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Research Article

Using Information Technology in Pharmaceutical Supply Chain Management by Decision-Making Trial and Evaluation

Yaser Esmaeillou [1],Donya Sheibani Tehrani [2*], Iravan Masoudi Asl[1],
Abdolmajid Cheraghali[4]

[1]Department of Health Service Management, Baqiyatallah University of Medical Sciences , Health Management Research Center, Tehran, Iran.
[2. *]Faculty of Information Technology Management, Alzalra Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran
[4]School of Pharmacy, Baqiyatallah University of Medical Sciences and Pharmaceutical Management and Economic Research Center, Tehran, Iran.

Abstract

Background and Objective: Use of information technology in Pharmaceutical supply chain management provides improved visibility and accountability.The aim of this study is evaluating the approaches of using IT in the pharmaceutical Supply Chain Management by Decision-Making Trial and Evaluation.

Method: In this mixed study, the Information Technology experts and executives were included in the FDA,the MOHME in a way that10of them would complete the paired comparison questionnaire purposefully.four main criteria of Information Technology were identified and30features were categorized as sub-criteria.The selected factors were considered as the effective factors of using the Information Technology in fewer than four strategies in the pharmaceutical supply chain.Finally,the effectiveness of any strategy was determined according to criteria using the Decision-Making Trial and Evaluation.

Results: According to the obtained results during the trial and evaluation,the mechanism criteria had the most effect and structure was found to have the greatest influence on other criteria among the four determined criteria.

Conclusion: the strategy to achieve agility in the pharmaceutical supply chain has received the most effect and assessing the pharmaceutical supply chain was found to have the greatest influence on other criteria.Since there are many effective factors in choosing the right strategy for using the Information Technology systems,determining the influence value of each factor can be a sensitive step for the decision-makers.Also,it can add to the favourable effect of the pharmaceutical supply chain.

Keywords: Information Technology; Supply Chain Management; Pharmaceutical; Decision-Making Trial and Evaluation; pharmaceutical supply chain.

Background and Objective

Today, organizations are required to achieve a competitive advantage in order to sustain. They have many efforts to optimize the organizational processes and cooperate with partners[1]. Frazelle considers the supply chain as one of the newest and most important factors for the organizations as it can be used to create value for stakeholders and obtain the competitive advantage[2]. Supply chain management is a new model of network economy[3] that continues as a set of methods for managing and coordinating the whole chain - from supplier to customer management[4].

Products of various industries, especially the pharmaceutical industry, are designed and produced with an increasing complexity value and the necessity for the development and application of various advanced technologies along with the processes and suppliers' partnership in the range of the supply chain of a firm[5, 6].

*Corresponding Author: Donya Sheibani Tehrani
Email: abi_6891@yahoo.com

Porter states that the supply chain network design and the various communication within it can be a source of competitive advantage for the organization and can also guarantee the success or failure of the organization[7]. In the health market, the customer has been seen from a different perspective and the pharmaceutical industry has come to be known as one of the important markets of the health and care industry[8].

Medicine also converts the subjective and intangible interests in the customer's mind, along with the objective and tangible interests such as reliability, convenience, and satisfaction[9]. It is also concerned with identifying the effective factors will cause more added value and profitability for the companies, providing better service, increasing satisfaction level for health service centres and welfare improvement, confidence and health for patients at each stage of the production process, and marketing and selling the pharmaceutical[10].

Moreover, health and hygiene are considered as two of the most important and effective pillars for the sustainable development of each society. The role of medicine is quite basic, effective and decisive, hence, it reveals its effects generally in the last and most critical stage in the cycle of health[11].

The pharmaceutical industry is based on information like any other industry, hence, the efficient transmission and distribution of its information relies on the Information Technology. Among other factors, supply chain management is emphasized for long-term sustenance and total profitability for all partners of the supply chain through accurate and robust transmission, and distribution of information. This indicates the importance of Information Technology in supply chain management[12, 13].

