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A Network Data Envelopment Analysis Model for Supply Chain Performance Evaluation: Real Case of Iranian Pharmaceutical Industry

M. Ebrahimpour Azbari, L. Olfat*, M. Amiri & J. Bamdad Soofi

Mostafa Ebrahimpour Azbari, *Assistant Professor, Department of Management, Faculty of Humanities, University of Guilan, Rasht, Iran , mostafaim@gmail.com*
Laya Olfat, *Associate Professor, Department of Industrial Management, Management and Accounting Faculty, Allameh Tabataba'i University, Tehran, Iran, layaolfat@gmail.com*
Maghsoud Amiri, *Associate Professor, Department of Industrial Management, Management and Accounting Faculty, Allameh Tabataba'i University, Tehran, Iran, mg_amiri@yahoo.com*
Jahanyar Bamdad Soofi, *Assistant Professor, Department of Industrial Management, Management and Accounting Faculty, Allameh Tabataba'i University, Tehran, Iran, bamdadsoofi@yahoo.com*

KEYWORDS

Supply Chain Performance Evaluation,
Performance Indicators, Factor Analysis,
Network Data Envelopment Analysis.

ABSTRACT

Having a comprehensive evaluation model with reliable data is useful to improve performance of supply chain. In this paper, according to the nature of supply chain, a model is presented that able to evaluate the performance of the supply chain by a network data envelopment analysis model and by using the financial, intellectual capital (knowledge base), collaboration and responsiveness factors of the supply chain. At the first step, indicators were determined and explained by explanatory Factor Analysis. Then, Network Data Envelopment Analysis (NDEA) model with variable returns to scale was used. This paper is the result of research related to supply chain of pharmaceutical companies in Tehran Stock Exchange and 115 experts and senior executives have been questioned as sample. The results showed that responsiveness latent variable had the highest correlation with supply chain performance and collaborative, financial and intellectual capital (knowledge base) latent variables were respectively after that. 12 of the 28 supply chains which were studied obtained 1 as the highest performance rate and the lowest observed performance was 0.81.

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1. Introduction

There is a significant corpus summarizing different studies on the performance evaluation models applied in a corporate framework [1,2,3]. Identifying performance evaluation systems was a key concern in the 1990s, the aim having mainly been to devise measurement systems whose dimensions would be broadly aligned with the corporate strategy [1]. There have been a huge variety of measurement systems, starting with the best known ones such as the Balanced Scorecard [4] or the EFQM Excellence Model [5] mainly geared towards measuring autonomous entities including, companies, subsidiaries, business units, etc. These models did not take the complexity of value-creating company chains into account. A number of measurement models were then defined in the 2000s and helped to analyses supply chains in terms of some

* **Corresponding author Laya Olfat**
Email: *layaolfat@gmail.com*
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or all of their components (collaboration, human resource management, sustainability, etc.). Supply chain performance measurement models developed in recent years include Supply Chain Operation (SCOR), Global Supply Chain Forum (GSF) and Efficient Consumer Response (ECR) [6]. Moreover, SCM involves challenges such as developing trust and collaboration among supply chain partners, identifying best practices that can facilitate supply chain process alignment and integration, and successfully implementing the latest collaborative information systems and Internet technologies that drive efficiencies, performance, and quality throughout the supply chain [7].

However, traditional assessment methods are less related to SCM since they are too limited to evaluate a wide range of activities. In recent decade, SCM has reached a remarkable growth in disseminating theories and operations of this area. Noteworthy, supply chain Performance measurement has not been sufficiently paid attention by the researchers. Also Performance measurement based on reliable data is a factor which is considered crucial for a company to return its investments fully [8].

In conventional Data Envelopment Analysis, DMUs are generally treated as a black-box in the sense that internal structures are ignored, and the performance of a DMU is assumed to be a function of a set of chosen inputs and outputs. A significant body of work has been directed at problem settings where the DMU is characterized by a multistage process; supply chains and many manufacturing processes take this form. Recent DEA literature on serial processes has tended to concentrate on closed systems, that is, where the outputs from one stage become the inputs to the next stage, and where no other inputs enter the process at any intermediate stage.

The current paper examines the more general problem of an open multistage process. Here, some outputs from a given stage may leave the system while others become inputs to the next stage and new inputs can enter at any stage. In order to address these issues, Cook et al (2010) [12] propose a performance evaluation methodology based on Data Envelopment Analysis, which can incorporate multiple inputs and outputs in multiple stages and results in a single relative efficiency measure. Since the conventional DEA models are found to be ineffective in measuring the performance of various supply chain related functions, many multi-stage DEA models have been developed to accommodate various indirect processes and their contribution to corporate performance [9,10,11,12).

In the current paper, we use the two-stage DEA model developed by Cook et al (2010) [12] to incorporate the effect of mediating and moderating variables on supply chain performance. This two-stage DEA model is capable of accommodating intermediary data such as Collaboration, Responsiveness and amount of sales.

After embracing supply chain performance and performance evaluation models some important questions must be asked. What indicators should be used to measure supply chain performance? How Performance Indicators including input, intermediate and output, can be selected?

According to the nature of a decision making unit in the network form, what type of Network data envelopment analysis model is appropriate for supply chain performance evaluation? The following sections of the paper have been organized as follows. Section 2 has been allocated to introduce a brief literature of supply chain performance and Network DEA models. Then, the research methodology and the proposed NDEA model which is able to measure the performance of supply chain has been proposed in Section 3. Experimental results are discussed in Section 4. Section 5 has been assigned to represent the conclusion remarks.

