Journal of System Management (JSM)
Online ISSN: 2538-1571
Print ISSN: 2322-2301
Vol. 7, No. 2, (26) 2021, pp. 59-81
Research Paper

A New Model to Analyze the Efficiency of a Multilevel Drug Supply Network for Hospitals

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Abstract It is of special importance to procure medicines as strategic commodities. The purpose of this study is to manage a drug supply network using a non-radial data envelopment analysis (DEA) model. This study is conducted in private hospitals in Tehran. In this regard, a drug supply chain at three levels of suppliers, distributors, and consumers (pharmacies and hospitals) is examined. Indicators and limitations of the network are identified and then the appropriate model is formulated using mathematical equations on the basis of a non-radial DEA model. In order to validate the proposed model, data related to 30 hospitals during 2019 and 2020 is evaluated. According to this model, 5 hospitals had efficient supply networks and 25 hospitals had deficient supply networks. The proposed new model is able to evaluate the multilevel supply network and intermediate components in hospitals. The problems of the drug supply network are due to the increase in demands for the time *period under* consideration and the existence of inconsistencies in the drug supply chain in hospitals, which has led to an increase in inefficient hospitals.

Keywords *Non-radial Model, Data Envelopment Analysis, Sustainable Supply Chains, Coronavirus Pandemic*

Introduction and Problem Statement

Companies are likely to consider supply network management as one of the most significant areas, especially in economic and social

Received: 09/05/2021 Accepted: 11/08/2021

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crises. A *supply chain* is a network including all businesses and departments that work *directly* and *indirectly* to meet demands of *final consumers.* Therefore, if the role of any of these entities is eliminated or diminished, the supply network will not function properly and as a result of breaking one *link* in any part of the supply *chain*, a *broken link can* cause unplanned disruption in the continuation of operations for other links. In other words, supply chain is a professional approach to the operational realities of market relations that instead of focusing solely on the delivery of goods, manages the flow of inputs between businesses and locations in a network to increase productivity and *resilience* of companies through *collaboration with* other players, and reduce their risks and costs. *Today's* marketplace is characterized by turbulence and *uncertainty*. Increasing *uncertainty* for the sake of disruptions and threats has made the task of managing supply networks more *challenging* (Nasr Isfahani et al., 1399). Since in today's volatile and uncertain markets, supply chain vulnerabilities have become an important issue for many companies, even in a well-structured and highly operational supply chain, risks are still a concern and should not be neglected (Mohammadifar et al., 2015). *The field of healthcare is one of the most important functional areas in nations and healthcare supply chain management is of great importance which is typically a very complex and fragmented process. Its supply chain costs have a direct impact on the cost of pharmaceutical items. On the other hand, this field should be able to cover the pharmaceutical needs of the society with the highest speed and accuracy in special and critical situations such as the prevailing pandemic situation of coronavirus disease- COVID-19, and for this aim, analysis of the efficiency of the drug supply network seems necessary (*Sheikh Begloo et al., 1399). Gradually, the role of drugs in healthcare systems is increasing. The drug supply network is part of the healthcare system, and if not properly addressed, the concept of health in that community is unlikely to grow significantly. The drug supply network includes a set of operations for the flow of drugs from raw materials to end customers, as well as related information and financial flows (Fallahpour et al., 2017). In a competitive environment, pharmacies, distributors and hospitals in order to survive and develop sustainability need to measure the performance of their drug supply network as the most prominent source of nutrition in the field of healthcare (Azadi and Jafarian, 2015). In recent years, the issue of sustainable supply chain in the pharmaceutical industry has received growing attention, and in the current situation of *COVID*-19 *pandemic*, also known as the *coronavirus pandemic*, this issue is being vigorously pursued by researchers. Managers of the pharmaceutical industry and hospitals seek to identify factors affecting sustainable performance in the network by creating appropriate methods (Genovese et al., 2017), and use them to measure efficiency and reduce undesirable costs. In this regard, they become able to make appropriate decisions to improve efficiency and effectiveness (Androage et al., 1398). The three main processes (supply, distribution, and consumption) do not fully guarantee optimal performance in the drug supply network, and even the situation becomes much more ambiguous and complex in critical and special situations. The current business environment is such that health-related organizations have been forced to turn to new management approaches such as supply chain management to gain competitive advantage for the *survival*, continuation and *growth* (Alamdari and Najafzadeh, 1399). But these complexities have caused many issues for both organizations and the society. Organizations have resorted to using new management methods to solve these problems. *Coronavirus* impact highlights the need to transform traditional *supply chain*. Its outbreak has caused a negative supply-side and demand-side shock and has spread to all sectors of the economy by affecting the supply chain. But these effects are not only in terms of supply and demand shocks, but also related to another phenomenon called "coordination failure" which is part of the secondary effects of supply and demand shocks that lead to drastic changes in expectations and risk management patterns of economic actors including consumers, and a government. The basic elements of the chain include information exchange, logistics (physical exchange of inputs and outputs) and credit exchange (monitoring the flow of information exchange or physical input in the form of online transactions), which will be disrupted by the phenomenon of coordination failure (Fallahpour et al., 2017). The *coronavirus pandemic* first affects the supply-side of the economy in the area of production and supply of medicines by shutting down economic activities, closing factories and stagnating many service-based activities. It also shocks the supply-side due to the effect of mortality and reduction of manpower and the effect of disease on the reduction of labor activity and productivity. These factors double the effects of shock by directly affecting employment. As a result of the *coronavirus* outbreak, there is a huge decline in demands because of changes in consumer preferences, mainly due to fear and consequently a change in consumption patterns (Hatami-Marbini et al., 2017). There is also a reduction in demands for transportation-related activities such as business travel and tourism. Demands for educational services, and entertainment and leisure services are diminished as well, all of which account for demand-side shocks. Besides, on behalf of the closure of land borders by countries in the region, including Iraq, Afghanistan and Turkey, and air borders, especially Turkey, Georgia and the UAE, which directly lead to less production, there is a decrease and in some cases the cessation of exports and imports. Thus, they have doubled the effects of supply and demand shocks in the pharmaceutical and healthcare industries. On account of the phenomenon of "coordination failure", the standards and mechanisms of information exchange in the traditional or organic supply network have become inefficient and with the occurrence of a domino effect, the credit exchange network will also malfunction. In addition, the physical exchange of inputs and outputs is directly disrupted due to hygiene reasons (De Camargo Fiorini and Charbel José, 2017).

