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RESEARCH PAPER

# Real Options Based Analysis for Supply Chain Management

**Abolfazl Khatti Dizabadi[1], Abdollah Arasteh[2*]& Mohammad Mahdi Paydar[3]**

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**ABSTRACT**
*Supply chain management is one of the requirements for achieving economic growth in any supply chain. Changes in production and logistical capacity, fluctuations in demand, and variations in lead times are all potential causes of disruption in the supply chain. Supply chain planning that allows for some degree of flexibility is a good way to deal with this issue and mitigate the effects of uncertainty. Due to the increasing complexity and dynamics of the situation, decision-making in this area requires more advanced analytical methods. Accordingly, the Real options valuation (ROV) has emerged, introducing a new way of thinking about investing, especially in conditions of uncertainty. This study addresses two core problems: (i) how to measure the effect of uncertainty on supply chain activities and (ii) how to manage these operations to reduce the negative risk provided by uncertainty. The primary concept behind the suggested ROV technique is that an organization's internal planning choices would benefit from being informed by external market prospects. In the case of the uncertainty parameter, sensitivity analysis is performed, and under different values of this parameter, the obtained result is evaluated and validated.*

**KEYWORDS:** *Supply chain management; Uncertainty; Real options theory; Decision tree; Monte carlo simulation.*

## 1. Introduction

In recent years, supply chain planning has become an essential tool for efficiently managing various business processes in manufacturing companies. A supply chain today consists of several worldwide production sites seamlessly integrated, with each production site or chain link whose task is to convert the raw product into the final product, and eventually, the products are distributed to customers.

Supply chain planning is concerned with the smooth operation of an organization's most important processes, from sourcing raw materials to delivering finished goods to clients. Supply chain planning has been more important in recent years to streamline the management of a manufacturer's many operational activities. Most modern supply chains include a network of factories all over the globe that work in tandem to take raw materials and turn them into intermediate and final goods, which are then sent out to clients. To maintain and strengthen their competitive margins in the market, organizations need to coordinate this business process from production to distribution [1]. Maintaining an efficient and flexible supply chain in ever-changing markets is essential for any organization. Therefore, systematic planning and basic scheduling techniques based on mathematical principles must be developed to solve supply chain management problems.

In the real world, nothing is certain, so the role of management is difficult in the face of uncertainty and prediction of the future. Uncertainties in today's business climate and business practices directly impact Supply Chains (SCs). Disruptions in demand or supply, variations in lead times, and shifts in production or logistical capacity are some of the most prevalent causes of uncertainty [2-4].

Adaptability has been acknowledged across fields as a useful tactic for coping with various forms of uncertainty. There is consensus that SCs may improve their responsiveness to SC uncertainty

* **Corresponding author:** ***Abdollah Arasteh***
arasteh@nit.ac.ir

1. *Industrial Engineering, Babol Noshirvani University of Technology, Babol, Iran.*
2. *Department of Industrial Engineering, Babol Noshirvani University of Technology, Babol, Iran.*
3. *Department of Industrial Engineering, Babol Noshirvani University of Technology, Babol, Iran.*

by implementing effective flexibility options/measures [2, 5, 6]. Reduced effort, time, and money may greatly enhance a system's capacity to respond rapidly to changing conditions [6-8]. Because of the ever-changing nature of modern marketplaces, businesses must keep their SCs lean and nimble to keep up with their clientele's demands and satisfy them [3, 9].

According to research, the application of stochastic programming models is limited to comparing deterministic models due to their large computational content. One of the main causes of uncertainty is uncertain demand. Demand determines the amount of production in each complex. Uncertainty also increases when the demand has to be forecasted for the next few periods. Therefore, management must make decisions in case of uncertainty for each period. There are many proposed methods for dealing with uncertainty, one of which is the Real options method. "Authority" or "option," in this sense, is the choice made by investors or managers to delay decisions or change strategies [10]. In simple terms, “authority” is “the permissibility of doing something without being forced to do it.”

Natural discretion is like you have an accident, and you can use your insurance or do not want to ruin your insurance history. The decision is yours, and there is no compulsion behind it. The same example is extended to the supply chain, where costs are estimated in several ways, and cost-cutting measures are proposed. Is it the opinion of managers whether they want these measures to be taken or not? This method is suggested because it is closer to reality and gives managers the power to make decisions at the end of each period.

Therefore, in this study, we intend to provide a multi-period model that estimates the lowest cost of the supply chain and provides managers with options for decision-making. One of the approaches to expanding profitability and solid presence in the serious market flexibly chains the executives in states of uncertainty [11]. As we know, one of the main goals of the supply chain is to minimize the costs of procurement, production, and distribution and to maximize the flow of materials in the chain. On the other hand, by using the Real options theory, it is possible to increase the productivity of production and the flow of materials and reduce some production costs [10]. By production in each period, the flow of the product, the correlation of the periods to each other, and the permission to outsource can be a good performance in changes in demand. Therefore, modeling for the three concepts of supply chain management, uncertainty, and Real options theory helps managers make decisions. In general, the objectives of this paper can be presented in the following two sections:

1) Design a mathematical model to minimize costs
2) Designing real options for decision-making and presenting them to managers

## 1.1. Flexibility in short-term inventory planning

Tactic SC planning may benefit from including flexibility if the SC’s attributes and flexibility choices are identified. This section begins by outlining the research goals and how an integrated approach to planning may help achieve those goals and then moves on to provide many key flexibility choices that should be a part of the SC planning that this study aims to improve. Flexibility must be specified before it can be included in SC planning. Without a precise definition, it may be impossible to evaluate the relative adaptability of different SCs [12-15]. Confusion exists over flexibility's dimensions and phases, and its meanings vary from one field or environment to another [16]. In manufacturing, for instance, "flexibility" refers to the many configurations a system may assume in order to produce a wide variety of products in a wide range of quantities [8, 17]. A production system can respond rapidly to changes by switching between different states of the system with little impact on time, cost, and performance [8, 18]. Recent studies on SCs' adaptability have included [14, 15, 19-21]. Options for operational, tactical, and strategic procurement, production, and distribution processes are offered within a general framework for developing SC flexibility.

Tactical SC planning and optimization may use the three-dimensional framework shown in Figure 1, which quantifies the choices for SC flexibility discussed in this research. The three facets of SC flexibility are supply flexibility (in terms of procurement and sourcing), manufacturing flexibility (in terms of production and assembly), and distribution/logistics flexibility (in terms of distribution and storage).

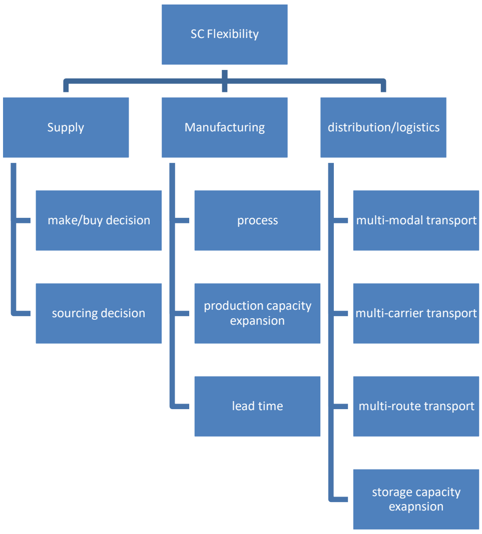



**Fig. 1. SC flexibility options in a three-dimensional framework**

There are a few different alternatives for each of the three dimensions of flexibility in the created framework, as illustrated in Figure 1. Incorporating these choices into the study's SC planning model is a major goal.