2. Literature of Performance Evaluation Indicators and NDEA

One of the new models of network economy is SCM used as a group of methods for managing and coordinating the whole chain ranging from suppliers' supply management to customers' customer management [13]. Besides, SCM, like any other management systems and approaches, needs a performance evaluation in order to recognize achievement, satisfying customers' needs, helping the organization to understand the process better, coming to new understanding of the previous issues, and brining about improvements for planning. Performance evaluation has an undeniable impact on the development of organizations; this is why it has been the major focus of many researchers and organizations as well.

As evolutionary process of organisations, has evolved from single approach to network approach and supply chain (SC), the performance evaluation systems have undergone some changes so that they are gravitated towards network performance evaluation (NPE) and SC [14]. In the following pages, the supply chain performance indicators including financial, intellectual, and collaborative and responsiveness will be examined.

2-1. Performance Evaluation Indicators

In traditional economy, property was considered as a group of possessions involved in the process of production. In other words, the meaning of fixed assets was associated with building, production facilities, materials, transport equipments, and machines as possessions employed in the process of production and they do not undergo any change except depreciation. The current assets were referred to raw materials and generally circulating capital as goods which were totally changed throughout the production process. Accordingly, assets are financial resources whose costs

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and prices can be calculated and controlled as inventory during gaining. Sometimes assets values are calculated based on comparison between expected expenses and potential incomes [15]. Measurement in productive systems was multi-faceted by developing systematic approaches. When the view towards production as a system improved, the concept of production as a process of converting inputs such as labour, raw materials, and etc, into outputs developed in the same way [16].

Responsiveness is the ability to identify changes and respond to them quickly, reactively or proactively, and also to recover from them [17]. Supply Chain Responsiveness today is an important issue in supply chain management. Supply Chain Responsiveness Refers to the time where businesses produce the product and deliver it to the end customers. The key measurement metric is the lead time, where the end product reaches the customer. At the end of the day, managers at the helm of decision making are interested in increasing productivity by reducing process costs and time, increasing process responsiveness, and improving product and service delivery quality [18]. Responsiveness, serves to shift operational emphasis from forecasting future requirements to accommodating customers on a rapid order-to-shipment basis.

In a response-based system, inventory is not deployed until a customer commits. To support such commitment, a firm must have inventory availability and timely delivery once a customer order is received. The global competitive climate of the 21 st century is facilitating the development of new manufacturing techniques designed to increase flexibility and responsiveness while maintaining unit cost and quality. Traditional practice has focused on achieving economy of scale by planning long manufacturing runs. In contrast, flexible and lean manufacturing logic is driven by a desire to increase responsiveness to customer requirements [19].

Customer responsiveness indicator is order fulfillment rate [20]. Responsiveness, however, comes at a cost. For instance, capacity must be increased, to respond to a wider range of quantities demand, which increases costs [21].

Supply chain collaboration has been defined in many different ways, and basically they fall into two groups of conceptualization: process focus and relationship focus. Supply chain collaboration has been viewed as a business process whereby two or more supply chain partners work together toward common goals [22], while SCC has also been defined as the formation of close, long term partnerships where supply chain members work together and share information, resources, and risk to accomplish mutual objectives [19].

The literature review reveals the importance of planning activities, integrating cross-functional processes, coordinating the supply chain, setting supply chain goals and establishing information sharing parameters [23,24]. Combining both process and relationship focus, SCC is defined as a partnership process where two or more autonomous firms work closely to plan and execute supply chain operations toward common goals and mutual benefits. SCC consists of information sharing, goal congruence, decision synchronization, resource sharing and incentive alignment among independent supply chain partners. Another overlooked but crucial variable in supply chain collaboration is joint knowledge creation. Cao and Zhang (2011) define supply chain collaboration as seven interconnecting components: information sharing, goal congruence, decision synchronization, incentive alignment, resources sharing, collaborative communication, and joint knowledge creation. These seven dimensions are expected to be inter correlated and co vary with each other although there might be causal relationships among them.

They add value to supply chain collaboration by reducing costs and response time, leveraging resources, and improving innovation. Information sharing refers to the extent to which a firm shares a variety of relevant, accurate, complete, and confidential information in a timely manner with its supply chain partners [24].

During previous decades, the process of production of many goods has undergone huge changes. Introduction of knowledge-based economy gave priority to knowledge rather than other production factors such as land, capital, and machine so that traditional factors gradually lost its importance. In other words, knowledge is considered as a vital factor concerning competitive advantage in many organizations [25]. In today world, knowledge is considered as one the most important intangible assets of an organization. In knowledge-based economy the success of an organization lies in the ability of managing its intangible assets. Therefore, some new models of organization assets are needed [26]. The concept of intellectual capital about traditional capital is different in calculations. As a result, assessing performance of intellectual capital based on financial reports is a big challenge for managers of organizations [27]. In order to assess efficient performance of intellectual capital not only quantity indicators but also quality indicators should be taken into account [28]. In fact, in traditional economy the priority was given to tangible capital while modern economy is based on intangible capital [15]. In this paper the performance indicators of SC are investigated from different aspects and on different levels. In addition, different models and different performance indicators are investigated. The different models and performance indicators given by experts is considered as a model in relationship with financial, responsiveness, collaborative, and intellectual capital indicators in pharmaceutical SC. The result of the research is given in Table 1.