On the other hand, the firm's network integration, its flow of material and information, and harmonization of its financial resources can be considered as the main pillars of supply chain management[14]. This harmonization of the chain length has been improved through the effective use of up-to-date and advanced information and communication technology[15]. Since the important issues in the pharmaceutical supply chain include the reduction of uncertainty of demand for each medicine, keeping track of the delivery time to the expiry date of the medicine, maintaining quality and ensuring pharmaceutical safety, falsification of information, existence of infrastructure and necessary coordination, and supporting the decision-making within the chain length, keeping a tab on the information flow can prevent the problems caused by inefficient maintenance of information[6,16].

The Information Technology can help to expedite the flow of information throughout the supply chain and help to integrate supply and demand by creating a combination of telecommunications achievements, strategies, and methods of troubleshooting[17].

The Information Technology also creates a secure platform for major savings in the cost of the supply chain, including the integration of information, transportation, inventory, storage, medicine transfer, and packaging[18].

The Information Technology is responsible for creating the internal coordination among the chain components, the information sharing with suppliers, planning; demand forecasting, communication and providing services to customers in the supply chain[19, 20].

Although the Information Technology offers many opportunities and benefits for the countries, it also affects and damages the system if neglected[21]. Computer viruses, hackers, leakage of confidential information, system failure, service interruption. have incurred many damages to the organization[22].

Information security poses as one of the most challenging issues in this field. Information security management is a part of the information technology that is responsible for determining the safety and evaluating the barriers in the way of achieving these goals and providing the necessary solutions[23].

The Information Technology has provided the exchange of information and also the physical exchanges, in the context of information security, and improves the performance of information and communication system by introducing a management system based on standards and technical guides[24] through the integration of information, an increase in control, centralization of the information systems, and an increase in the compatibility of information system[25].

Mootmeni stated that the continuity of the organizations and companies depends on several important factors in today's turbulent business environment, including a deep and lasting relationship with the customers, for which it needs the e-readiness of the organizations. He has proposed and chosen the Verdict model as a convenient model for assessing the e-readiness of the medicine distribution companies[26].

Wigand considers the intrusion of counterfeit medicine into the supply chain as the main concern forthe supply chain of medicine and acknowledges the necessity of using information management. He considers the use of the chips (Radio-frequency identification) as one of the appropriate solutions that, in turn, can provide an appropriate infrastructure to trace every product as unique and identifiable[17].

Kaya states that customers' satisfaction depends on the efficiency of supply chain activities in providing the services. The information system in the chain management can provide considerable help to the shopping, property management, warehousing sectors. It will also help to build a better relationship with the customer and production services processes, using the Internet. It will also help to improve communication, speed, reliability, accessibility, cost, punctuality, and solve integrated planning applications issues of organizational resources[27].

Tseng has assessed the effect of information technology on supply chain management by using the Decision-Making Trial and Evaluation technique. He has evaluated the effective indicators of the application of information technology to achieve high performance of the company, including the marketing performance, financial performance, and customer satisfaction[28].

the first batch of sub-criteria was clarified, based on the existing software and technology at the first level. These sub-criteria are divided into following 30 elements:

Business process reengineering (I_1)[29], Adherence to the ethical standards and protocols (I_2), Medicine quality control methods (I_3), Manufacturing resource planning(I_4)[30], Network and information security(I_5),Software appropriate infrastructures (I_6),Global Positioning System (I_7)[31], Electronic Data Interchange(I_8)[32], Hardware appropriate infrastructures(I_9), Material requirements planning(I_{10})[33], Enterprise resource planning(I_{11})[34], Data analysing software (I_{12}), Valid backup companies(I_{13}), Flexible Manufacturing System(I_{14}),Expert Systems(I_{15}),Radio-frequency identification (RFID) (I_{16})[35,36],Cloud Computing(I_{17})[37], Information sharing (I_{18}), Optimized production technology(OPT) (I_{19}),Local Area Network(LAN) (I_{20}),Point of sale (POS) (I_{21}),Wide Area Network (WAN) (I_{22}),Wireless Fidelity (Wi-Fi) (I_{23}),Application and mobile service(I_{24}), Automatic Identification and Capture Date(I_{25}),Extensible Mark-up Language

(XML) (I_{26}), Internet(I_{27}),Electronic Automatic Ordering System (EOS) (I_{28}),Just In Time (JIT) (I_{29}), and Personal Area Network (I_{30})[38].

