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Bullwhip effect reduction map for COVID-19 vaccine supply chain

Seyed Mojtaba Hosseini Bamakan*, Pooria Malekinejad, Mehran Ziaeian, Amirhossein Motavali

Department of Industrial Management, Yazd University, Yazd 89195-741, Iran

ARTICLE INFO

Keywords:
Bullwhip effect
COVID-19 vaccine
Supply chain
Fuzzy cognitive map

ABSTRACT

The growing COVID-19 virus pandemic outbreak causes an urgent need to produce its vaccine. Pharmaceutical companies would encounter a massive wave of unforeseen demand for the COVID-19 Vaccine after the vaccine production that could lead to a bullwhip effect in the COVID-19 Vaccine Supply Chain (CVSC). The main objective of this study is to design a cognitive map based on the influential factors on the Bullwhip Effect Reduction (BER) of CVSC. Hence, in the first step, the affecting factors on the BER of CVSC are identified and ranked based on their importance from the pharmaceutical experts using the AHP technique. In the second step, 13 out of 18 identified factors are considered for further analyzing and understanding their relationship by Fuzzy Cognitive Mapping (FCM) technique. Furthermore, three different forward scenarios and three backward scenarios are carefully constructed to find the optimal solution for BER on pharmaceutical organizations. The obtained results show that the flexibility factor is the starting point of the backward scenario, which reduces the bullwhip effect in CVSC. Beside, by improving the inventory management and reliability factor, it would be effectively possible to control the lead-time factor and consequently, overcome the bullwhip effect in CVSC.

Introduction

Nowadays, studies on healthcare issues are growing profusely and there are a special focus on pharmaceutical supply chain (PSC) challenges [6,53]. The pharmaceutical industry plays a critical role in providing medicine and saving humans’ life. Any unexpected occurrences in PSC would disrupt the efficiency of the healthcare system and medicine supply [50]. Disorders of the PSC not only lead to financial losses of members, partners, and stakeholders, but also can directly compromise patients’ safety [5,78]. Hence, the pharmaceutical supply chain is a complex and vital supply chain that is directly related to human lives and health [65]. Furthermore, pharmaceutical supply chains are always facing many uncertainties and risks, which can be a reason for the attention of many researchers in the past years [7,83].

Currently, the outbreak of COVID-19 is a challenge in the 21st century that can put the agility and capability of healthcare systems to a great test and reveal the frailties of the existing healthcare systems and pharmaceutical supply chains [155]. In December 2019, an unprecedented number of Pneumonia cases were reported in adults from Wuhan, China [67]. Despite prompt action by the Chinese government and the World Health Organization (WHO), the number of similar cases grew at an alarming rate [28]). In January 2020, a novel zoonotic agent known as an acute coronary syndrome called COVID-19 was identified in respiratory specimens of patients with Pneumonia [32]. The COVID-19 has made a massive negative impact on world healthcare systems, jobs, and lives, and unfortunately, the number of deaths cases is still growing significantly in many countries [63]. In fact, from the beginning of the COVID-19 pandemic till December 2019, more than 95 million positive COVID-19 cases were identified and more than two million COVID-19 deaths were recorded [25].

Due to the current situation of the COVID-19 outbreak in the world, the pharmaceutical industry plays an essential role in the production of medicine and vaccines against COVID-19 [116]). It should be noted that preventing infection through vaccination is one of the most successful public health interventions.

In recent years, the production and marketing of vaccines have become a complex process. This complexity can be reduced through market coordination with producers and other sides [23]. Vaccine supply chain (VSC) is an appropriate solution to provide the vaccine for COVID-19 patients at the right time and right place with the lowest cost [117]). One of the influential factors that significantly decreases the performance of the pharmaceutical supply chain and the disruption of the vaccine, is the bullwhip effect [86]. The recognition of the bullwhip effect in supply chains dates back to the 1950s [42]. The bullwhip effect in supply chains is defined as a kind of distortion in the process of transferring order’s information in the upstream supply chain and creating fluctuations in the number of upstream orders that happens when there are changes in the demand in the downstream supply chain [20]). The bullwhip effect has been described as the effect of increasing diversity in the supply chain from the lowest to the highest level
The bullwhip effect is due to the changes in product demand and fluctuations in the upstream part of the supply chain including retailers, distributors, manufacturers, and suppliers [41]. The bullwhip effect can lead to different outcomes such as over-inventory across the supply chain, over-hiring and firing employees, surplus and shortage of inventory, and poor service to customers in the supply chain [2]. A bullwhip effect in the vaccine supply chain would significantly affect the production and distribution of pharmaceutical products, especially vaccines [26]

Due to the great importance of supplying and producing the COVID-19 vaccine in the world, pharmaceutical companies should be able to control a variety of disruptions including the bullwhip effect in the vaccine supply chains as much as possible. This study intends to identify the influential factors of reducing the bullwhip effect on the COVID-19 Vaccine Supply Chain (CVSC) and then will introduce a unique Bullwhip Effect Reduction (BER) plan to provide practical solutions for vaccine manufacturers.