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Tab. 1. The result of the previous research

Factors	Indicator	Reference List
Responsiveness	Response time to requests for new products	**(Lai et al, 2002[29];Bhagwat & Sharma, 2007[30];Kannan & Tan, 2002[29])**
	Delivery Lead Time	**(Bhagwat & Sharma[30], 2007;Kannan & Tan, 2002[31]; Xu et al, 2009[30]; Lai et al, 2002[27]; Chan, 2006[31])**
	Determine the future needs of customers	**(Bhagwat & Sharma, 2007[30], Gunasekaran, 2001, 2004[2,34])**
	Responsiveness to urgent deliveries	**(Bhagwat & Sharma, 2007[30], Gunasekaran, 2001, 2004[2,34])**
	Supplier lead-time	**(Gunasekaran, 2001, 2004[2,34])**
Collaboration	buyer–supplier partnership	**(Kim, 2007[23]; Bhagwat & Sharma, 2007[30];Kannan & Tan, 2002[31]; Hult et al, 2007[35]; Flynn et al, 2010[36])**
	Level and degree of information sharing	**(De Toni et al. 1994[37]; Kannan & Tan, 2002[31]; Kim, 2007[23])**
	Willingness to integrate supply chain management goal congruence	**(Stank & Lackey, 2001[38], Kannan & Tan, 2002[31])**
	Resources sharing between supply chain	**(Angeles and Nath, 2001[39])**
	Extent of mutual co-operation leading to improved quality	**(Sheu et al., 2006[22])**
	Consistent information and communication systems for supply chain members	**(Graham et al.,1994, Gunasekaran, 2001, 2004[2,34)**
		(Kannan & Tan, 2002[31], (Gunasekaran, 2001, 2004[2,34])
Intellectual capital (Knowledge Base)	Specialist staff to total staff ratio	**(Bontis, 2004[40], Khavandkar et al[15])**
	Brand	**(Bontis, 2004[40], Khavandkar et al[15])**
	Customer Loyalty	**(Brooking, 1996[41])**
	Investment in new products and services	**(Bontis, 2004[40], Khavandkar et al[15])**
	R & D budget or cost	**(Bontis, 2004[40], Khavandkar et al[15])**
	Customers satisfaction in supply chain	**(Brooking, 1996[41])**
	Supplier and manufacturer innovations to reduce costs	**(Gunasekaran, 2001, 2004[2,34])**
	Training per employee	**(Bontis, 2004[40], Khavandkar et al[15])**
Financial	Sales of products and services	**(Lai et al, 2002, [29])**
	Rate of return on assets (ROA)	**(Bhagwat & Sharma, 2007[30]; Xu et al, 2009[32])**
	Earnings per share	**(Bhagwat & Sharma, 2007; Gunasekaran, 2001, 2004[2,34])**
	Cost of information exchange	**(Bhagwat & Sharma, 2007[30])**
	Production costs (cost of raw materials, manpower, energy)	**(Bhagwat & Sharma, 2007[30])**
	The total cost of maintaining inventory	**(Lai et al, 2002[29]; Xu et al, 2009[32])**
	Capacity utilization	**(Gunasekaran, 2001, 2004[2,34])**
	Inventory turnover	**(Dehning et al. 2007[42]; Chen et al 2004[9])**

2-2. A Brief Review of Network DEA

DEA determines the relative efficiency values of comparable Decision Making Units through linear programming. DEA has gained too much attention by researchers because of its successful applications and case studies [43]. CCR model was first introduced for efficiency measurement by Charnes et al (1978) [44]. Then, the BCC model was developed by Banker et al (1984) [45]. Cook et al (2010) [12], develop models for DMUs with network structures based upon additive efficiency decomposition.

Their approach can be viewed as a centralized model. These types of DMUs have not only inputs and outputs, but also intermediate measures that flow from one stage to the other. Each stage may also have its own inputs and outputs. Recently, a number of studies have focused on DMUs that appear as two-stage processes.

For example, Seiford and Zhu (1999)[46] view the profitability and marketability of US commercial banks as a two-stage process. In their study, profitability is measured in the first stage using labor and assets as inputs and profits and revenues as outputs. In the second stage for marketability, the profits and revenue are then used as inputs, while market value, returns and earnings per share, constitute the outputs. Kao and Hwang (2008)[11] describe a two-stage process where 24 non-life insurance companies use operating and insurance expenses to generate premiums in the first stage, and then underwriting and investment profits in the second stage.

Other examples include the impact of information technology used on bank branch performance [9], two stage Major League Baseball performance [47], health care application and many others. Conventional DEA approach does not, however, address potential conflicts between the two stages arising from the intermediate measures.

For example, the second stage may have to reduce its inputs (intermediate measures) in order to achieve an efficient status. Such an action would, however, imply a reduction in the first stage outputs, thereby reducing the efficiency of that stage. Novel approaches have

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been developed to model the intermediate measures that exist between stages within DMUs.
For example, Kao and Hwang (2008) [11] modify the standard radial DEA model by decomposing the overall efficiency of the DMU into the product of the efficiencies of the two stages. Such multiplicative efficiency decomposition is also studied in Liang et al. (2008)[10], More recently, Chen et al. (2009)[48] has presented a methodology for representing overall radial efficiency of a DMU as an additive weighted average of the radial efficiencies of the individual stages or components that make up the DMU.