The current problems of hospitals in the management of the drug supply network include the followings (Fallahpour et al., 2017; Alamdari and Najafzadeh, 1399; De Camargo Fiorini, Charbel José, 2017):

- Inability to access accurate information throughout the supply network,
- Concern about fulfilling the commitments of the parties of the contract throughout the supply network and lack of confidence in timely delivery of orders,
- Density of activities of industrial units of drug production across a network and their domino effects on each other,
- Cessation of activities of some manufacturers, especially upstream companies and suppliers of raw materials required for the production and supply of drugs in other parts of a chain,
- Market and demand loss for downstream businesses and pharmacies as endpoints of sale in drug supply chains,
- Increased storage costs of ready-to-deliver *drugs* authorized for *non-covid* disease due to reduced demand and lack of storage required or the inability to maintain some products because of spoilage,
- Impossibility of timely transportation of raw materials, production requirements or final product along the supply network for reasons such as reduced labor force, vehicle traffic restrictions, driver traffic restrictions, especially in road transport, and the need to use the limited capacity of rail transport,
- Decline in production as a consequence of reduced labor for reasons such as unit closure, labor adjustment or reduction of the number of workers because of temporary closures and shifts, and
- Reduction or cessation of production as a result of lack of liquidity caused by reduced sales, or overpayment due to the

coronavirus outbreak such as health costs, cancellation of orders, drop in demand, loss of perishable goods with a short shelf life.