The criteria were determined based on the information technology characteristics at the second level.

Proper management of the information holds great importance in the identification and validation of the medicine, their ingredients, the method of transporting, marketing, and delivery, according to what was stated. The pharmaceutical industry possesses critical and important information. Pharmaceutical safety, real price of medicines and the intrusion of counterfeit medicines into the supply chain are issues that are rarely considered while visiting a pharmacy. Hence, these issues are rising with an increasing speed[17]. In addition to these issues, there are other factors in the pharmaceutical supply chain such as customer orientation, importance of medicine in public health, maintenance of the pharmaceutical cold chain, transportation from production to distribution, and disease pattern.

Hence, this study aims to provide a framework for evaluating the use of Information Technology in managing the pharmaceutical supply chain using the Decision-Making Trial and Evaluation approach and provide answers to questions such as which factor has the most importance in the system or has the greatest effect and influence. Eventually given the importance of the drug and the pharmaceutical economy, proper planning for the use of drug supply chain management can have a significant impact on the success and effectiveness of hospital management in the treatment of patients.

Methods

This study follows a type of mixed (quantitative-qualitative). It is due to the multi-criteria decision-making type of data analysis, and also due to the high levels of decision-making authorities in the matters of medicine, including the Food and Drug Organization, the MOHME and pharmaceutical companies. In order to collect the data of the study, the library and survey methods were used.The library method was used to collect the literature on the issue and to identify the default strategies. Also, the survey method was executed using the paired comparisons questionnaire (Influential and effective Criteria) to collect the required data for communication matrices. The sampling was objective because it requires specialized and expertise knowledge in the discussed issue.The statistical population consisted of 10 experts and executives from the pharmaceutical system in the country ,the Food and Drug Organization and the MOHME. It also addresses the main criteria of IT, based on the specific conditions of the industry, and also the public features of an efficient supply chain using the decision-making trial and evaluation model[39]. The conceptual model is shown in Figure (1).

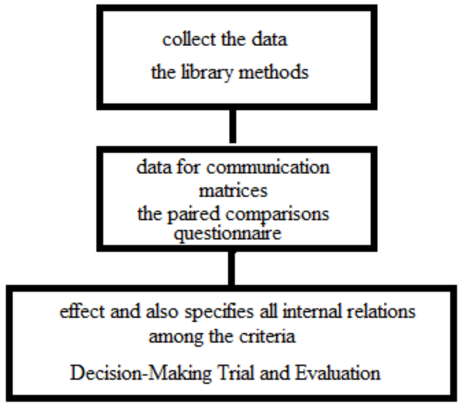

Figure (1): The conceptual model

This study aims at identifying the effective factors of using the Information Technology in the appropriate supply chain management of the pharmaceutical industry.

Decision-Making Trial and Evaluation

The Decision-Making Trial and Evaluation model was first presented by Fontela and Gabus in 1974. This approach is based on the paired comparison and the instruments of multi-criteria decision-making, based on the graph theory. The model includes a diagram that divides the criteria into two groups of cause and effect and also specifies all internal relations among the criteria. The principles of the graph theory provide a hierarchical structure of the existing factors in the system with mutual interaction relationships so that the effect of these relationships is defined as a numerical score. In other words, this method may verify the relationships among variables or limits the relationships in a process of development. Thereliability of the paired comparisons questionnaire was obtained using the compatibility rate. Since the compatibility rate was less than 0.1, the paired comparison matrix was identified to be compatible and valid. This approach can identify the interdependencies among the factors and makes them understandable, in addition to changing the cause and effect relationship into a visual structural model.

Five steps have been identified to perform the Decision-Making Trial and Evaluation approach:

1. Forming a direct communication matrix (M):

When the approach is used in some opinions, it has been used on the simple average of the opinions and it forms the matrix M.

2. Making the direct communication matrix normal:

N = K*M

In this formula, K is calculated as follows:

First, the sum of all rows and columns is calculated. Then,

the inverse of the greatest number of the rows and columns forms K.