3. The Research Methodology

The research methodology in the first part is descriptive-casual (in order to recognize the present situation and examine factor loading). In the second part, the descriptive-analytical method that is NDEA is employed.
The research population is the pharmaceutical companies in Tehran Stock Exchange. Pharmaceutical SC is chosen based on those pharmaceutical companies registered in Tehran Stock Exchange and considered as producers of SC. The major suppliers of each of these pharmaceutical companies are recognized which totally consist 28 SCs. It should be mentioned that in the first part of the research (factor analysis for finding the indicators) experts and managers of production and operation unit, research and development unit, and logistic and supply unit, who had BA degree and five-year work experience at least, were included. The number of samples according to theoretical sampling and the sampling adequacy (0.998) was 115 experts and managers.

3-1. Conceptual Model for Measurement of Supply Chain Performance

To measure different levels of supply chain performance the input, intermediate and output oriented indicators concerning performance should be retrieved through literature review. As mentioned, different frameworks have been reported in literature for measuring the performance of organizations and supply chains.
There are a few efforts to adjust supply chain performance measures systematically. Additionally, neither there is a consensus among the authors on the most appropriate method of the assessment nor the categorization of the methods [49].
By reviewing the literature, the conceptual model consisting of four factors (latent variables) influencing SC performance, including financial, responsiveness, collaborative, and knowledge-based (intellectual capital) is presented. 28 out of 35 performance indicators (overt variables) were selected based on the frequency of each indicator in the literature. The results are shown in Table. 1.

As it can be seen in conceptual model (Fig. 1) having determined the performance of SC indicators, input, intermediate, and output variables are chosen and implemented by employing Network Data Envelopment Analysis.

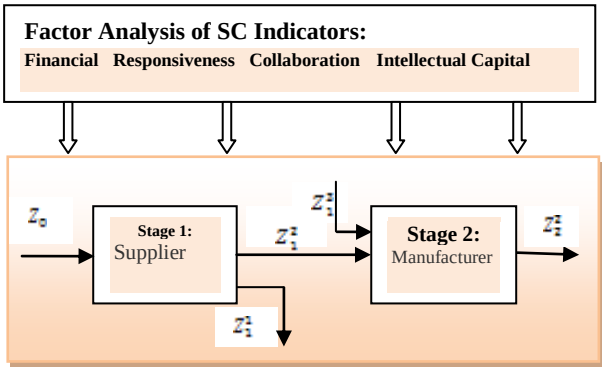

Fig. 1. Conceptual model

3-2. Proposed Network DEA Model for Evaluation of Performance

In this paper the NDEA model of Cook et al [12] under the assumption of constant returns to scale (CRS) has been used and we have developed this model to variable returns to scale (VRS). Consider the P-stage process pictured in Fig.1. The input vector to stage 1 displayed by z_0. The output vectors from stage p (p = 1,... ,P) take two forms, namely z_p^1 and z_p^2. Here, z_p^1 represents that output that leaves the process at this stage and is not passed on as input to the next stage. The vector z_p^2 represents the amount of output that becomes input to the next (p + 1) stage. There is the provision for new inputs z_p^3 to enter the process at the beginning of stage p + 1. Specifically, when p = 2,3,..., we define:

(1) z_{pr}^{j1} the rth component (r = 1,...,R_p) of the R_p-dimensional output vector for DMUj flowing from stage p, that leaves the process at that stage, and is not passed on as an input to stage p + 1.
(2) z_{pk}^{j2} the kth component (k = 1,...,S_p) of the Sp-dimensional output vector for DMUj flowing from stage p, and is passed on as a portion of the inputs to stage p + 1.
(3) z_{pi}^{j3} the ith component (i = 1,..., I_p) of the I_p-dimensional input vector for DMUj at the stage p + 1, that enters the process at the beginning of that stage.

Note that in the last stage P, all the outputs are viewed as z_{pr}^{j1}, as they leave the process. We denote the multipliers (weights) for the above factors as:

(1) u_{pr} is the multiplier for the output component z_{pr}^{j1} flowing from stage p.
(2) η_{pk} is the multiplier for the output component z_{pk}^{j2}at stage p, and is as well the multiplier for that

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same component as it becomes an input to stage p + 1.

(3) v_{pi} is the multiplier for the input component z_{pi}^{j3} entering the process at the beginning of stage p + 1.

$$\theta_p = \left(\sum_{r=1}^{R_p} U_{pr} Z_{pr}^{j1} + \sum_{k=1}^{S_p} \eta_{pk} Z_{pk}^{j2}\right) / \left(\sum_{k=1}^{S_{p-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} V_{p-1i} Z_{p-1i}^{j3}\right) \quad (1)$$

Note that there are no outputs flowing into stage 1. The efficiency measure for stage 1 of the process (namely, p = 1), for DMUj becomes:

$$\theta_1 = \frac{\left(\sum_{r=1}^{R_1} U_{1r} Z_{1r}^{j1} + \sum_{k=1}^{S_1} \eta_{1k} Z_{1k}^{j2}\right)}{\sum_{i=1}^{I_0} V_{0i} Z_{0i}^{j}} \quad (2)$$

The overall efficiency measure of the multistage process can reasonably be represented as a convex linear combination of the P (stage – level) measures, namely:

$$\theta = \sum_{p=1}^{p} w_p \theta_p \quad where \quad \sum_{p=1}^{p} w_p = 1 \quad (3)$$