The following sections of this paper are organized as follows: in Section "Literature review" we provide some literature review on the vaccine supply chain and the bullwhip effect. In Section "Methodology", we have provided the methodology of this research and the results are provided in Section "Results". Section "Discussion" provides a discussion and Section "Conclusion and future work" concludes the entire paper providing suggestions to mitigate the bullwhip effects on the CVSC.

Literature review

The vaccine supply chain

Vaccines are one of the best and the most effective ways to prevent infectious diseases [92]). Millions of people around the world are vaccinated every year to control a disease outbreak and reduce the mortality rate [188]. According to estimates, vaccination can reduce the mortality caused by nine diseases by 97.8% [96]). Vaccination is generally considered an essential tool for strengthening the health and welfare of human beings. However, using a poorly designed supply chain to produce and distribute the vaccine in a worldwide pandemic, could lead to unfortunate consequences, including the death of millions in any country [91]).

Nowadays, the vaccine supply chain has been studied by many researchers [Mvundura et al., [93]) and there is a continued effort of balancing the supply and demand. In vaccine supply chains, several factors make the supply/demand procedures complicated. These factors include product complexity, globalization, regulation, regulatory requirements for manufacturers, product quality improvement [23], government policies, public security, counterterrorism and security interests, and general health sector supports [47]. As mentioned in previous researches, some factors such as traceability of digital health initiatives, vaccine stockpiling and new packaging technologies can generally improve vaccine supply chain performance [89]). Chandra & Kumar identified some other factors including strengthening managers and leaders in the vaccine supply chain, continuous improvement planning, and increasing coordination throughout the vaccine supply chain [17] (Fig. 3).

Recently, COVID-19 vaccine production and distribution is considered an ongoing challenge that has been addressed by some researchers [26]. The authors in [71] studied some effective approaches to decrease the demand fluctuations in the CVSC. Their results revealed that employing expert managers alongside well-trained human resources and appropriate transportation could significantly decrease the demand fluctuations’ effects and would make the supply chain much more stable [71]. Weintraub et al. [97] believed that using tracking systems, improving interoperability along the supply chains, and deploying well-trained human resources in vaccine production and distribution are the most important factors affecting the performance of the vaccine supply chain [97]). In another study, the CVSC logistics readiness was investigated and their result shows that proper Information Management Systems (MIS) and well-trained personnel are among the most important factors affecting the COVID-19 supply chain performance [95]). Although COVID-19 vaccines production is accelerating, due to the huge difference between its demand and supply, would not cure all around the world [21]). The authors in [87] has studied the possible vaccine distribution plans and their results showed that not only the vaccine distribution speed is an important factor but it should be fair and balanced all around the world. Beside the all mentioned factors, vaccine packaging, healthcare staffs, and disease monitoring specialists’ knowledge, healthcare policymaker, information management specialist, and investors are the other important factors affecting a healthcare supply chain [46].

Bullwhip effect

Supply chain management (SCM) faces a variety of challenges and problems due to the variability in demand and the complexity of the interactions between organizations involved [69]. Many researchers and suppliers have found that order quantities tend to be more fluctuate than customers’ demands across the supply chain [72]. This phenomenon is defined as a bullwhip effect that always leads to the inefficiency of products in the supply chain [69]. The bullwhip effect has been considered in many industries [39] including the automobile sector [12], machine tool industry [4], and the computer and semiconductor industry [79]. The bullwhip effect examines how a small change in consumer demand would result in greater fluctuations and deviations in the upstream supply chain (manufacturer, supplier, distributor, etc.). However, the bullwhip effect can be defined as a kind of distortion in customers’ demands of information [18]. The bullwhip effect is the result of different parameters including price fluctuations, order categorization, and changes in customers’ demand [54]. It needs to be mention that the bullwhip effect is a critical phenomenon, which directly affects the total production costs and the economic effectiveness of the supply chain. According to the literature, it is shown that the bullwhip effect is affected by many unknown parameters.