Equation (1)[40]: $$k = \frac{1}{\max \sum_{j=1}^{n} a_{ij}}$$

3. Calculation of the full relationship matrix:

Equation (2): [40] $T = N \times (I - N)^{-1}$

4.Causal diagram

Sum of elements of each row (D) for each factor is an indicator of the effectiveness value of that factor on other system factors.

- Sum of elements of each column (R) for each factor is an indicator of the effectiveness value of that factor on other system factors.

- So, the horizontal vector (D+R) is the effect and influence value of the factor in the system.

In other words, the higher the amount of D+R of the factor holds, the more interaction it will have with other factors in the system.

- Vertical vector (D-R) shows the influence of each factor.

Generally, if D-R is positive, the variable is considered as a causal diagram. If it's negative, it is considered as an effect factor.

- Finally, a Cartesian coordinate system is drawn. In this system, the longitudinal axis indicates the values of D+R and the transverse axis is based on the value of D-R. The position of each factor is determined with a point at the coordinates of (D+R, D-R) in the system. So, a graphical chart will be achieved as well.

5. Calculating relations threshold:

For Network Relation Map (NRM), a threshold value should be calculated. This method can be used to neglect the detailed relationships and to draw a reliable connection network. Only the relationships with values in the T-matrix larger than the threshold value will be displayed in the NRM. In order to calculate the threshold value of relationships, it is sufficient to calculate the mean values of the T-matrix. After the intensity of the threshold is determined, all values of the T-matrix that are smaller than the threshold becomes zero. This means that it is not considered as a causal relationship[40-41].

Data analysis

In this study, 30 sub-criteria have been used to evaluate the effect of using the Information Technology in the pharmaceutical supply chain. Five qualitative terms were used to compare the sub-criteria. The names of these scoring phrases and values are shown in Table 1.

Table 1: Used quality terms and scoring values

Verbal expressions	Values
No impact	0
Very low impact	1
Low impact	2
High impact	3
Very high impact	4

These criteria are divided into four categories of human factors (S_1), including human resources, concepts and ideas, innovation, and mechanism (S_2) that includes rules, regulations and methods, recovery and growth mechanisms, valuation and financial mechanisms, instruments (S_3) such as software, hardware, network, communications, and organizational, relevant cross-organizational, and universal structure (S_4)[40-47].

The main strategies were determined according to the characteristics of the supply chain at the third level. These strategies are divided into four categories of the agility of pharmaceutical supply chain (S_1), its assessment (S_2), integrity (S_3), and customer-orientation (S_4)[42-48].

In order to evaluate the sub-criteria, a 30x30 matrix was first placed in the hands of each expert. The sub-criteria formed the columns and rows of the matrix. The experts completed this matrix using the qualitative terms of Table 1 and on the basis of the paired comparisons of each block.
Also, a 4x4 matrix was used to evaluate the criteria. The verbal terms were converted to numbers after collecting the matrices and the arithmetic mean was calculated to take all experts' opinions into account. It should be noted that the importance value of the opinions was considered to be the same in all cases and the effect coefficient was also considered the same throughout this study. Before starting the work, the necessary permits were obtained from the relevant authorities. Also, sufficient information on the research objectives and its importance, maintaining the anonymity of the participants, and confidentiality of the obtained information was given to experts.

Results:

The research model and estimation method:

The following steps have been taken to perform the mentioned procedures and execute the necessary calculations on the data.

Decision-Making Trial and Evaluation Steps:

Step One: The evaluated constituent elements of the system have been shown in Figure 2.