Note that the weights w_p are intended to represent the relative importance or contribution of the performance of individual stages p to the overall performance of the entire process. One reasonable choice for weights w_p is the proportion of total resources for the process that are devoted to stage p, and reflecting the relative size of that stage. We then have:

$$w_1 = \sum_{i=1}^{I0} v_{0i} Z_{0i}^{j} / \{\sum_{i=1}^{I0} V_{0i} Z_{0i}^{j} + \sum_{p=2}^{p} (\sum_{k=1}^{S_{P-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} v_{p-1i} z_{p-1i}^{j3})\} \quad (4)$$

$$w_p = \left(\sum_{k=1}^{S_{p-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} V_{p-1i} Z_{p-1i}^{j3}\right) / \left\{\sum_{i=1}^{I0} V_{0i} Z_{0i}^{j} + \sum_{p=2}^{p} (\sum_{k=1}^{S_{p-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} v_{p-1i} z_{p-1i}^{j3})\}, p > 1 \quad (5)$$

Thus, we can write the overall efficiency θ in the form

$$\theta = \sum_{p=1}^{p} \left(\sum_{r=1}^{Rp} u_{pr} z_{pr}^{j1} + \sum_{k=1}^{Sp} \eta_{pk} z_{pk}^{j2}\right) / \left\{\sum_{i=1}^{I0} V_{0i} Z_{0i}^{j} + \sum_{p=2}^{p} (\sum_{k=1}^{S_{P-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} v_{p-1i} z_{p-1i}^{j3})\right\} \quad (6)$$

For developing NDEA model with constant returns to scale (CRS) (presented by Cook et al 2010) to variable returns to scale (VRS) we added the free-in-sign variable (L) in our ratio efficiency definition for each stage of supply chain. Thus by adding the free-in-sign variable, when p = 2, 3,. . . , the efficiency ratio for DMUj (for a given set of multipliers) be expressed as:

$$\theta_p = \left(\sum_{r=1}^{R_p} U_{pr} Z_{pr}^{j1} + \sum_{k=1}^{S_p} \eta_{pk} Z_{pk}^{j2}\right) + \boldsymbol{L_p} \; / \; (\sum_{k=1}^{S_{p-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} V_{p-1i} Z_{p-1i}^{j3}) \quad (7)$$

The efficiency measure for stage 1 of the process (namely, p = 1), in variable return to scale (VRS) model, for DMU_j becomes;

$$\theta_1 = \left(\sum_{r=1}^{R_p} U_{pr} Z_{pr}^{j1} + \sum_{k=1}^{S_p} \eta_{pk} Z_{pk}^{j2}\right) + \boldsymbol{L_1} \; / \; \sum_{i=1}^{I_0} V_{0i} Z_{0i}^{j} \quad (8)$$

Thus, we can write the overall efficiency θ with added free-in-sign variable (L) for two stages SC in the form;

$$\boldsymbol{\theta} = \left(\sum_{r=1}^{R_p} U_{pr} Z_{pr}^{j1} + \sum_{k=1}^{S_p} \eta_{pk} Z_{pk}^{j2}\right) + \sum L_p \; / \; \left\{\sum_{i=1}^{i0} v_{0i} z_{0i}^{j} + \sum_{p=2}^{p} (\sum_{k=1}^{S_{p-1}} \eta_{p-1k} Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} v_{p-1i} z_{p-1i}^{j3})\right\} \quad (9)$$

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Thus the overall efficiency θ of the two stage process, subject to the restrictions that the individual measures θ_p must not exceed unity, or in the linear programming format shown in Eq. 3-2;

$$
\begin{aligned}
&\max \quad \sum_{p=1}^{p}\Big(\sum_{r=1}^{R_p} U_{pr}\, Z_{pr}^{01} + \sum_{k=1}^{S_p} \eta_{pk}\, Z_{pk}^{02}\Big) + \boldsymbol{L_1} + \boldsymbol{L_2} \\
&subject\ to: \\
&\left\{\sum_{i=1}^{i0} v_{0i}\, z_{i0}^{0} + \sum_{p=2}^{p}\Big(\sum_{k=1}^{S_{p-1}} \eta_{p-1k}\, Z_{p-1k}^{o2} + \sum_{i=1}^{I_p} v_{p-1i}\, z_{p-1i}^{o3}\Big)\right\} = 1 \\
&\left(\sum_{r=1}^{R_1} U_{1r}\, Z_{1r}^{j1} + \sum_{k=1}^{S_1} \eta_{1k}\, Z_{1k}^{j2}\right) + \boldsymbol{L_1} \le \sum_{i=1}^{I_0} V_{0i}\, Z_{0i}^{j} \qquad \forall j \\
&\left(\sum_{r=1}^{R_p} U_{pr}\, Z_{pr}^{j1} + \sum_{k=1}^{S_p} \eta_{pk}\, Z_{pk}^{j2}\right) + \boldsymbol{L_2} \le \Big(\sum_{k=1}^{S_{p-1}} \eta_{p-1k}\, Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} V_{p-1i} Z_{p-1i}^{j3}\Big) \qquad \forall j \\
&U_{pr}, \eta_{pk},\ V_{pi}, V_{0I} > 0 \\
&\boldsymbol{L_1},\ \boldsymbol{L_2}\ free - in - sign
\end{aligned}
\tag{10}
$$