Efficiency and performance indicators were examined in numerous studies (Pilevari et al., 2013; Ebrahimi et al., 2013). One of the most important factors in performance measurement of organizations such as hospitals is calculating their efficiency score. For the sake of the network-based structure in the drug supply chain, it is not possible to calculate the efficiency of this network using classical models. Therefore, a model is needed to consider the relationships between the links while considering the network structure. Recently, data envelopment analysis (DEA) is used as a non-parametric method in many studies. It is used for evaluating units of the same type, which was first developed by Cooper et al. (1978) to evaluate a training center in the United States under the title of CCR (Chames, Cooper and Rhodes). Benker et al. (1984) further developed this method under the title BCC (Benker, Charnes & Cooper) (Darvish Motevali and Motamedi, 2020). Then, based on these models, other models such as Slacks-Based Measure (SBM), additive model, network model, etc. were introduced to strengthen the DEA. The study of drug supply network performance is an example of multi-stage and network decision-making units (Babazadeh et al., 2017). It has a very important role in economics and management and their logistics are composed of interrelated activities (De Camargo Fiorini and Charbel José, 2017). In traditional DEA models, the relative efficiency of the decision making unit (DMU) is evaluated according to the inputs used to generate the final outputs (Mariz et al., 2018). One of the problems of these models is ignoring intermediate products and transition activities between different parts within the system. In order to solve this problem and improve the classical models, a model is presented in which each activity should belong to either the input or the output and not both, so the evaluation is done in two stages (Tavassoli et al., 2015), in one stage intermediate products are used as outputs and in another stage as inputs, which is the same as the simple network model. The most important drawback of these models is the neglect of multi-part or intermediate component products in which the output of the first part is used directly in one step (Hosseinzadeh-Lotfi et al., 2017). However, despite all the advances that have been made in this field, the point to be noted is that in studies, evaluation over time has been neglected, and models with cross-sectional data are generally used to evaluate DMUs (Tone, 2001). These models usually do not pay attention to the transition activities and internal interrelationship of components between several consecutive periods and only in a separate time period, they independently consider local optimization in a specific period (Cook et al., 2010). In this case, the simple network optimization model is not suitable for performance evaluation because it ignores the private or shared relationship of the internal parts of the system and does not have the ability to measure efficiency and performance in several consecutive periods. To counter this point of view and consider long-term efficiency, the DEA model is used, which incorporates transition activity. This model is able to measure the efficiency of a specific period based on long-term optimization (Chen, 2009). To measure the efficiency of a network system a network DEA model is needed. What distinguishes a network DEA from conventional DEA is that transition activities link two consecutive periods (Hsu and Kuo, 2013).

Method

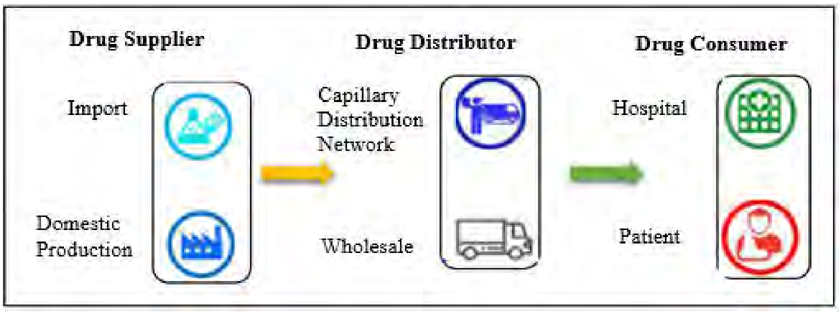
The present study is applied-developmental and intends to provide a model for determining the efficiency of the network of drug suppliers in hospitals, evaluating their performance based on effective indicators, and finally measuring performance. This research is descriptive in terms of purpose and is hybrid in terms of implementation process.

- In the first step, the desired indicators for building a mathematical model are identified. Accordingly, using theoretical studies and reviewing previous research, outstanding and effective indicators in the drug supply network are determined. Afterwards, using the knowledge and experiences of experts, the determined indicators are combined based on the hybrid method. Finally, relevant data are collected for two categories of quantitative and qualitative indicators.

- In the second step, using the previous methods, a new non-radial model DEA is built with network structure in order to evaluate the performance of the drug supply chain. In this regard, by conducting theoretical studies and models presented by previous researchers, we expand these models to develop a research model. Since the model presented in this research should have features such as networking, and the ability to measure sustainability factors including financial, production and operations, and environmental factors, a non-radial model based on slacks as a basic model to build the mathematical model is applied. The main reason for using this model is the data structure, which has positive and negative values at the same time, and the non-radial nature of the model helps to not be sensitive to expansion and contraction at the inputs and outputs.
- In the third step, after designing the model, we evaluate the performance of the drug supply network for 30 hospitals during 2019 and 2020.