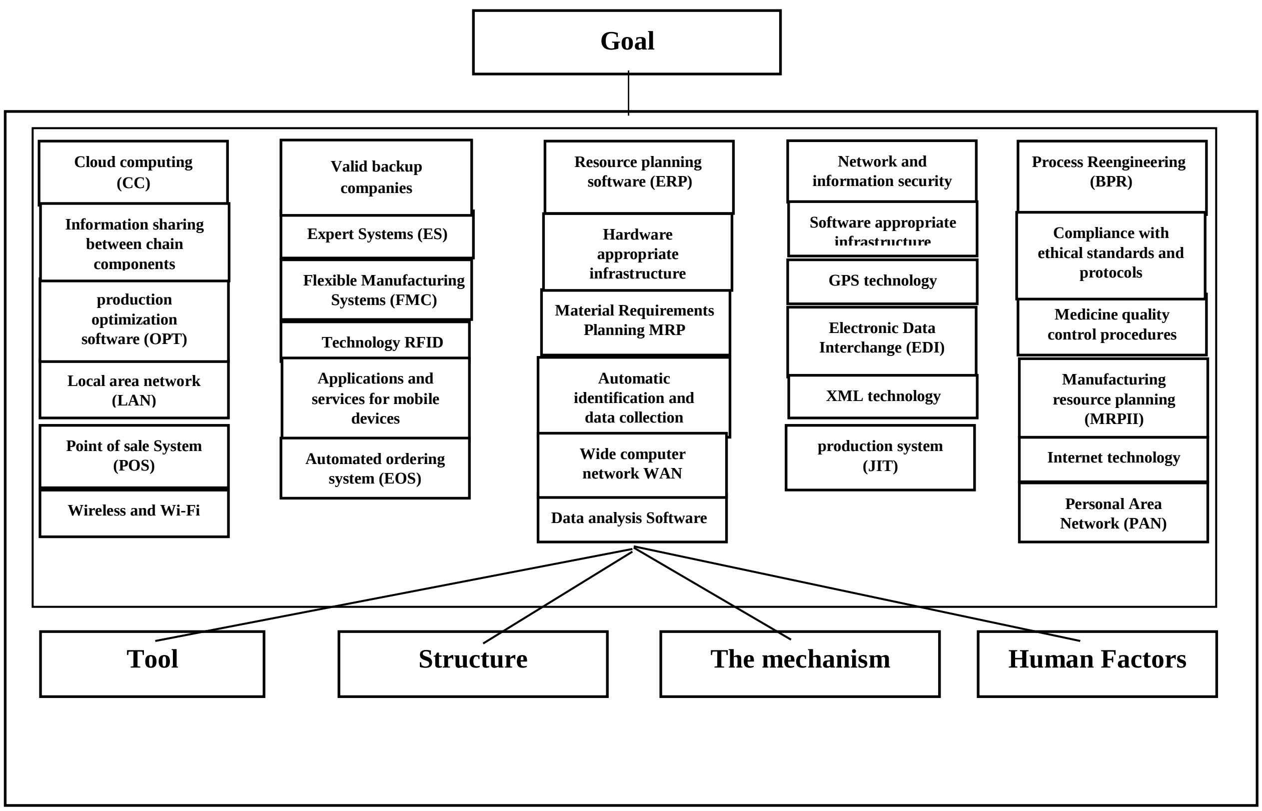

Figure 2: The constituent elements of the evaluated system

TIP: All calculations are performed by the software and the outputs are reported

Step Two: The given items are put on the heads of diagraph then the relationship which should govern on the relations among heads are determined (For example, the influence of the element L1 on the elementL2). Comparisons of the elements had been executed as the paired and experts' judgments questioned the elements for direct communication. Then, the average of the obtained results was calculated. The mean of the experts' opinions has been mentioned in Table 2 for comparing the criteria and procedures to compare the criteria with the sub-criteria and the relationships among the criteria after calculating the mean of the opinions. (Final tables have been provided to avoid displaying the massive tables).

Table 2: Mean of experts' opinions to compare criteria and procedures

	C_1	C_2	C_3	C_4
S_1	0.3	0.9	3.3	0.1
S_2	1.9	3.2	0.3	1.2
S_3	1.1	0.4	3.4	0.9
S_4	3.7	0.5	1.8	1.6

Step Three: The normalized matrix in the Sowftware of Table 2 has been shown in Table 3. These tables are normalized to change their scales to the comparable scales and standards. In order to normalize the obtained matrices, the sum of all the matrix elements is multiplied by the reverse sum of the largest column value.