Eq. 10. Variable returns to scale NDEA model

Note that we should impose the restriction that the overall efficiency scores for each j should not exceed unity, shown in Eq. 3-3.

$$
\boldsymbol{\theta} = \left(\sum_{r=1}^{R_p} U_{pr}\, Z_{pr}^{j1} + \sum_{k=1}^{S_p} \eta_{pk}\, Z_{pk}^{j2}\right) + \sum L_p \;/\; \left\{\sum_{i=1}^{i0} v_{0i}\, z_{0i}^{j} + \sum_{p=2}^{p}\Big(\sum_{k=1}^{S_{p-1}} \eta_{p-1k}\, Z_{p-1k}^{j2} + \sum_{i=1}^{I_p} v_{p-1i}\, z_{p-1i}^{j3}\Big)\right\} \tag{11}
$$

But, by adding the last two constraints on the VRS model these are redundant and unnecessary.

3-3. Data Gathering

In this section the performance indicators of financial, knowledge-based, responsiveness, and collaborative of SC are examined. The investigation is carried out through examining and analyzing articles, highly cited articles and research-scientific journals, and review of previous literature. Afterwards, the results were consulted and approved by university professors of the related field of study and experts in pharmaceutical industry which are given in Table 1. After determining the efficient factors and indicators on the performance of pharmaceutical SC, data collection phase was carried out for performance analysis. This phase is divided into two parts: 1) collecting data for historical data, and 2) designing questionnaire and investigation for collecting quantitative data by visiting the pharmaceutical companies in person. The quantitative data are collected by reading financial reports and financial documents of companies. In addition, the qualitative data were collected by designing questionnaire on Likert scale. The questionnaire consists of two separated parts. In the first part, the views of experts were asked about the importance of performance indicators and in the second part, the present situations of indicators were considered. The validity of the research questionnaire is content validity which was approved by the experts and the reliability of the research was calculated using Cronbach's Alpha method which was 0.94.

4. Results

In this paper analyzing data was performed on two different parts. In the first part, first- order confirmatory factor analysis and second-order confirmatory factor analysis was used. In the second part, after performing factor analysis and explanation of model and evaluation factor loading, from among confirmed indicators of previous part, variables for performing of the NDEA model were chosen and Lingo 12 software was used. The results obtained are explained below. Moreover, in order to analyze the sampling adequacy, KMO and Bartlett tests were used for performance variable. Since the KMO value is 0.899 and significant value (sig<0.05) it can be concluded that data are appropriate for performing factor analysis.

4-1. First and Second-order Confirmatory Factor Analysis of SC Performance

In first-order factor analysis, Responsiveness factor (latent variable) is coded as RS, Collaborative as PS, Intellectual Capital (Knowledge-Based) as IS, and Financial indicator as FS. According to obtained results

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from measuring SC performance based on standard error of the estimate, it can be said that the corresponding indexes (fit statistics) are appropriate for measurement model since ($\frac{\chi^2}{df} = 1.77$) and RMSEA value is less than 0.09. In addition, all variables with t value are significant from statistical viewpoint$(t > 1.96)$.

The result of the model based on standard error of the estimate, shows that the correlation of one overt variable in relation to its collaborative latent variable and one overt variable in relation to financial latent variable are less than 0.5. As a result, the two variables were left out the model and another factor analysis was performed.

The results show that among overt variables related to latent variable of responsiveness, RS3 has the highest correlation with collaborative latent variable and its value is 0.73. In other words, variance $(0.73)^2$ of responsiveness variable can be evaluated by this overt variable. Among overt variables related to collaborative latent variable, PS5 has the highest correlation with collaborative latent variable and its value is 0.77. Among overt variables related to knowledge-based and intellectual capital variables, IS7 has the highest correlation with knowledge-based latent variable and its value is 0.81, among overt variables related to financial latent variable, FS8 has the highest correlation with financial latent variable and its value is 0.71.

Tab. 2. Results of confirmatory factor analysis of supply chain performance

Factors	Second-order factor loading	Indicators	First-order factor loading
Responsiveness	**0.98**	Response time to requests for new products	**0.67**
		Delivery Lead Time	**0.52**
		Determine the future needs of customers	**0.73**
		Responsiveness to urgent deliveries	**0.53**
		Supplier lead-time	**0.58**
Collaboration	**0.96**	buyer–supplier partnership	**0.52**
		Level and degree of information sharing	**0.72**
		Willingness to integrate supply chain management	**0.67**
		Resources sharing between supply chain	**0.77**
		Extent of mutual co-operation leading to improved quality	**0.62**
		Consistent information and communication systems for SC members	**0.51**
Intellectual capital (Knowledge Base)	**0.94**	Specialist staff to total staff ratio	**0.68**
		Brand	**0.57**
		Customer Loyalty	**0.79**
		Invest in new products and services	**0.68**
		R & D budget or cost	**0.63**
		Customers satisfaction in supply chain	**0.77**
		Supplier and manufacturer innovations to reduce costs	**0.81**
		Training per employee	**0.74**
Financial	**0.95**	Sales of products and services	**0.60**
		Rate of return on assets (ROA)	**0.68**
		Earnings per share	**0.60**
		Production costs (cost of raw materials, manpower, energy)	**0.65**
		The total cost of maintaining inventory	**0.59**
		Capacity utilization	**0.54**
		Inventory turnover	**0.75**

In the same way, throughout the confirmatory factor analysis, second-order factor analysis was performed in order to evaluate the degree of correlation of responsiveness, collaborative, knowledge-based, and financial latent variables with performance latent variable of SCP. The results obtained show that responsiveness variables have the highest correlation with performance latent variable of SCP and its value is 98%.