The primary goal of this study is to create a mathematical model for SC planning that considers the various forms of adaptability shown in Figure 1.2. The goal of the model is to reduce the SC's total cost as much as possible. The research also aims to assess the impact on SC performance by adjusting two crucial flexibility options: sourcing choice (using a single supplier against many suppliers) and multi-carrier transport (using a single transport carrier versus several transport carriers). Tactical SC planning inside a three-echelon SC is the focus of this research. The suggested model incorporates several flexibility possibilities shown in a three-dimensional flexibility framework into essential operations, including procurement, manufacturing, and distribution. The anatomy of the SC, which is the focus of this study, is shown in Figure 2.

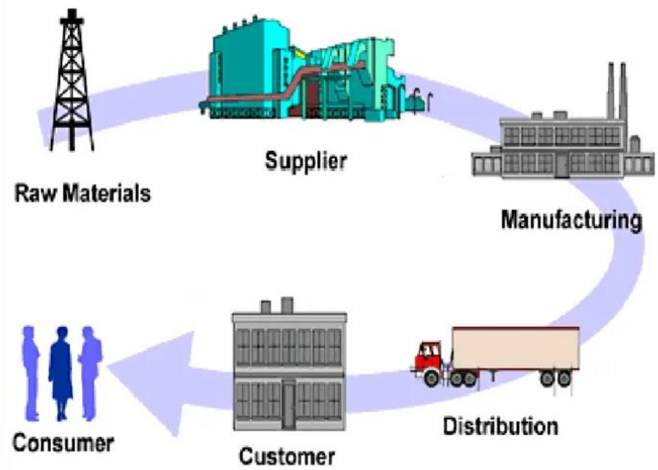



**Fig. 2. The structure of the concerned SC**

This study focuses on a planning challenge throughout a medium-term planning horizon. Industry differences in horizon length for planning are possible. The planning horizon may be broken down into smaller chunks of time, or periods, that are often weeks, fortnights, or months in length. Only the following concerns pertain to the planning challenge at hand:

- Because this study focuses on improving SC operations at the tactical level, issues like network architecture and configuration, which are more often discussed at the strategic decision-making level, are beyond the purview of this study. It is often believed that the SC configuration is supplied or understood while making tactical plans [22-24]. Consider the quantity and distribution of suppliers, manufacturing facilities, and distribution hubs. These numbers are a constant and well-known fact. Production, storage, and transit capacities may all be estimated to their absolute limits.

- Strategic supplier selection is beyond the scope of this study. The evaluation criteria that may be utilized for strategic supplier selection go beyond the scope of this research. This means we know the total number of suppliers, where they are located, and how much capacity they have.
- It is believed that demand is deterministic across all categories of goods. Even if demand fluctuates and changes throughout the planning horizon, it remains relatively consistent.
- Items that are damaged or need to be reworked are beyond the purview of this study.

### 1.2. The significance of this research

An SC strategy must be adaptable to the ever-changing market and its associated risks. There is a great deal of unpredictability in SC planning because of the very complex and dynamic interplay between the many business organizations involved [23]. Effective flexibility choices in an SC plan are a good way to deal with the unknowns.

It is well-established that implementing good flexibility measures into SC planning may increase a company’s responsiveness and resolve the vast majority of SC uncertainty problems [2]. An SC that can adapt to an ever-shifting business climate offers many possibilities [25]. Therefore, the importance of this study lies in the fact that it highlights the effects of increasing flexibility on the overall performance of SCs, which in turn improves their profitability and responsiveness.

*Profitability*

Organizations across all sectors, from services to manufacturing, have a common goal of minimizing running expenses. Since the entire cost of an organization's activities significantly impacts the profit it generates, minimizing system costs is a key objective in SC management. Constantly assessing ways to save costs and increase profits without sacrificing customer happiness is essential for every successful business, making SC optimization a top priority [26]. In the recent ten years, businesses in both the industrial and service sectors have recognized the significance of the cost savings that can be realized through better planning and administration of complex SCs [26].

*Strengthening flexibility and assessing the results of change that allows for more flexibility*

Multiple flexibility choices in procurement, sourcing, production, distribution, and logistics are essential to a flexible SC, according to the literature [4, 15]. Flexibility becomes important [27]. However, many businesses that want to decrease their product's price do so at the expense of their adaptability, which may make it difficult or impossible to meet emerging product needs [28]. Therefore, businesses that want to keep up with a possible growth in demand must include numerous flexibility alternatives.

Regarding long-term strategy, an SC that can flex in response to supply and demand fluctuations and other environmental constraints like lead time, currency rate, and capacity restrictions can make more informed decisions [4, 14].

## 2. Literature Review

Brief and comprehensive definitions of supply chain management can be provided: Supply chain management is an integrated philosophy for managing the overall flow of the distribution path from supplier to end-user and as a prudent philosophy, including the extent and scope of integrated customer behavior. The supplier is in the process of external integration [29]. The goals of supply chain management can be reduced costs or inventory, accountability to customers, improved supply chain communication, reduced production cycle time, and improved coordination. The three main factors that led managers to take supply chain management seriously are the rapid changes in the information, the demand for customers to purchase quality products and services at a lower cost, which ultimately led to increased competition between manufacturers and manufacturers, as well as the need to Creating a new structure in inter-organizational relationships [29].

Supply chain management controls and improves the flow of information, materials, and money throughout the collection, intending to create added value, producing high-quality products, low cost, timely delivery, and ultimately creating value for customers so that issues such as demand uncertainty can Disrupt the process of the mentioned processes and improve it; therefore, these should be identified in advance, and the necessary measures should be taken according to their intensity. Companies must meet consumer demand in uncertain industrial environments to stay competitive [30].

Obtaining an accurate estimate of the forecast fluctuations in demand for new products is a challenge. Various methods have been proposed to estimate these fluctuations. For example, Ma and Feeder [31] predict the demand distribution for new products using data from past sales of other products and pre-purchase orders for new products. Another way to estimate demand uncertainty is to allow experts at confidence intervals. However, Soll and Klyman [32] show that experts do not have confidence when estimating the confidence interval of a random variable. The third method lets board experts determine the point of demand forecast for a particular product.

The standard deviation of these forecasts can be used to estimate demand. However, Gower et al. [33] show that Fisher and Raman's method minimizes the standard deviation of demand, and this error increases with scale. Another issue is that demand forecast fluctuations depend on time in our model. Forecasts change in the months before a product is introduced; expected changes are often small compared to changes when the product is close to being introduced to the market or is just introduced. Demand fluctuations also depend on the type of product. For example, when a new commodity is introduced with no precedent, the demand uncertainty is significantly greater than that of a commodity with a precedent. In this study, fluctuations from past periods are calculated. These estimates are based on the difference between demand forecast and actual demand for previous periods and interviews with people from the production and marketing departments.

## 2.1. Supply chain management under uncertainty

Due to technological developments and the formation of close competition to achieve greater market share, companies and organizations have been forced to participate in network economies. In this regard, supply chain management manages product flows, information, and demand probabilities. Although it has brought benefits and advantages for companies, the tendency towards this approach has brought many problems and complexities for managing in conditions of uncertainty and their business partners in a way that benefits all elements of the supply chain. To overcome these problems, in addition to developing the concepts of supply chain management and logistics, management in conditions of uncertainty was also developed to use solution, engineering, and management approach to minimize inefficiencies in the supply chain and the field of effective management throughout the supply chain using various tools and techniques [9]. Therefore, it can be said that the supply chain of goods includes planning, supply, production, and distribution, and the conditions of uncertainty and probability can be managed using different solution approaches and with efficient planning. This confirms that organizations today need new and appropriate tools and techniques to manage uncertain and possible situations in their chain due to the larger supply chain and more complex conditions. They seek solutions that increase accountability, transparency, efficiency, cost optimization, liquidity, and predictability in real and uncertain supply chain situations [30]. According to these explanations, in Table 1, previous studies on supply chain management under uncertainty and how to deal with uncertainties are discussed.