Table 2: Normalized matrix of the mean of experts' opinions to compare the criteria and procedures

	C_1	C_2	C_3	C_4
S_1	0.010	0.178	0.068	0.016
S_2	0.021	0.016	0.099	0.005
S_3	0.063	0.021	0.087	0.031
S_4	0.052	0.005	0.010	0.042

Step Four: Finally, the final matrix is calculated as the final paired comparison and its overarching theme (Table 4) is shown Table 5along with the values of dj-ri and dj+ri in the Sowftware. The effect of all criteria has been cleared on four strategies in the final matrix.

Table 4: The overarching theme of the final super matri

	I_1	I_2	....	I_{29}	I_{30}	C_1	C_2	C_3	C_4	S_1	S_2	S_3	S_4
I_1			Internal comparison of sub-criteria				Compare sub-criteria by criteria						
I_2													
......													
I_{29}													
I_{30}													
C_1			Compare matrices with sub-criteria				Internal comparison of the criteria						
C_2													
C_3													
C_4													
S_1							Compare the strategies with criteria						
S_2													
S_3													
S_4													

The importance value of (dj+ri) and the relationship between the criteria (dj-ri) are determined in Table 5. If 0<(dj-ri), the relevant criterion is effective and if (dj-ri)<0, the relevant criterion is affected.

Table 5: Values of dj-ri and dj+ri (decisive numbers of importance and influence of strategies)

Strategy	dj + ri	dj – ri
S_1	0.456	0.753
S_2	1.162	-0.220
S_3	0.594	0.100
S_4	1.037	-0.594

Step Five: At this phase, the cause and effect diagram can be drawn as shown in Figure 2. The effect and influence of the factors on each other can be recognized according to the figure. The threshold value should be calculated according to the Network Relation Map. Using this method, the detailed relationship can be neglected and the reliable connections network can be drawn. In the T-matrix, only the relationships with values larger than the threshold value will be displayed in the diagram. Just the mean values of the T-matrix are calculated to calculate the relationships' threshold value. After determining the threshold intensity, all values of the T-matrix that smaller than the threshold becomes zero. This means that a causal relationship cannot be considered. In this study, the threshold intensity equals to 0.05.

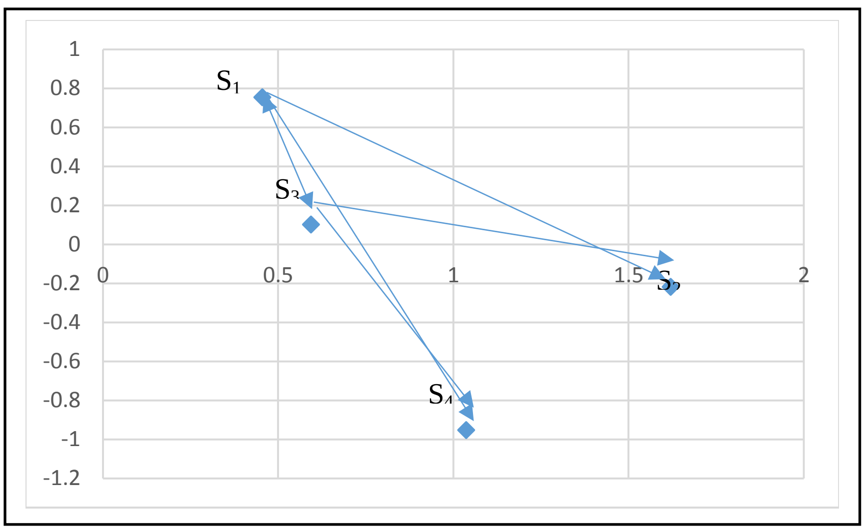

Figure 3: Diagram of causal and the relationship among strategies

According to the above diagram, the factors that have more interaction with the system, where the values of (dj+ri) are greater (or they have a significant effect on other factors are large R, or the influenced by other factors are large D or both), and have positive values of (dj-ri) are more important. Also, having a positive value of (dj-ri) represents the factor being effective and having a negative value represents it being influenced. Thus, according to the causal tables and diagrams, and the relationship among strategies, the supply chain agility has the most effect with the greatest total in the row among other strategies and analysing the supply chain has the least effect on other strategies with the lowest total in the row.