Factor loading of collaborative, knowledge-based, financial latent variables with latent performance variable is 96%, 94%, and 95%, respectively. Second-order factor analysis model when modified is shown in Fig.2. According to data obtained from Second-order factor analysis model, the measurement of SC performance based on standard error of estimate, it can be claimed that fit statistic indexes of the model are appropriate measurement tools. Because the proportion of ($\frac{\chi^2}{df} = 1.77$)and the RMSEA is less than 0.09. Besides, the loading factor of each of overt indicators related to latent variables of responsiveness, collaborative, knowledge-based, and financial in are given in Table 2.

4-2. Results of Network Data Envelopment Analysis Model

After administering first and second factor analysis of supply chain performance of pharmaceutical companies, factor loading of factors and indicators performance were determined. Also, fit statistics indicates showed that factor analysis model was an appropriate one. So after this phase, having used experts' views, the necessary data for administering the model based on their loading factor in factor analysis model were determined. The necessary data include input, intermediate, and output variables of 28

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pharmaceutical companies SC. Because of the network like nature of SC and intermediate data in the SC, the NDEA model with variable returns to scale (VSR) applied in part 3 of the research was used. Regarding the relationship $n > 3(s+m)$ in order to increase the differentiation and also using the maximum of variables, 10 variables as input, intermediate and output variables were chosen. All the variables are shown in Table 3.

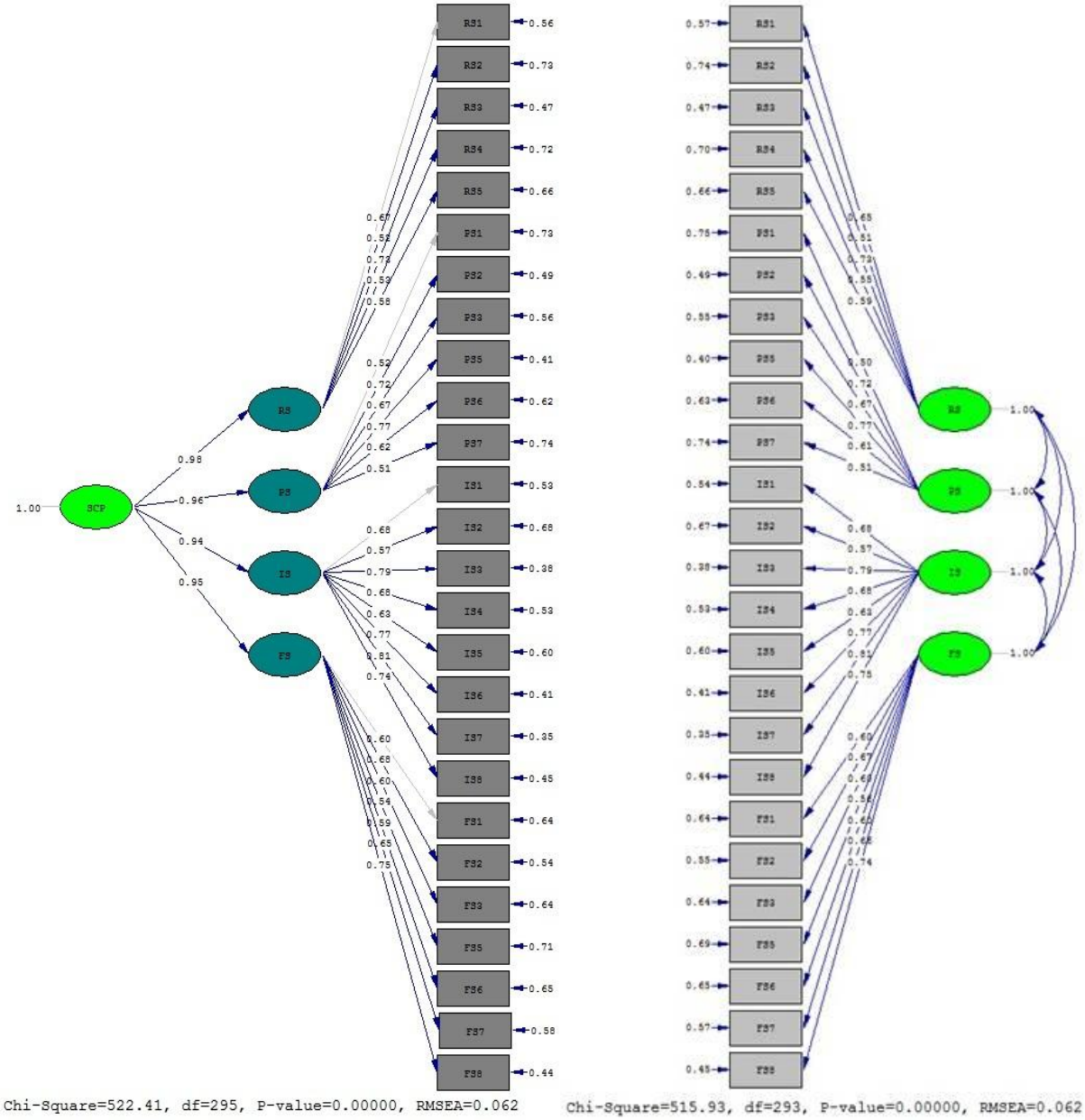

Fig.2. First and second-order confirmatory factor analysis of SC performance

Tab. 3. Variables used in NDEA

Variable	The nature of the variable in the chain
Supplier Production costs (cost of raw materials, manpower, energy)	**Supplier input**
Sales of products and services	**Intermediate data between supplier & manufacture**
Collaboration	**Intermediate data between supplier & manufacture**
Responsiveness	**Intermediate data between supplier & manufacture**
Sales of products and services to others	**Supplier output**
Manufacturer Production costs (cost of raw materials, manpower, energy)	**Manufacturer input in stage2**
Intellectual capital	**Manufacturer input in stage2**
Earnings per share	**Manufacturer output**