**Tab. 1. Previous studies on supply chain management under uncertainty and comparison with the present paper**

| Author (year of publication) | Topic | Solving method | Uncertainty |
|---|---|---|---|
| Azaron et al. (2008) [34] | A multi-objective stochastic planning approach to supply chain design with risk in mind | Develop a robust stochastic planning approach | stochastic |
| Mansini et al.(2012) [35] | The issue of selecting a supplier with a reduction in quantity and loading of goods | Innovative method | - |
| Hamami et al. (2014) [36] | Scenario-based random model for global supplier selection with multiple buyers, currency fluctuation uncertainty, and price discount | Scenario-based | stochastic |
| Ayhan et al. (2015) [37] | A two-step approach to the problem of supplier selection in a multidimensional / multi-supplier environment with quantitative discount | Fuzzy hierarchical analysis and mathematical modeling | fuzzy |
| Chai and Angai (2015) [38] | Selecting a multi-scene strategic supplier in uncertain environments | Hesitant fuzzy set | fuzzy |
| El-sayed et al.(2017) [39] | Development of a multilevel, multi-cycle | Random integer programming | stochastic |

| Author (year of publication) | Topic | Solving method | Uncertainty |
|---|---|---|---|
| | model for forwarding and reverse network integration | | |
| Ghelichi et al. (2018) [40] | A stochastic programming method for optimal design and planning of an integrated plant fuel supply chain management under uncertainty | Generalized random programming method and decision tree | stochastic |
| Tseng et al. (2018) [41] | A framework for evaluating the performance of sustainable supply chain management under uncertainty | Delphi fuzzy method | fuzzy |
| Fakhrzad et al.(2019) [42] | Design of green ring-chain supply chain network considering the reliability of supply centers under uncertain conditions | Mixed-integer is modeled using linear programming and solved from a definite two-step approach. | fuzzy |
| Arasteh(2020) [43] | Supply chain management under uncertainty with a combination Fuzzy multi-objective programming approaches and real options | Fuzzy hierarchical analysis and mathematical modeling | fuzzy |
| F Tayari, S Blumsack(2020) [44] | Real options approach production and injection timing under uncertainty for $CO_2$ sequestration in depleted shale gas reservoirs | Develop a robust stochastic planning approach | stochastic |
| P Shi, B Yan, J Zhao(2020) [45] | Appropriate timing for SMEs to introduce an Internet-based online channel under uncertain operating costs: a real options analysis | Random integer programming | - |
| SY Wang, CF Lee(2021) [46] | A fuzzy real options valuation approach to capital budgeting under uncertain environments | Delphi fuzzy method | fuzzy |
| Present paper | Supply chain management under uncertainty based on the real options theory approach | Monte Carlo Simulation and Decision Tree | stochastic |

## 2.2. Literature classification

The review technique proposed by (Seuring and Müller 2008) was utilized to develop the methodology to categorize the literature. After settling on the right keywords, the relevant articles are culled from the repository.

### 2.2.1. Classification based on incorporating flexibility options

Figure 3 represents the suggested three-dimensional framework that may categorize the published models based on the SC flexibility choices.

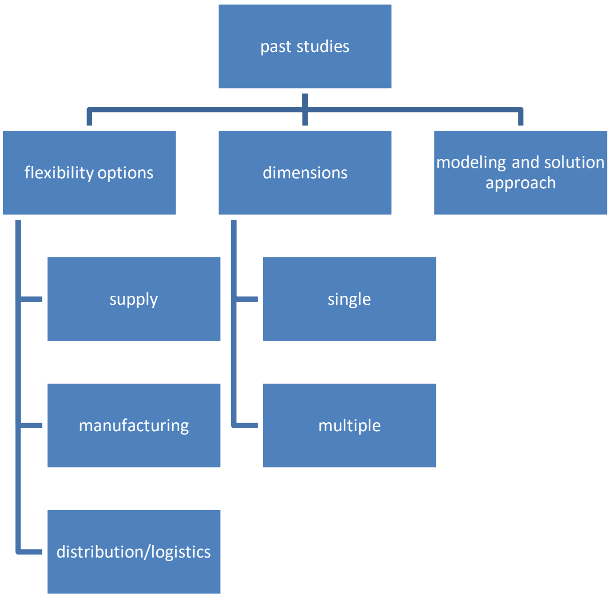



**Fig. 3. The structure used for classifying the literature**

To avoid prolonging the discussion, we only consider researches that have considered all three aspects of flexibility.

For an SC network with several plants and warehouses where items are solely sold from warehouses, Jolayemi and Olorunniwo (2004) created a MILP to address the production and transportation planning needs over various periods and multiple products [47]. Overall profit was intended to be maximized by using the suggested approach. An SC with multiple distributors, factories, and numerous suppliers is the basis for the MILP model created by Ylmaz and Atay (2006) [48]. This presupposes that a fixed cost may be used to expand the production capacity of suppliers, factories, and transportation.

With predictable demand for each period in mind, Ouhimmou et al. (2008) created a MILP model to aid decision-making during furniture SC tactical planning across twelve months. The researchers zeroed in on the wood SC segment of the broader furniture SC, where hardwood logs are sourced from public forests, processed in sawmills, dried in kilns, and then supplied to furniture factories. Bashiri et al. (2012) created a MILP model for designing and planning an SC that handles several periods and many products while considering a four-tiered network that includes suppliers, manufacturing facilities, storage facilities, and end users [49]. Although just the cumulative net revenue was included in this study's network expansion plan, it is important to note that it was not ignored. Table 2 summarises past studies' flexibility options with three dimensions.

**Tab. 2. Classification of the published models: integrated three-dimensional flexibility**

| Author(s) | Supply flexibility | | Manufacturing flexibility | | | Distribution/logistics flexibility | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sourcing decision | Make/buy | Process flexibility | Production capacity expansion | backlogging | Multi-modal transport | Multi-carrier transport | Multi-route transport | Storage capacity expansion |
| Jolayemi and olorunniwo (2004) [47] | | * | * | | | | | | * |
| Lejeune (2006) [50] | * | | * | | | * | | | |
| Yilmaz and Catay (2006) [48] | * | | * | * | | | * | | |
| Lejeune amd Ruszeznski (2007) [51] | * | | * | | | | * | * | |
| Gunnarsson et al. (2007) [52] | * | | * | | | * | * | * | |
| Ouhimmou et al. (2008) [53] | * | * | * | | | | * | | |
| Gunnarsson and Ronnqvist (2008) [54] | * | | * | | | * | * | * | |
| Fahimnia et al. (2011) [55] | | * | * | | * | | * | * | |
| Bashiri et al. (2012) [49] | * | | * | * | | | | | * |
| Zhou et al. (2015) [56] | * | | * | * | | * | * | * | |
| Li et al. (2017) [57] | | * | * | * | | * | | * | * |
| Chu et al. (2019)[58] | * | * | | * | * | | * | * | |
| Gu et al. (2021) [59] | * | * | * | | * | * | | * | * |
| Xylia et al. (2022) [60] | * | * | * | * | | * | | * | * |
| This model | * | * | * | * | * | * | * | * | * |

Many of the found possibilities were not included in previous research, even if they did include flexibility options in their created SC planning models. According to the data in the table, there is a void in the literature that the current study seeks to fill. The study's contribution to the existing literature is further shown by creating a tactical SC model that considers all flexibility choices and their associated quantitative measures inside the suggested three-dimensional tactical flexibility framework.