Finally, a strategy that has the highest weight coefficient among other strategies, and in the other words, has the greatest effect and influence on the whole system is the supply chain agility. According to the amounts of (dj-ri) , customer centre and evaluation of preparation chain are two permeable methods as well as agility and integrity are two penetrative methods in the system. Causal diagram and the relationship among criterions in figure (3) and causal diagram and the relationship ship among sub criterions are demonstrated in figure 4.

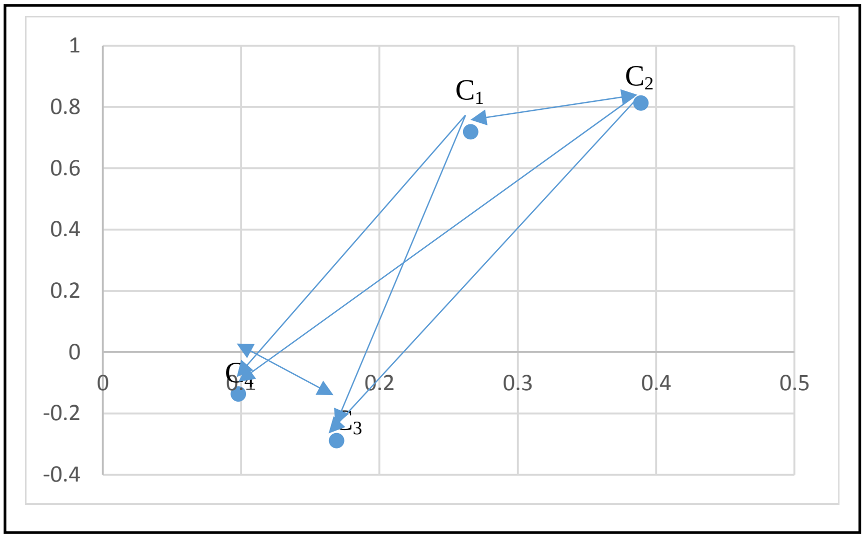

Figure 4: Causal diagram and relationship among criteria

Human factors and mechanisms in the pharmaceutical supply chain are two effective criteria in the system. Moreover, the instrument and the structure are the influenced criteria in the system, according to the causal diagram and relationship among the criteria (Figure 3).

Table 6: Values of (dj-ri) and (dj+ri)
(decisive numbers of importance and influence of sub-criteria)

sub-criteria	dj+ri	dj-ri	sub-criteria	dj+ri	dj-ri	sub-criteria	dj+ri	dj-ri
I_1	0.613	0.461	I11	0.729	0.461	I_{21}	0.412	0.203
I_2	0.346	0.199	I12	0.501	0.467	I_{22}	0.200	0.109
I_3	0.500	0.242	I_{13}	0.417	-0.431	I_{23}	0.321	-0.069
I_4	0.256	-0.187	I_{14}	0.169	-0.391	I_{24}	0.161	-0.108
I_5	0.627	0.548	I_{15}	0.428	0.228	I_{25}	0.089	0.215
I_6	0.392	-0.371	I_{16}	0.575	0.330	I_{26}	0.148	0.314
I_7	0.520	0.352	I_{17}	0.521	0.299	I_{27}	0.149	0.029
I_8	0.269	-0.300	I_{18}	0.519	0.263	I_{28}	0.136	0.269
I_9	0.349	-0.321	I_{19}	0.203	0.135	I_{29}	0.139	0.137
I_{10}	0.176	-0.163	I_{20}	0.323	-0.270	I_{30}	0.329	-0.219