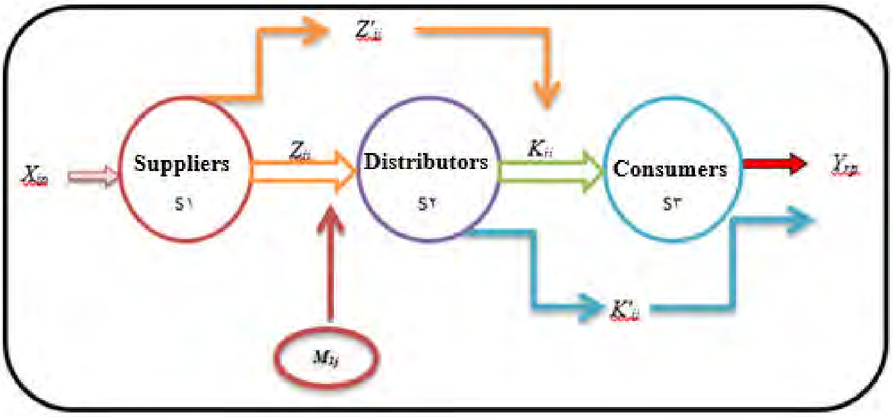
Generally, a three-level drug supply network structure as shown in Figure 1 is considered. Raw material suppliers for the pharmaceutical industry as well as drug importing companies are at the first level of the network, which supplies the medicine needed by the country. The second level includes wholesalers and retailers that are responsible for delivering drugs to hospitals and pharmacies. And the third level is the end users of drugs. In these three levels, some influential components and indicators are presented in Table 2.

Figure 1.
Three-level Drug Supply Network for Patients and Hospitals



To provide a mathematical model of the drug supply network for active hospitals in the area of coronavirus pandemic, Figure 2 is considered. As it is clear from the figure, there are transition activities between the three levels of the network that must be regarded in the model design.

Figure 2.
Input and Output Relationships in the Drug Supply Network



In order to develop a suitable model, the model parameters are defined as presented in Table 1.

Table 1.
Descriptions of Symbols and Parameters of Mathematical Model

Description	Parameter	Description	Parameter
The relative performance of the DMU under evaluation	P_0	The decision variable that represents the input vector to the drug supply network. This vector enters the first stage	X_{ij}
Number of DMUs $\mathbf{j = 1, 2, \dots, n}$	j	The decision variable that represents the output vector of the first stage. This variable is the input of the second stage in the drug supply network	Z_{ij}
Number of inputs $\mathbf{i = 1, 2, \dots, m}$	i	The decision variable that represents the output vector of the second stage. This variable is the input of the third stage in the drug supply network	K_{ij}
Number of outputs $\mathbf{r = 1, 2, \dots, s}$	R	The decision variable that represents the output vector of the entire supply chain network	Y_{ro}
Cell or part of the drug supply network (Stage) $\mathbf{r = 1, 2, 3, 4}$	S	The decision variable that represents the output vector of the first stage. This variable is the input of the third stage in the drug supply network	Z'_{ij}
The weight of output data number r	Ur	The decision variable that represents the output vector of the second stage. This variable is the final output of the drug supply network	K'_{ij}
The weight of input data number r	Vi	Slack input vectors	S^-
The amount of penalty for undesirable outputs	Mi	Slack output vectors	S^+

Description	Parameter	Description	Parameter
that is considered the input of the second stage.			
Weight control of parameter K	M	Weight control of parameter X	V
Weight control of parameter K’	P	Weight control of parameter Z	W
Weight control of parameter L	μ′	Weight control of parameter Z’	W′
Weight control of parameter Y	U		

The objective function of the model determines the relative efficiency of sustainable supply chains. Considering the structure of the SBM model, the objective function of the model is presented as follows. In this new model, the value of P_0^* refers to the efficiency of the whole nature of the input of DMU_0. Supposing $P_0^* = 1$, the input nature will be generally efficient.