### 2.2.2. Classification based on the solution methodology

From a scientific point of view, solution approaches are vital. The research under examination is organized below according to their approach to addressing the created model.

Numerous approaches and tools have been used to resolve the intricate SC planning models. Techniques developed and deployed in various contexts are invaluable because they not only point researchers in the direction of useful information about existing methodologies but also reveal promising new topics for methodologically focused inquiry. However, the specifics of the model and the nature of the issue at hand will dictate the approach used to find a solution. Table 3 shows the classification of the published models based on the solution methods.

**Tab. 3. Classification of the published models based on the solution methods**

| approach | model | Authors (year) | solution method |
|---|---|---|---|
| Exact | Linear Programming (LP) | Chen and Wang (1997) [61] | IMSL package |
| | | Mohamed (1999) [62] | Not specified |
| | | Lee and Kim (2002) [63] | A hybrid simulation-analytic method |
| | | Mohamed and Youseff (2004) [64] | LINDO solver |
| | | Oh, and Karimi (2006) [65] | CPLEX solver |
| | | Genin et al. (2008) [66] | CPLEX solver |
| | | Munoz-Delgado et al. (2016) [67] | Numerical simulations |
| | | Badiozamani et al. (2019) [68] | Not specified |
| | | Alotaibi et al. (2021)[69] | AMPL |
| | Mixed Integer Linear Programming (MILP) | McDonald and Karimi (1997) [70] | CPLEX solver |
| | | Dogan and Goetschalckx (1999) [71] | CPLEX solver (a primal decomposition method) |
| | | Dhaenens-Flipo and Finke(2001) [72] | CPLEX solver |
| | | Lee et al. (2002) [63] | Hybrid analytic-simulation method |
| | | Souza et al. (2004) [73] | CPLEX solver |
| | | Jolayemi and Olorunniwo (2004) [47] | LINDO solver |
| | | Meijboom and Obel (2007) [74] | MS Excel optimizer and simulation (IBM SCA) |
| | | Gunnarsson et al. (2007) [52] | Simulation (OrgSim-system) |
| | | Lim et al. (2006) [75] | CPLEX solver |
| | | Aydinel et al. (2008) [76] | CPLEX solver |
| | | Kanyalkar and Gajendra (2010) [77] | Gnu Linear Programming Kit solver |
| | | Safaei et al. (2010) [78] | A hybrid mathematical–simulation method |
| | | Alemany et al. (2010) [79] | CPLEX solver |
| | | Bashiri et al. (2012) [49] | CPLEX solver |
| | | Franco et al. (2015) [80] | CPLEX solver |
| | | Panteli (2018) [81] | CPLEX solver |
| | | Jabarzadeh et al. [82] | CPLEX solver |
| | | Masum et al. [83] | Simulation |
| Heuristic | | Jayaraman and Pirkul (2001) [84] | MILP model solved using Lagrangian relaxation techniques and a heuristic solution procedure |
| | | Jang et al. (2002) [85] | MILP model solved using Lagrangian heuristic and GA |
| | | Park (2005) [86] | MILP model solved using a heuristic based on local improvement procedure |
| | | Gen and Syarif (2005) [87] | MILP model solved using spanning tree-based hybrid GA and fuzzy techniques |
| | | Lei et al. (2006) [88] | MILP model solved using a two-phase approach (CPLEX + Load Consolidation heuristic) |
| | | Ekşioğlu et al. (2006) [28] | MILP model solved using primal-dual based heuristic |
| | | Armentano et al. (2011) [89] | MILP model solved using two approaches: tabu search and an integrated path relinking/tabu search |
| | | Varthanan et al. (2012) [90] | Multi-objective MILP model solved using analytic hierarchy process combined with PSO |
| | | Varthanan et al. (2012b) [91] | MILP |
| | | Hernández et al. [92] | apply planning rules as simple as Wager-Whitin, Silver-Meal, FOQ and L×L |
| | | Razavi et al. (202) [93] | CPLEX solver and the proposed GA |
| Meta- | | Lejeune (2006) [50] | MILP model solved using variable neighborhood |

| approach | model | Authors (year) | solution method |
|---|---|---|---|
| heuristic | | | decomposition search |
| | | Aliev et al. (2007) [94] | Fuzzy LP model solved using a GA-based solution method. |
| | | Calvete et al. (2011) [95] | Mixed-integer bi-level model solved using ant colony method. |
| | | Raa et al. (2013) [96] | A construction-based metaheuristic |
| | | Canca et al. (2016) [97] | Adaptive Large Neighborhood Search (ALNS) algorithm |
| | | Samadi et al. (2018) [98] | Red Deer Algorithm (RDA) and Genetic Algorithm (GA) |
| | | Gao et al. (2020) [99] | Swarm intelligence, Evolutionary algorithms |
| | | Nayeri et al. (2022) [100] | queuing theory and robust fuzzy stochastic optimization |

Heuristic and meta-heuristic approaches are used in SC planning and optimization due to the complexity of the modeling environment. When compared with meta-heuristic techniques, heuristic ones have seen much greater adoption. This may be because most tactical SC planning issues are very complicated, requiring the creation and use of bespoke heuristics solution methodologies instead of generic ones.

## 2.3. Real options theory

This study emphasizes the presence of a method based on real options theory to evaluate possible investment options or non-investment at different stages of the supply chain. Using the proposed method, management can evaluate opportunities by considering the conditions of uncertainty and make the best decision based on the specific risks of the supply chain. Due to increasing supply chain uncertainty and factors such as political issues, demand fluctuations, currency fluctuations, technological changes, financial instability, and natural disasters, organizations must use resources to forecast demand and supply to reduce vulnerability and increase supply chain resilience. Internal uncertainties were organized [101]. Attention to these uncertainties and risk factors led to the issue of the Real options theory in the supply chain so that one of the common uncertainties in the supply chain is the uncertainty in demand, which always challenges and issues related to production and supply and demand have created a foothold for producers, especially dependent producers in the supply chain As the supply chain grows, demand uncertainty increases, and the decision-making position of managers in the supply chain becomes more important [30]. In general, supply chain uncertainties affect supply chain outputs. In other words, any disruption in the supply chain directly affects the continuation of the company's operations and the final impact on the customer. Lee et al. [102] focused on supplier selection to reduce supply chain costs. Their model modeled supplier selection with developmental and general discounts, and a genetic algorithm was used to solve their complex model.

The term “Real options” was first coined by Myers to describe corporate investment flexibility [103]. Of course, the background of the theory of authority has been discussed in relatively distant years; the foundations of the theory of authority proposed in the doctoral paper of Louis Bachler are related to 100 years ago [104]. The 1970s were a decade of revolution in the world of investment finance.

In 1973, Black and Scholes first formulated the options theory in a productive way and proposed a model that could be calculated the value of authority analytically. Over time, newer models and methods have been proposed to evaluate other financial powers that have evolved this theory.

The findings point to a wide range of industrial applicability, from long-lasting discrete manufacturing items to process-oriented products. Regarding modeling, most sectors are looking for more holistic, holistic functional viewpoints. Intriguingly, all three functional characteristics were included in pulp and paper-sector simulations. That is why it seems sensible to assume that models with real-world applications would have more intricate and thorough optimization schemes. Table 4 represents the background of the Real options theory in various fields.