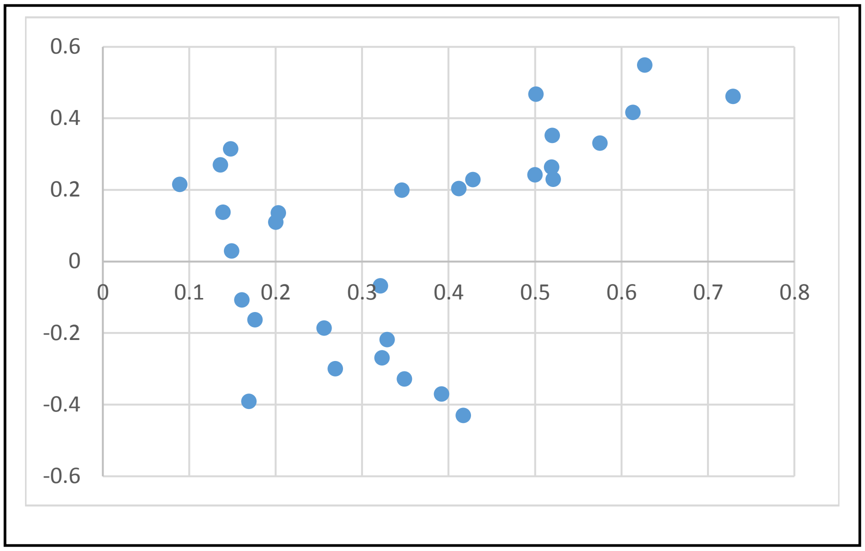

Figure 5: Cause and effect diagram of sub-criteria

According to Table 6 and the sub-criteria in the cause and effect diagram (Figure 5) the following criteria in the pharmaceutical supply chain are among the permeable sub-criteria in the system: Business process reengineering, Adherence the ethical standards and protocols, Medicine quality control methods, Manufacturing resource planning, Network and information security, Software appropriate infrastructures, Global Positioning System (GPS), Electronic Data Interchange, Hardware appropriate infrastructures, Material requirements planning, Enterprise resource planning, Data analysing software, Valid backup companies, Flexible Manufacturing System, Expert Systems, Radio-frequency identification (RFID), Cloud Computing, Information sharing, Optimized production technology (OPT), Local area network (LAN),Point of sale (POS),Wide Area Network (WAN), Wireless Fidelity (Wi-Fi),Application and mobile services, Automatic Identification and Capture Date, Extensible Mark-up Language (XML), Internet, Electronic Automatic Ordering System (EOS), Just In Time (JIT), and Personal Area Network (PAN).

Discussion

Advancement of the information technology and its introduction into the health and care industry has brought significant gains.In this article, an attempt was made to identify the dimensions and the constituent elements of the Information Technology that can be effective in the pharmaceutical supply chain and be utilized, and their effect and influence value is determined. In order to expand the use of supply chain with the information technology approach, the careful planning in education, the expansion of e-government strategies, strong satellite communication channels, use of appropriate Information Technology infrastructure, and the establishment the national network of the pharmaceutical supply chain is required. This study was consistent with the studies conducted by Vigrand [17] and Kaya [27]. However, it has also evaluated the different aspects of the use of Information

Technology in the supply chain. According to the obtained results, the use of Information Technology improves the agility and integration in the overall supply chain and also follows its performance improvement. It also causes the coordination of information, prevention and reduction of the errors, and secures the accuracy of the information in the electronic security. Due to the sensitivity of the pharmaceutical industry, it is necessary that at the macro level, the classifications of medications are separated in proportion to the importance of treatment, the frequency of the use of medicine, the effectiveness value and other considered items, and that it is based on the duration of pharmaceutical maintenance, cold chain, type of transportation and necessary storage space for maintenance. The medicines should be marketed in the right manner and given to the consumer at areas uunable price. It should also abide by the framework of laws and regulations. It should also be made available in the shortest possible time, thereby, causing an added value in the market and ensuring customer satisfaction.

Conclusion

Determining the appropriate criteria for the Pharmaceutical supply chain causes the right choice of the pharmaceutical company of the contracting party, reducing the time and increasing the speed of Pharmaceutical supply, increasing patient satisfaction and treatment staff, especially physicians, increasing productivity and reducing related costs in resistance economy, correct volume and Principles of medicine, reducing risks, lobbying and the formation of informal markets and related corruption, increasing control over Pharmaceutical supply and reducing drug waste have therefore had a significant impact on hospital management.

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Conflict of Interest

There was no conflict of interest.

Authors' Contributions

Yaser Esmaeillou contributed in the protocol design, language translation and article review.

Donya Sheybani Tehrani contributed in the study design, data interpretation, article preparation and the correspondence.

Iravan Masoudi Asl contributed in the literature search, quality assessment, article preparation, and the article review.

Abdolmajid Cheraghali contributed in the literature search, study design, the literature review.

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