The main constraints of the problem must be formulated depending on the type of relationship between the main variables in the problem and the relationship between the cells of the supply network, so that it first covers the mentioned relationships and secondly the links established by the constraints are not violated. These two principles are formulated with regard to the definition of three $\boldsymbol{\lambda_j}$ for every three levels or cells under study. In case of this parameter, there are the equations (8 and 9).

$$min\, P_0 = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{S_i^-}{|X_{ip}|}}{1 + \frac{1}{S}\sum_{r=1}^{s} \frac{S_r^+}{|Y_{rp}|}} \tag{1}$$

$$\sum_{j=1}^{n} \lambda_j^1 X_j + S_i^- \leq X_p \tag{2}$$

$$\sum_{j=1}^{n} \lambda_j^1 Z_j \geq \sum_{j=1}^{n} \lambda_j^2 Z_j \tag{3}$$

$$\sum_{j=1}^{n} \lambda_j^1 Z'_j \geq \sum_{j=1}^{n} \lambda_j^3 Z'_j \tag{4}$$

$$\sum_{j=1}^{n} \lambda_j^2 K_j \geq \sum_{j=1}^{n} \lambda_j^3 K_j \tag{5}$$

$$\sum_{j=1}^{n} \lambda_j^2 K'_j \geq \sum_{j=1}^{n} \lambda_j^4 K'_j \tag{6}$$

$$\sum_{j=1}^{n} \lambda_j^4 Y_j - S_r^+ \geq Y_p \tag{7}$$

$$\lambda^1 \geq 0 \,, \lambda^2 \geq 0, \lambda^3 \geq 0 \,, \lambda^4 \geq 0 \tag{8}$$

$$\sum_{j=1}^{n} \lambda_j^1 = 1 \,, \sum_{j=1}^{n} \lambda_j^2 = 1 \,, \sum_{j=1}^{n} \lambda_j^3 = 1 \tag{9}$$

Since the problem has weight constraints and the need for dual of this model is essential, first we linearize the above model and write its focal form:

$$min \ \varphi - \frac{1}{m} \sum_{i}^{n} \frac{s_i^-}{|x_{ip}|} \tag{10}$$

$$Q(q + \frac{1}{s} \sum_{r=1}^{s} \frac{S_r^+}{|Y_{rp}|}) = 1 \tag{11}$$

$$V(-\sum_{j=1}^{n} \lambda_j^1 X_j - S^- + X_p q) \geq 0 \tag{12}$$

$$W(\sum_{j=1}^{n} \lambda_j^1 Z_j - \sum_{j=1}^{n} \lambda_j^2 Z_j) \geq 0 \tag{13}$$

$$W'(\sum_{j=1}^{n} \lambda_j^1 Z'_j - \sum_{j=1}^{n} \lambda_j^3 Z'_j) \geq 0 \tag{14}$$

$$\mu(\sum_{j=1}^{n} \lambda_j^2 K_j - \sum_{j=1}^{n} \lambda_j^3 K_j \ ) \geq 0 \tag{15}$$

$$\rho(\sum_{j=1}^{n} \lambda_j^2 K'_j - \sum_{j=1}^{n} \lambda_j^4 K'_j) \geq 0 \tag{16}$$

$$U(\textstyle\sum_{j=1}^{n} \lambda_j^4 Y_j - S^+ - Y_p\, q) \geq 0 \tag{17}$$

$$u_0^1\left(\sum_{j=1}^{n} \lambda_j^1 - q\right) = 0 \ , u_0^2\left(\sum_{j=1}^{n} \lambda_j^2 - q\right) = 0 \ , u_0^3\left(\sum_{j=1}^{n} \lambda_j^3 - q\right) = 0 \tag{18}$$

In order to economically interpret the performance of the drug supply network in hospitals, the dual model is presented as follows:

$$max \ \varphi \tag{19}$$

$$\boldsymbol{-VX_j + WZ_j + W'Z_j{}' + u_0^1 \leq 0 \, , \forall j} \tag{20}$$

$$\boldsymbol{-WZ_j + \mu K_j + \rho K_j' + u_0^2 \leq 0 \, , \forall j} \tag{21}$$

$$\boldsymbol{-W'Z_j{}' - \mu K_j + \mu' L_j + u_0^3 \leq 0 \ , \forall j} \tag{22}$$

$$\boldsymbol{-\rho \ K_j' - \mu' L_j + UY_j \leq 0 \ , \forall j} \tag{23}$$

$$\boldsymbol{\varphi\left(\frac{1}{S|Y_{rp}|}\right) - u_r \leq 0 \ , \forall j} \tag{24}$$