**Tab. 4. Research on the background of Real options in various fields**

| Researcher | Research topic | Research summary |
|---|---|---|
| Metron [105] | Pricing Real options theory | Coinciding with the rapid growth of securities trading in the United States in the 1970s, research into how Black Scholes evaluated these securities gave rise to a special structure. |
| Black- Scholes [106] | Pricing options and corporate debt | They pointed to the possibility of expanding the evaluation of economic units. |
| Tourinho[107] | Optional assessment of natural resource reserves | He stated that developing a natural gas field is similar to applying financial authority on shares. If the expense of building up the gas field is thought to be known and fixed, the estimation of petroleum gas nearby will carry on, like the estimation of stocks in the monetary market. He made the optimal timing for expanding the gas field and evaluated the profits using the Black Scholes method. |
| Brennan and Schwartz [108] | Assessing natural investment resources | While developing the 1979 model, they considered the optimal timing for developing a copper mine. They knew that mining projects had a high degree of uncertainty in terms of storage as well as pricing. as a result, they considered the fundamental technique of real options based on the technique of dynamic arbitrage. This theory is a way to maximize the stock value of asset owners. |
| McDonald,[109] | They are investing and valuing companies when there is an option to close. | They showed that the main point of microeconomic theory is that a project should be shut down if operating income is less than variable costs. This simple theory raises the basic question of how and when a project should open and close. |
| Trigeorgis et al. [10] | Managerial flexibility and resource allocation strategy | They have submitted several different projects, introducing the authority to submit, extend, and decide on several similar investment projects, especially in natural resources. They showed that decision-making in natural resource projects depends significantly on commodity price fluctuations. |
| Padak et al.[110] | They are assessing the option of receivables related to real assets: Offshore oil lease file. | They developed the theory of financial authority to evaluate the leasing of offshore oil tankers. In that useful article, they concluded the postponement of an oil project. An alternative to avoiding bankruptcy in the future. |
| Kig [111] | Experimental experiments with real-world pricing models | Used real options in other projects and examined an empirical model of real authority price on a large scale of the market price for real estate using an economic model as a symbol of authority for land development or deferral for the future. |
| Berger et al. [112] | Investor evaluation of investment abandonment | The right to leave a company was examined, and the real options theory over the validity of the right to leave a project. Other research on using real authority in natural resources, mining, and oil and gas has concluded that powers such as procrastination, delay, change, and closure increase the value of a project. As a result, the real options theory was introduced as a new evaluation method for various industries. |

## 2.6. Research gaps

The approach used in this study is outlined below in order to fill the void that has been observed. Projects based on research tend to fall into one of two main categories: qualitative or quantitative. The category a project falls into determines the research approach selected.

As a result of its methodology, this study is classified as quantitative. We have developed a mathematical model to quantify SC activities and have solved a planning challenge for the SC that addresses a research need. The tactical SC planning issue is modeled mathematically, and many plausible variations on the standard three-dimensional framework are presented as solutions.

Research on multi-period supply chain models is such that the purpose of the basic model is to minimize costs; the solution of the multi-period model is compared between the two methods of Real options theory and current net worth. The result is that the natural discretion method saves the total cost and thus increases profitability. The existing research gap is estimated to provide a solution for more sales and, thus, more profitability. Various factors are involved in the supply chain to sell more, including marketing and demand, increasing production, capacity, pricing, and many other factors. Increasing production depends on estimating customer demand and increasing capacity in the supply chain. If we increase capacity, the chain will suffer if demand is low. Therefore, it has been proposed that outsourcing be economically viable in both high and low demand. In this way, we defined a parameter with a cost higher than the cost of production and less than the cost of lost sales; if the demand exceeds the available capacity, managers can decide whether to outsource the additional demand. Be accountable or bear the cost of lost sales.

By solving the suggested model for each situation and comparing the resulting information, we can examine how changing the SC's degree of adaptability affects its overall performance. Total SC expenses and service quality (measured by backlog cost) were used to conclude. Finally, several management inferences have been formed from this research by analysis of the data collected.

## 3. Modeling

Despite significant progress over the last several years, the vast majority of process systems engineering literature has ignored the presence of financial markets in favor of investigating phenomena inside the confines of a single firm. Mid-term production planning [9, 113]; long-range, capacity expansion planning [114-118]; multi-echelon supply chain design [119-122]. All of the works above share a central assumption: the need to adopt an adaptable stance in the face of uncertainty. We will use a simple planning scenario to demonstrate the shortcomings of the conventional NPV approach to decision-making in the face of uncertainty. The Real Options Valuation (ROV) method is an economic correction to the NPV analysis. Applications of the method are emphasized, such as pharmaceutical pipeline management and emissions trading, and quantitative comparison between the NPV and ROV techniques is shown using multiperiod production planning with demand uncertainty as a benchmark.

### 3.1. Limitations of NPV approach under uncertainty

We considered a single-product and multi-period supply chain. For the production of each unit of product, the costs of construction, transportation, inventory, and lost sales are calculated. We also have a fixed production cost in case of production or non-production. If there is an inventory, it is transferred from one period to the next. Also, the shortage, like inventory, is transferred to the next period. We only have steady demand in the first period. Production decisions are determined at the beginning of each period and the amount of demand at the end of each period. This expresses the uncertainty of the model. For previous periods, we have information about the demand for this product in each period, and based on this, according to the standard deviation rate, the probability of increase or decrease in each period is determined. Due to the interconnectedness of the periods, the supply chain's total cost is calculated from the last period, respectively, and returns to the first period. Based on demand estimation and simulation, the lowest cost scenario is estimated. The intended capacity for the product is costly. Thus, the development of this research is to reduce costs and allow outsourcing in the event of oversupply.

### 3.2. Real options valuation (ROV) approach

According to the examination of relevant literature, the key concept underlying the ROV method is the application of the theory established for financial options [123, 124] to actual, non-traded assets [125].

1. First, it is more feasible to monitor the cause of uncertainty than its consequence using market-traded instruments.
2. A diversified portfolio of securities is preferable as an alternative to using a single asset to monitor a project's worth.
3. The risk profile of a project may evolve, and a tracking portfolio may be rebalanced at regular intervals to account for this.

The ROV technique is applied to the problem of streamlining supply chain operations as an illustration of how these aspects are included. In light of this, let us assume the produced good is market-traded, which necessitates the existence of both spot and futures markets where it may be purchased and sold in a timely and orderly manner.

The New York Mercantile Exchange (www.nymex.com) and The Chicago Board of Trade (www.cbot.com) are examples of markets where various products from different industries can be bought and sold today. These products range from fuels (crude oil, heating oil, and natural gas) to precious metals (gold, copper, and silver) and even food (soybean, wheat, corn). Such market structures efficiently convert the equilibrium of supply and demand into a transparent price signal. In this case, the price of a futures contract on the product is anticipated to rise if total demand exceeds total supply (decrease). Figure 4 illustrates how a futures contract may be utilized as twin security to monitor fluctuations in demand. The ROV strategy places a premium on these market-traded securities and other financial possibilities, such as borrowing and lending at a risk-free rate. Borrowing (loan) money in the securities market is the same as selling (purchasing) US Treasury bonds. With these tools at hand, the ROV strategy entails setting up a mirrored portfolio of the twin security and risk-free security that matches revenue unpredictability (Figure 5).

