategic marketing	Strategic marketing places the customer at the center of attention and concentrates the organization's marketing programs and resources on gaining customer awareness, interest, trial, and acceptance of the new product.
Supply-networks management	Supply-networks management is the process of effectively managing the flow of materials and finished goods, information, and relationships from suppliers, through distribution channels, to customers using a systems perspective to achieve a high level of performance.
Sustainable development	Sustainable development is the search, discovery, and cure for hidden defects that may seriously affect the viability of the new product. Sustainable development focuses on creating products that are more capable and attractive from an environmental management perspective as well as from economic, social, technological, and legal perspectives. The construct focuses on minimizing the risks and liabilities and improving the longevity of the new product.
Target-market size	The size of the selected target market relates to the total projected cash flow, the cost of the product relative to volume, and the expected volume over time.

Term/concept	Definition or use of the term or concept
Technical or product risk	Risk includes the failures of the design to meet expectations or to apply the technical specifications correctly. It also includes the failure to manufacture the product properly.
Technology development	R&D and/or related constructs for the invention, discovery, and development of new technology(s). It also includes enhancing technology platforms, and improving existing technologies and derivatives thereof.
Theoretical construct	A management model that represents the real-world situation or a management system showing how the elements are linked together and indicating the responsibilities, relationships, and actions.
Theory of inventive problem solving (TRIZ)	TRIZ uses analogous situations and design principles for discovering solutions that focus on eliminating conflicts within a design envelope rather than developing compromises. It attempts to avoid the middle-ground solution by mitigating the negative effects.
Time horizon	The projected time that the new product is viable in the market, starting at commercialization and ending at its replacement.
Time to market	The total time required for getting the new product to market, based on the initial phase of the NPD process. It is often measured in terms of the completion of all of the phases of the NPD process.
Timing	Timing is a measure of when the new product has to be commercialized from a seasonal or calendar perspective.
Total quality management (TQM)	A widely accepted management system related to the product delivery system or operating system; it incorporates quality-management practices and techniques necessary for meeting customer expectations in terms of quality, reliability, and responsiveness. The basic philosophy of TQM is to build quality into every product and process and to strive for continuous improvement.
Unit-cost calculations	The calculated cost of a single product. The actual calculations depend on volume since for many products the costs decrease with volume.
Value creation	The positive gains and improvements created during the new-product development and the translation of those benefits to meet the needs and expectations of customers and stakeholders.

(*cont.*)

Term/concept	Definition or use of the term or concept
Value-driven pricing	Value-driven pricing assesses the competitive products and determines price based on the performance-to-price position of the new product. It is determined by the value proposition.
Value proposition	The benefits that customers and constituents derive from the product based on the investment they have to make to obtain the benefits.
Value system	Michael Porter's construct that includes the primary dimensions of the product delivery system, supply networks, and customers.
Virtual product development	Virtual product development incorporates significant improvements to the underlying premises of IPD by using computer and information technologies to streamline the development process.
Vision	Vision is the high-level, future-oriented construct which translates external forces, opportunities and challenges, and internal capabilities and desires into a new reality for the organization.
Window of opportunity	The total time available to exploit the new-product opportunity. It is the time available from the very beginning of an opportunity to when it dissipates.
Zero-sum game	A situation where one individual or group succeeds (wins) and the other individual or group fails (loses). The net results in such situations equal zero.

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