$$-v_i \leq \frac{-1}{m|x_{rp}|}, \forall j \tag{25}$$

$$\varphi + VX_P - UY_P - u_0^1 - u_0^2 - u_0^3 \leq 1 \tag{26}$$

$$\varphi, U_0 \text{ free} - \text{in} - \text{sign variable}$$

$$V, U, W, \mu, \mu', W' \geq 0$$

Findings

Data related to input and output variables from the studied hospitals, Food and Drug Administration evaluation forms, drug factories, field surveys were collected according to the indicators in Table 2 and then programmed and solved in GAMS software. As mentioned, the proposed model in this article is tested based on the actual data of the drug supply network in the form of a network during the years 2019 and 2020, and the network efficiency score based on the implementation of this model is obtained as follows. As shown in Table 4, the performance scores are compared on the basis of the proposed network model. 21 drug supply networks for the studied hospitals were declared inefficient in 2019 and only hospitals (2, 8, 10, 14, 22, 25, 27 and 30) had efficient performance. The efficiency of these hospitals has had a better performance in 2020 and the number of efficient drug supply networks has increased to 11. Efficient hospitals are (2, 6, 9, 14, 16, 18, 19, 22, 24, 25 and 30). Diagrams of changes in the efficiency of drug supply networks based on the network model for the time *period under* consideration and the model are presented in Figure 3. The results show that in the mentioned period, the average efficiency in the drug supply network in the studied hospitals is about 87% in 2019 and about 92% in 2020.

Table 2.
Mathematical Model Parameters Based on Selected Indicators

Selected Indicators	**Parameter**
Investment - Cost of raw materials - Cost of staff - Cost of research and development - Cost of quality - Cost of advertising	$\mathbf{X_{ip}}$

Selected Indicators	Parameter
- Cost of drug import - Cost of ecodesign	
Total drug production - Total drug stock in warehouses - Efforts to use advanced technologies and alternative raw materials	Z_{ij}
Total Shipping Cost - Distribution Company Reputation – Cost	K_{ij}
Total drug used in hospital - Total revenue - Total profit or loss - Total exports - Annual growth rate based on performance - Patient and customer satisfaction - Social responsibility - Drug consumption rate – Infiltration	Y_{rp}
Industrial waste generated from production and transfer of drugs, greenhouse gas emissions, energy consumption	M
Flexibility - Direct transfer of drug to the consumption section - Frequency and cycle of drug ordering	Z'_{ij}
Improving relationships throughout the supply chain - Total cost to increase reliability in the supply network - Considering the principles of legal standards and government regulations along the chain	K'_{ij}

Sources: (Nasr Isfahani et al., 1399; Fallahpour et al., 2017; De Camargo Fiorini and Charbel José, 2017; Kannan and Sousa Jabbour, 2014; Kiyani et al., 2014; Olfat et al., 2016; Khalili-Damghani and Ghasemi, 2016; Farzipoor Saen andTorabipour, 2013; Bagheri et al., 2011; Soleimani Damaneh, 1398; Boudaghi and Farzipoor Saen, 2018)

Table 3.

Results of Implementing and Solving the New Model

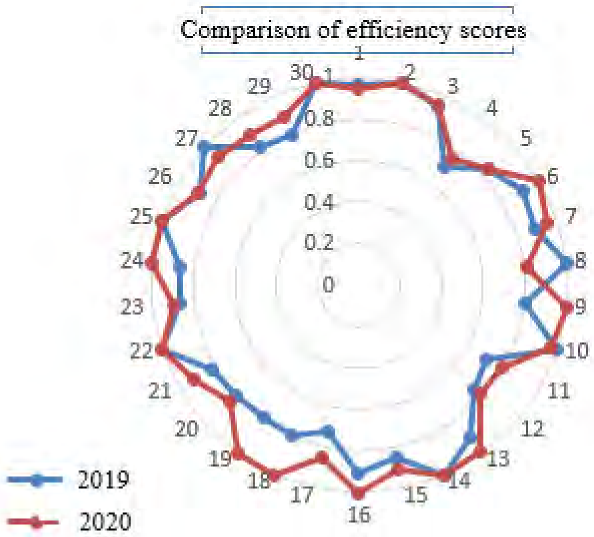
Efficiency Status	Efficiency Score in 2020	Efficiency Status	Efficiency Score in 2019	Hospital Code*
Deficient	0.948	Deficient	0.968	1
Efficient	1	Efficient	1	2
Deficient	0.946	Deficient	0.938	3
Deficient	0.756	Deficient	0.698	4
Deficient	0.833	Deficient	0.833	5
Efficient	1	Deficient	0.913	6
Deficient	0.952	Deficient	0.887	7
Deficient	0.814	Efficient	1	8
Efficient	1	Deficient	0.804	9
Deficient	0.966	Efficient	1	10
Deficient	0.798	Deficient	0.709	11
Deficient	0.784	Deficient	0.749	12