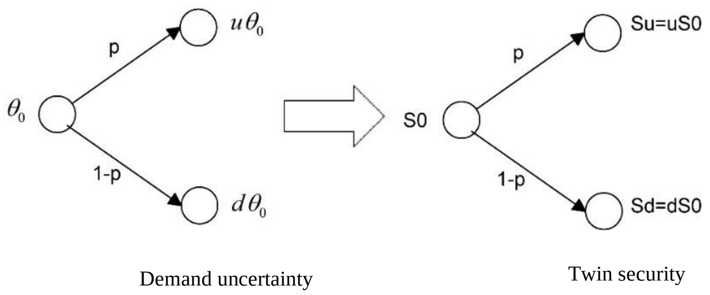
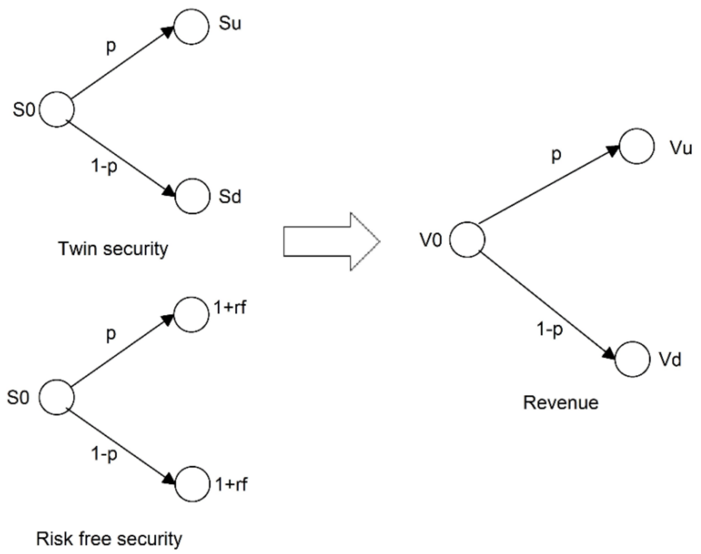



**Fig. 4. Demand uncertainty tracked by correlated market-traded security**




**Track revenue uncertainty with a portfolio of market-traded securities**
**Fig. 5. Basic idea of the ROV approach**

$$V_u = NS_u - B(1+r_f) \quad (1)$$

$$V_d = NS_d - B(1+r_f) \quad (2)$$

The solution of Equations 1 and 2 determines the composition of the replicating portfolio as given by

$$N = \frac{V_u - V_d}{S_u - S_d} \quad (3)$$

$$B = \frac{1}{1+r_f}\left(\frac{dV_u - uV_d}{u-d}\right) \quad (4)$$

Using Equations 3 and 4, the present value of the replicating portfolio is

$$NS_0 - B = \frac{1}{1+r_f}[qV_u + (1-q)V_d] \quad (5)$$

Where

$$q = \frac{1+r_f - d}{u-d} \quad (6)$$

If two assets have the same reward in all possible future states, then their prices must be similar to avoid arbitrage. As a result, this theory implies that the unpredictable future income streams have a present value equal to the present value of the replicating portfolio.

$$V_0 = \frac{1}{1+r_f}[qV_u + (1-q)V_d] \quad (7)$$

These equations show the two key distinctions between the NPV and ROV methods. The discount rate used in NPV analysis is the anticipated rate of return (*r*), whereas the discount rate used in ROV analysis is the risk-free rate of return ($r_f$). Secondly, the NPV method, as opposed to the risk-neutral ROV method, calculates the anticipated value of future cash flows by factoring in the genuine likelihood (*q*) of demand unpredictability.

### 3.3. Supply chain planning model

We will first utilize a streamlined version of the midterm planning model as a baseline to demonstrate the ROV technique.

**Assumptions**

1- Single product is considered
2- Several periods are considered
3- The demand for the first period is assumed to be constant and is probable from the second period
4- If we do not have production, we do not have outsourcing; in other words, it is not possible to have outsourced and not produce.
5- Inventory in each period can be transferred to the next period.
6- Deficit is considered as lost sales.
7- The amount of production in each period is equal.

**Sets**

A set of periods $T = \{t\}$

**Parameters**

$C^{set}$ = Fixed cost of repairs
$C^{\text{var}}$ = Variable production cost
$C^{tran}$ = transportation costs
$h$ = Inventory maintenance cost
$\mu$ = cost of customer shortage
$\theta_t$ = demand in the period *t*
$\hat{p}$ = The amount of production capacity
*L*= The amount of outsourcing capacity
$I_0$ = initial inventory

**Variables**

$y_t$ = If the product is made in period $t$ =1; otherwise, =0
$\alpha$ = If outsourcing is required=1; otherwise, =0
$p_t$ = Production level in period *t*.
$S_t$ = supply to the customer in the period *t*
$S_t^-$ = number of customer shortages in period *t*
$I_t$ = Inventory level at the end of period *t*
$W_t$ = amount of production by outsourcing

**Objective function**

$$\min \quad C^{set}Y_{(t=0)} + \alpha_{(t=0)}W\beta + C^{\text{var}}P_{(t=0)} + C^{tran}S_{(t=0)} + \mu S^-_{(t=0)} + hI_{(t=0)} + Q_{(t=0)}(S^-_{(t=0)}, I_{(t=0)}, \theta_{(t=1)}) \quad (8)$$

**Constraints**

$$P_{(t=0)} \le (\hat{P} + L\alpha)Y_{(t=0)} \quad (9)$$
$$S_{(t=0)} \le \theta_{(t=0)} \quad (10)$$
$$I_{(t=0)} = I^0 + P_{(t=0)} - S_{(t=0)} \quad (11)$$
$$S^-_{(t=0)} = \theta_{(t=0)} - S_{(t=0)} \quad (12)$$
$$\alpha_t \le y_t \quad (13)$$
$$p_{(t=0)}, S_{(t=0)}, I_{(t=0)}, S^-_{(t=0)} \ge 0,,,,, Y_{(t=0)} \in \{0,1\} \quad (14)$$

**Where**

$$Q_t(S_t^-, I_t, \theta_{t+1}) = \min C^{set}Y_{(t+1)} + \alpha_t WY_{(t+1)} + C^{\text{var}}P_{(t+1)} + C^{tran}S_{(t+1)} + \mu S^-_{(t+1)} + hI_{(t+1)} + Q_{(t+1)}(S^-_{(t+1)}, I_{(t+1)}, \theta_{(t+2)}) \quad (15)$$

**Constraints**

$$P_{(t+1)} \le (\hat{P} + L\alpha_{(t+1)})Y_{(t+1)} \quad (16)$$
$$S_{(t+1)} \le \theta_{(t+1)} \quad (17)$$
$$I_{(t+1)} = I_t + P_{(t+1)} - S_{(t+1)} \quad (18)$$
$$S^-_{(t+1)} = \theta_{(t+1)} - S_{(t+1)} \quad (19)$$
$$\alpha_{(t+1)} \le y_{(t+1)} \quad (20)$$
$$p_{(t+1)}, S_{(t+1)}, I_{(t+1)}, S^-_{(t+1)} \ge 0 \quad (21)$$
$$Y_{(t+1)} \in \{0,1\} \quad (22)$$

Equation 8 shows the objective function in period zero. The first part shows the fixed cost in the case of production. The second part is the cost of outsourcing in the case of production and the need for outsourcing (demand exceeds capacity). The third part is the variable costs according to the amount of production. The fourth part is the cost of transportation according to the amount of supply to the customer. The fifth part is the cost of the deficit in terms of the number of sales lost, and the sixth part is the cost of maintaining the inventory in terms of the number of inventories in each period. The return function from the last period is considered zero, and period t shows the cost of period t + 1 and is added to the cost of period t and follows the same process until the first period to calculate the total cost of the supply chain. A recursive function exists because the amount of inventory and shortage in each period affects other periods.

Equation 9 is the production capacity limit, which becomes 1 if there is a need for outsourcing and the demand is greater than the capacity, and the outsourcing capacity is also increased; otherwise, it is only the specified capacity for production.

Equation 10 is the supply constraint, which is less than the demand.

Equation 11 shows the amount of inventory at the end of each period, including the inventory at the beginning of the period (remaining from the previous period) and the amount of production in this period minus the amount of supply.