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Rate of return on assets (ROA)	**Manufacturer output**
Inventory turnover	**Manufacturer output**

The data obtained from NDEA are shown in Fig.3.

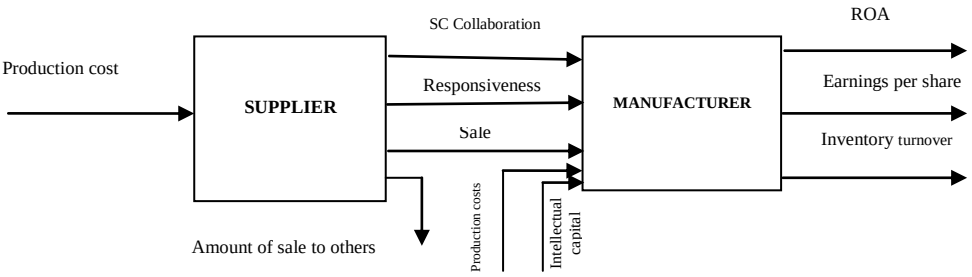

Fig. 3. Input, intermediate and output variables of SC

After performing factor analysis and determining factor loading of variables, evaluation indicators were chosen based on higher factor loading and experts' views and then the current situation of quality indexes were determined based on Likert scale. Among approved and chosen indicators, based on experts' views, the data related to revenue expenditure, the amount of sale, the earning per share, the return of investment, and inventory turnover variables were based on financial reports and other related documents. For responsiveness variable of SC the mean numerical value of four of approved indicator was chosen. For qualitative variable of collaborative indicator of SC the mean numerical value of six, and for intellectual capital variable the mean numerical value of four of approved indicator were chosen. The results are given in Table 4. The results show that the 12 decision-making units have efficiency value 1. However, the least value of efficiency is 0.81.

Tab. 4. Results of NDEA

DMU	performance	DMU	performance
1	**0.81**	15	**1.00**
2	**0.84**	16	**1.00**
3	**1.00**	17	**1.00**
4	**0.92**	18	**0.87**
5	**0.88**	19	**0.84**
6	**0.86**	20	**1.00**
7	**0.88**	21	**1.00**
8	**0.96**	22	**0.96**
9	**1.00**	23	**1.00**
10	**0.82**	24	**1.00**
11	**1.00**	25	**1.00**
12	**0.81**	26	**1.00**
13	**0.84**	27	**0.89**
14	**0.94**	28	**0.95**

The model and method employed for the second part of the research indicate, concerning the kinds of indicator and the network-like nature of SC, using NDEA gives more accurate and appropriate information in comparison to classical models of DEA. Administering the model shows that it is possible to consider the operations of SC, and also, to use different quality and quantity indicator on different level of SC.

5. Conclusion Remarks

The article major aim, focusing on development of comprehensive indicators and model in accordance with nature of supply chain, is to evaluate the performance of supply chain. In so doing, the evaluative indicator of supply chain performance of pharmaceutical companies was determined and explains by factor analysis model based on; financial, intellectual capital, collaborative, and responsiveness indicators of SC.

The results of the approved indicators indicate that in pharmaceutical supply chains it is not only the financial indicators which are taken into account, but also a group of financial, intellectual capital, responsiveness, and collaborative indicators of supply chain, approved by managers and experts are considered. Furthermore, as the results of the second-order factor analysis show the responsiveness variable has the highest loading factor (0.98). In other words, it implies the long-term planning of the mangers concerning performance and evaluation factors in pharmaceutical supply chain. Some of these major indicators are the time of responding demand, the delivery lead time, and Responsiveness to urgent deliveries.. In the second part of the research, based on the kind of approved indicators of factor analysis, it was necessary to use a model to evaluate the performance of supply chain. It was necessary because it made possible to use approved indicators in supply process of raw materials and production.

On the other hand, to evaluate the performance of supply chain, it was needed to suggest a model to take into account the operations of input, intermediate, and output data concerning the nature of supply chain. In the same vein, it was supposed to calculate a mathematical model in order to assess the performance

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and processes of the whole of supply chain at the same time. Therefore, the network data envelopment analysis with variable returns to scale is used. The results show that the given model is an appropriate model for evaluation of the performance of supply chain since it gives the possibility of considering operations of chain items and indicators. Additionally, the results of performance ranking have the highest differentiation vigor. Finally, as for approved of SC indicators such as collaborative, intellectual capital, and responsiveness supply chains, it is recommended that in order to improve the SC performance, managers and decision makers to pay attention to these indicators. To expand the result of the research, it can be applied in other industries and to develop the model the distributors of the supply chain can be included.

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