Efficiency Status	Efficiency Score in 2020	Efficiency Status	Efficiency Score in 2019	Hospital Code*
Deficient	0.991	Deficient	0.904	13
Efficient	1	Efficient	1	14
Deficient	0.909	Deficient	0.851	15
Efficient	1	Deficient	0.911	16
Deficient	0.853	Deficient	0.722	17
Efficient	1	Deficient	0.795	18
Efficient	1	Deficient	0.783	19
Deficient	0.839	Deficient	0.799	20
Deficient	0.914	Deficient	0.815	21
Efficient	1	Efficient	1	22
Deficient	0.898	Deficient	0.872	23
Efficient	1	Deficient	0.867	24
Efficient	1	Efficient	1	25
Deficient	0.894	Deficient	0.882	26
Deficient	0.916	Efficient	1	27
Deficient	0.896	Deficient	0.819	28
Deficient	0.888	Deficient	0.791	29
Efficient	1	Efficient	1	30

* Due to the existing restrictions, the names of the hospitals have been introduced as codes.

Figure 3.

Comparison of Efficiency Scores of the Drug Supply Network



The trend of changes in the efficiency scores and the average efficiency of the drug supply network of the studied hospitals are compared and shown in Figures 4 and 5, respectively in 2019 and 2020.

Figure 4.
Comparison of Efficiency Scores with the Average Efficiency of the Drug Supply Network in 2019

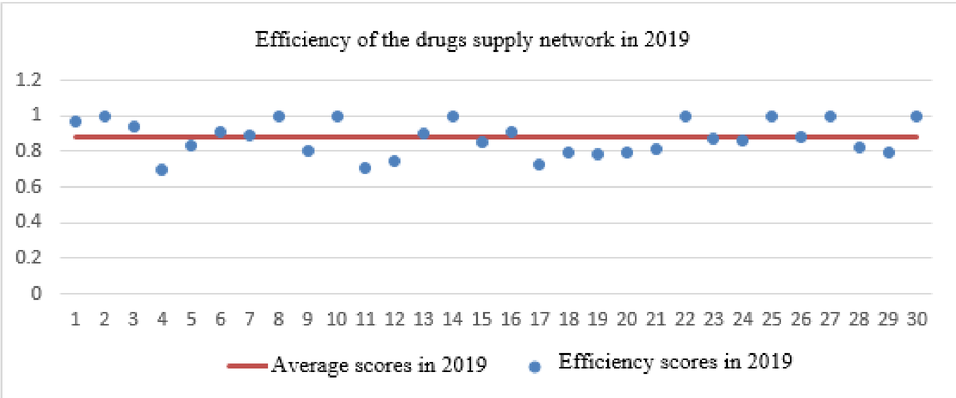
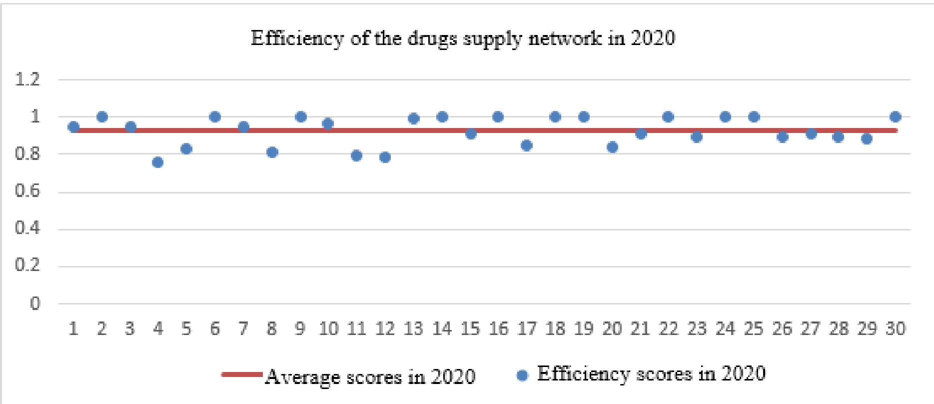