Equation 12 shows the level of shortage in each period (demand minus supply)

Equation 13 Shows that we can outsource if we have production; If we do not produce, we are not allowed to outsource.

Equation 14 also shows that the variables are integers and non-negatives.

Equation 15 The objective function from the second period indicates that the demand is probable.

Equation 16 shows the capacity constraint from the second period onwards.

Equation 17 shows the amount of supply, which should be less than this according to the potential demand.

Equation 18 shows the amount of inventory in each period that can be transferred to subsequent periods.

Equation 19 shows the amount of shortage in each period, which is due to excess demand over supply, which is lost and has nothing to do with the shortage of the previous period.

Equation 20 means that production is preferable to outsourcing, and we do not have outsourcing if there is no production.

Equations 21 and 22 also show the integer and non-negative number of variables in the periods of potential demand.

In the first phase of the model, the demand is fixed at (*t=0*), and preparations are made for the present period. Each of the current period's fixed setup, variable production, transportation, customer shortfall, and inventory holding costs is represented by the first five terms in the objective function. Minimizing these expenses is constrained by production capability (Equation 9), customer supply (Equation 10), inventory balance (Equation 11), and customer shortfall (Equation 12) limitations. In order to account for future periods' expenses, the goal function incorporates a recourse function $Q_t(S_t^-, I_t, \theta_{t+1})$.

The objective function and constraints were repeated because the amount of demand in period zero is deterministic and is considered probabilistic from the first to the fourth period. For this reason, the objective function and constraints are written for both modes.

ROV and NPV vary from one another in the setting of models because of the rates of return (r) and probabilities (p) utilized in the discounting process and the application of the expectation operator $\varepsilon_{\theta_{t+1}}(.)$. Using the risk-free rate of return and risk-neutral probability, NPV calculates an investment's value, whereas ROV calculates an investment's value using objective probabilities and the anticipated rate of return, as previously discussed. An additive discrete binomial process is used to represent the volatility in demand. Assuming this scenario, we can calculate the ROI using

$$r = pu + (1-p)d - 1 \quad (23)$$

It incorporates the NPV method. Next, we will offer a sample planning scenario to show how a different model might lead to drastically different outcomes in both the ROV and NPV planning frameworks.

## 3.2. Monte carlo simulation

Monte Carlo simulation is a method that can estimate the solution of quantitative problems through statistical sampling. In this method, the final uncertainties of the model are obtained based on the initial uncertainties of the model. Uncertainties are shown quantitatively. The whole system runs in large numbers (for example, 10,000 times). All input parameters are sampled each time execution; a random value is selected from the random distributions associated with each parameter. The system is then simulated. Finally, many of the results are separate and independent. The results of highly executed performances are summarized and shown as probability distributions. Monte Carlo simulation is a method that uses random samples to obtain solutions to a model [126].

### 3.3. Decision tree

The decision tree method is similar to the binomial tree. These networks represent possible asset value changes over the property's life. Optimizing future decisions at different decision-making points and reversing them is the optimal solution. The Rami binomial model can be used with the binomial tree shown in the figure below to show that $S_0$ it is the initial asset value. This value can go up or down in different periods. Going up or down is indicated by the factors $u$ and $d$ , where $u > 1$ and $d < 1$ . The probability of realization of ascending branches $p$ ,and the realization of descending branches $1-p$ are. These probabilities are obtained from the neutral risk probability method to obtain the natural discretion value [127]. Figure 6 shows a binomial tree.

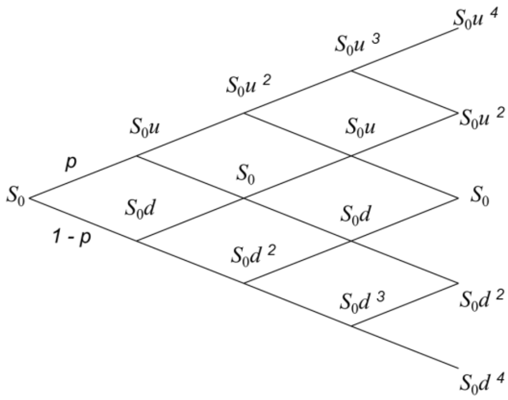



**Fig. 6. binomial tree**

### 3.4. Proposed solution method

After estimating different demands with the help of the decision tree using MATLAB software, this data is simulated and forms different scenarios for the amount of demand in several periods. With the help of Monte Carlo simulation, all input parameters are sampled at each execution to estimate the probability of randomness, and finally, the set of answers is called the simulated cost and the best cost, which is the estimated cost of the entire supply chain. MATLAB software code runs on a Pentium computer with 4 GB of RAM and Windows 10. The total simulation time is estimated to be 9 seconds for each run in the outsourced mode and 7 seconds for the non-outsourced mode. In the appendices section of the article, the code written in the MATLAB software for two modes, with outsourcing and without outsourcing, is displayed.

## 4. Numerical Results

A case study is about an international company in Tehran. The main factory of this company is in Shahroud. The products of this factory are all kinds of plastic and disposable accessories. The product under study is single salt. There are three machines for packing salt in the factory. This product has a high demand that, in some cases, the factory can not meet demand. We offered to outsource to this factory, which we modeled based on a forecast of 4 one-month periods. For ease of calculation, three zeros in the model have been removed. That is, the final answer must be multiplied by a thousand. Table 5 shows the value of the parameters based on company data.

**Tab. 5. Parameter values**

| parameter | value |
|---|---|
| $\theta_0$ | 200 |
| $p$ | 0.8 |
| $u$ | 1.3 |
| $d$ | 0.8 |
| $\tilde{P}$ | 250 |
| $C^{set}$ | 1000 |
| $C^{\text{var}}$ | 12 |
| $C^{tran}$ | 2 |
| $h$ | 3 |
| $\mu$ | 30 |
| $\beta$ | 14 |

With Table 3 data, we use the MATLAB

program to solve the model for ROV and NPV. Using a risk-free rate of 5%, the ROV method achieves a risk-free probability of 0.53. We compare the optimum projected costs found by the two valuation methods and split them into their constituent parts. These findings suggest that switching from an NPV to an ROV-based planning strategy might produce savings of about 42%. The cost analysis also reveals interesting information about the origins of these reductions. More specifically, customer shortfall fines have been reduced by a factor of three, which accounts for the bulk of these cost benefits. In this study, to calculate the value of real options, we divide modeling into two options:

1. Estimating the total cost taking into account the cost of shortage
2. Estimating the total cost of the supply chain by implementing the outsourcing plan and the cost of shortages in case of excess demand over outsourcing capacity.

Outsourcing is, in fact, an option in the real world that faces obstacles such as advertising problems and competitor growth that make managers different. After each execution of the model code in MATLAB software, 500 simulated answers have an output that has been repeated 1000 times. This set of answers changes each time the software is run and provides a new output. First, we examine the amount of supply and shortage in two different cases. Using the outsourcing option, product supply rates changed in all periods. Table 6 shows the difference between the supply amount in the two options with outsourcing and without outsourcing in 10 simulation scenarios.

**Tab. 6. Fluctuation of supply quantity in two different options**

| Scenario | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | max | min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No outsourcing | 976 | 1000 | 1000 | 756 | 1000 | 532 | 989 | 1000 | 1000 | 966 | 1000 | 532 |
| By outsourcing | 954 | 670 | 989 | 12199 | 12199 | 16086 | 667.5 | 954 | 16086 | 12199 | 1608 | 670 |

According to the above table and comparing the amount of supply in each option, it is inferred that in the case of outsourcing, in addition to the production capacity, demand can be met. Normally, the factory has a production capacity of 250 in each period, and in 4 periods, it can produce and supply 1000 products. In the case of outsourcing, in addition to production capacity, according to the volume of demand, the company can supply up to 1608 products. On the other hand, in the case of low demand, the company can respond more due to flexibility in production volume and outsourcing in the latter case. Next, in two different options, we examined the number of lost sales shown in Table 7.