Figure 5.
Comparison of Efficiency Scores with the Average Efficiency of the Drug Supply Network in 2020



Discussions and Conclusion

The models presented by researchers so far are classified into two dimensions. Qualitative dimension such as Balanced Scorecard (BSC) and the European Foundation for Quality Management (EFQM) and quantitative dimension such as DEA models, decision making and operations research techniques. Although these models have not been able to solve many supply chain problems, there are still unknown problems in supply chains with larger dimensions and more complex relationships that jeopardize the efficiency of the chain. The main novelties of this study compared with previous models and researches are categorized into three main points as the followings:

- The first point includes selected indicators in the supply network, which in previous research have generally focused on the simple supply network, lean supply network, agile supply network and green supply network. Consequently, only the indicators of these areas were applied. However, in this research, the sustainable supply network is the criterion for performance evaluation and certainly covers a wider range of key indicators.
- The second point of the novelties in this paper relates to the data envelopment analysis (DEA) model. In most previous researches, the basic model used has been based on either constant returns to scale such as the CCR (Chames, Cooper and Rhodes) model or variable returns to scale on the BCC (Benker, Charnes & Cooper) model. However, the model presented in this study are based on auxiliary variables and designed based on the non-radial model, which have a high dimension compared to the changes of input and output variables. In previous researches, a simple network model, or a maximum of 2 stages, has generally been regarded by researchers and they have not paid attention to related activities and sub-links. In this paper, a 3-stage network with multiple links and activities is considered.

- In most previous researches, goal programming, fuzzy analysis, and neural network have been used. In this research, dynamic programming has been applied to evaluate the accurate performance in the sustainable supply network and long-term optimization has been considered. The proposed model captures well the identified indicators at different levels and cells of the chain and with the network-based view, shows how all these indicators and operational levels are related. Since in the sustainable supply network, there is an urgent need to study the behavior of the chain over time, this model uses the nature of dynamics and considers the transition activities with regard to the time dimension. In this approach, part of the output of each stage is aggregated with the input of the next stage so that the model is out of cross-sectional view and can examine the performance in a longitudinal process.

According to the results of implementing this model in the drug supply network, out of 30 supply networks under review in two consecutive periods, only 5 supply networks have been able to reach the efficiency limit during the 2-year period as a consequence of the outbreak coronavirus pandemic. By consuming primary inputs and internal transition inputs, these chains have been able to produce desirable intermediate outputs and consequently final outputs, and maintain the chain at the best level of performance and efficiency. These chains are considered as reference chains and performance models for deficient chains. Among the inefficient sustainable supply chains, 14 supply networks in 2019 and 16 supply networks in 2020 have had above average performance and can reach the efficiency limit by better managing resources and benchmarking the efficient supply network. Supply chains that have not been able to meet the requirements of sustainability have received an inefficient score with the implementation of the new model. The network of these chains has not been able to produce desirable outputs by consuming inputs. Some of these inputs have turned into waste of energy and primary resources, waste generation and undesirable outputs, which practically endanger the supply network and take it away from the optimal situation. And the other inputs that leads to acceptable production and output in terms of quantity and quality cannot meet expectations. Although with the implementation of the new model, the performance status of the supply network is practically measured over time, but considering the transition activities in the dynamic nature, it is observed that like the network method, a large number of supply chains under study are in the inefficient status. In general, it is suggested that revisions of the programs of supply chains and their implementation provide the basis for modeling sustainable supply chains. With reference to important indicators of supply network at operational, process and strategic levels along with level of sustainability indicators can improve the performance of production, design and development, warehousing, sales and marketing, finance in addition to flexibility of internal systems of a wide network such as an effective drug supply network. It is essential to pay more attention to the supply chain management, which has not been able to achieve efficiency based on the new model because the presented model, while including a large number of important and effective indicators in the supply network, shows the relationship between departments and internal activities in operational cells and is able to evaluate these activities in a dynamic nature by considering time factor. As a final suggestion for future research is to use the hybrid approach of fuzzy logic and the proposed model to measure the efficiency of hospitals' drug supply network in the post-corona era.

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