**Tab. 7. Compare lost sales in two options**

| Scenario | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | max | min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No outsourcing | 608 | 118 | 338 | 0 | 608 | 608 | 608 | 0 | 118 | 219 | 608 | 0 |
| By outsourcing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Using input and simulation data in different cases, the maximum amount of deficiency in the normal case is 608. According to different scenarios, it is possible that the amount of deficiency in the method without outsourcing is zero, but the frequency of zero is low. According to the table, we do not incur any shortage costs; But this does not mean that no deficiency occurs in the case of outsourcing. A deficit occurs if the demand exceeds the total production and outsourcing capacity.

The software pays two outputs per run: the best answer and the simulated answer. The best answer is the average of all scenarios, and the simulated answer is randomly selected from 500 scenarios. Figure 7 shows the difference between the best cost and the simulated cost.

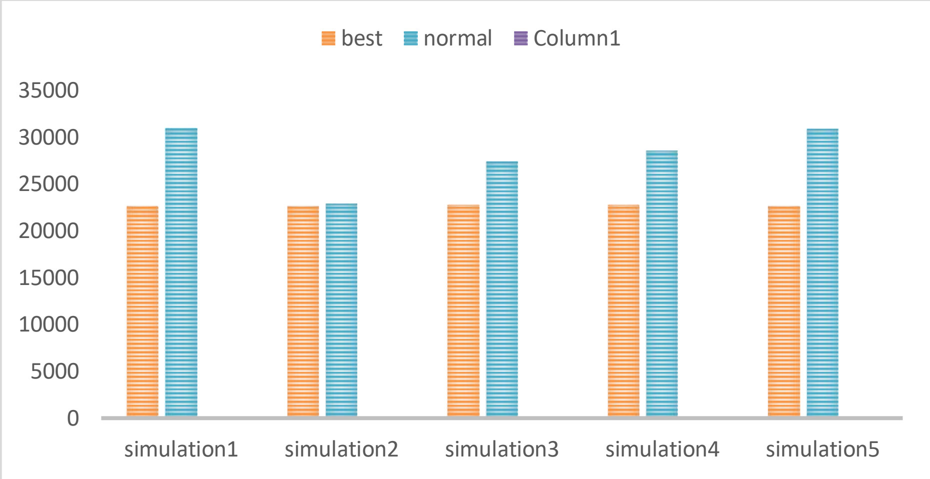



**Fig. 7. The difference between the best answer and the random answer each time simulated**

The previous figure shows the difference between the best and the random answers in the outsourcing situation. The same situation applies to the simulation without outsourcing. In simulation without outsourcing, an approximate number of 27000 is the best answer. The random output cost is the same as the previous case of approximate numbers around the axis of this number. Figure 8 shows the difference between the best answer in the case with outsourcing and without outsourcing.

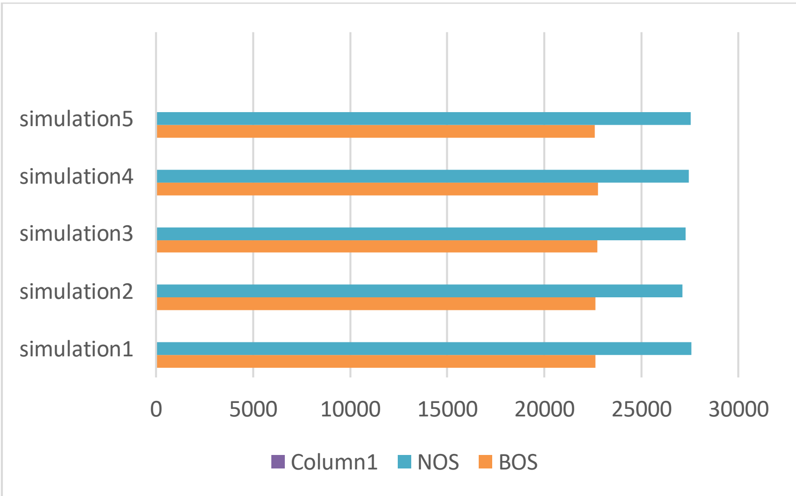



**Fig. 8. Comparison of costs between two methods with outsourcing and without outsourcing**

Figure 8 shows the cost difference between the two methods with and without outsourcing in 5 simulations. It is concluded that each time the software is run for each model gives an almost close answer. For the case with outsourcing, the total cost for four periods is 22 million, and for the case without outsourcing, considering the cost of shortage, it costs 27 millions. These two models are provided to managers for better decision-making. Depending on the circumstances, managers can decide to outsource or accept the cost of lost sales.

## 4.1. Sensitivity analysis

To confirm the efficiency of the solution method, we examined the MATLAB software code with different data. In the case of outsourcing, we doubled the amount of initial demand and the amount of production capacity and outsourcing to the amount of the previous data, and the result was a cost almost double the equivalent of 42 million tomans. On the other hand, we made the same changes for the model without outsourcing, and the result was estimated at 51 million tomans, almost twice the cost of the previous data. Also, the cost difference between the two methods is about 17.5%, which is the same as the difference in the initial data.

We have now halved the amount of demand, production capacity, and outsourcing capacity for both methods compared to the original data, and the result is that the same amount reduces the total cost of both methods. The percentage difference with the new data is 17.5% as before.

## 5. Conclusions

Real options allow companies to make decisions in uncertainty. They estimate the value of real options and give it to managers to make better decisions. This article combines supply chain management, decision-making, uncertainty, and real options theory. The main purpose was to implement the theory of natural authority in the supply chain. We considered the uncertainty in customer demand and assumed the price rate to be fixed for four periods. We considered a multi-period model, assuming that the costs of each period are related to each other. We estimated the uncertain demand for four periods using the decision tree and the Monte Carlo simulation. We simulated the total cost of the supply chain, including lost sales. Given the cost of lost sales, we came up with the idea of outsourcing to meet surplus demand. After estimating the total cost of the supply chain using outsourcing, we provided managers with two costs in two ways. Using Monte Carlo simulations and estimating demand uncertainty, outsourcing costs have been reduced by almost 20%. Given the positive value of the authority, it depends on the decision of the managers and the actual circumstances and interests of the company to decide to outsource or bear the cost of the lost sale. Future suggestions for developing the model include exchange rate uncertainty. Probability should be estimated by examining fluctuations in the stock portfolio, and the current value should be calculated. Also, maximizing supply chain profits and providing options for more profits can help improve the current model.

In this study, we considered the demand parameter uncertain and assumed the price rate and currency fluctuation to be constant. Using past demand data, we obtained future demand probabilities. In future research, it is possible to estimate future price fluctuations with the help of the stock portfolio and assess the current value and future growth rate for each product. Interest rates and risk-free interest rates can be added. Options such as divestiture, non-production, and the development of a new product can also be used to apply the theory of discretion. The objective function in this research is cost minimization; In future research, the goal function of maximizing profit and income can be added. It is also suggested that the option's value be calculated for several products at several levels of the supply chain and that different options be considered to optimize costs and revenue.

The computational findings for large-scale supply chain setups were given. It was shown that the suggested technique significantly improved computing needs compared to the direct use of commercial solvers by at least an order of magnitude. By removing constraints like grouping products into families and looking at various product architectures, we could examine how the solution method performs under different conditions. Computational studies showed that the suggested approach has a significant advantage over direct solution techniques utilizing commercially-available software, especially for real-world situations with many variables and restrictions.

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