The results of previous studies confirm that information sharing throughout the supply chain would significantly reduce the bullwhip effect in the supply chain. If Information sharing and coordination are not done throughout the supply chain, the bullwhip effect can affect its performance and it would lead to supply chain failure [58]. The other factor which would reduce the bullwhip effect is identified as supply chain coordination, lead time reduction, accurate demand forecasting, information technologies alignment, real-time inventory management [85]. In addition, the authors in [76] studied the important reasons for bullwhip effect creation in the vaccine supply chain and suggested that poor production planning, inappropriate transportation, incorrect demand prediction, and increases in raw materials cost are among the most important factors that lead to a bullwhip effect in a vaccine supply chain [76].

Research motivations

Although the bullwhip effect in a supply chain is not a new issue and has been studied for several years, there are limited studies available that specifically consider the COVID-19 vaccine supply chain. In fact, the main remaining challenge after discovering the coronavirus vaccines is balancing the supply and demand of this product. It means that the bullwhip effect in the COVID-19 vaccine supply chain would consequently cause serious crises for governments and their healthcare systems. Hence, the main objectives of this research are to identify the most important factors regarding the bullwhip effect in the CVSC and provide effective solutions to mitigate its negative effects.
Methodology

The main objective of this study is to provide the applicable knowledge to reduce the bullwhip effect in the CVSC. The steps of this research are presented in Fig. 1.

According to Fig. 1, in the first step, we identified the influential factors affecting bullwhip reduction in a vaccine supply chain. In Step 2, the identified factors were presented to 72 experts from Iranian pharmaceutical companies to weight them according to their importance in bullwhip effect reduction of the COVID-19 vaccine supply chain. Hence, we utilized the AHP technique (64) to do the pairwise comparison and weight the identified factors. The pairwise comparison questionnaire formed in this study indicates the importance of each factor in relation to the others in the form of a nine-point Likert scale in which the number 1 indicates the same preference of two factors over each other and the number 9 indicates the complete preference of one factor over the other one. To analysis the results we adopted ‘EXPERT CHOIS’ software. By using EXPERT CHOIS software, the incompatibility rate for each of the 72 experts was determined less than 0.1, and the opinions of experts are aggregated by using geometric mean. Afterward, the most important factors are selected by Pareto Analysis.

At the fourth step, the remaining factors from step three were again presented to the previous 72 experts with a 5-point Likert scale questionnaire to identify their “current status” in the COVID-19 vaccine supply chain. Then in Step 5, we map the relationship between the most affecting factors in bullwhip effect reduction of the CVSC by Fuzzy Cognitive Mapping (FCM) technique (43). FCM is a well-known technique for analyzing complex and complicated problems that allow researchers to effectively analyze a complicated problem from a systemic perspective ([90]). It needs to be mention that FCM is the relationship matrix that is designed to present the factors’ relationship type, the strength, and the direction between the factors [59]. In order to do the FCM analysis, we adopted steps introduced by Rodriguez ([94]) and the Fuzzy Cognitive Map is illustrated by “Pajek” software.

Finally, by using the results of the FCM technique and the values of input and output degrees, six scenarios were designed including three forward scenarios and three backward scenarios. These scenarios would help to obtain better insights towards the sequence of influencing factors and consequently improve the performance of the intended factors.

The information of 72 experts involved in this research is presented in Table 1. These experts were selected and identified by snowball sampling technique in which, after getting the ideas of the first expert, he was asked him/her to introduce the next one. The sampling procedure continued until no other experts were accessible.

Results

According to the studied literature, the most influential factors on bullwhip effect reduction of the CVSC are listed in Table 2. In addition, the last column of Table 2 shows the weight of each factor obtained by the AHP technique. These weights indicate the importance of each of the affecting factors on the bullwhip effect reduction of the CVSC.

By using Table 2 and based on the weight obtained for each factor, those factors with a lower degree of importance in the BER of CVSC were removed by using the Pareto principle and the famous 80:20 principle as illustrated in Fig. 2.

According to Figs. 2, thirteen important factors are chosen as internal processes, information sharing, accuracy in order quantity, inventory management, lead time reduction, quick responsiveness, flexibility, reliability, Employees training, management skills, optimize resource allo-
cation, management commitments, and establishing logistics transport centers. Moreover, these factors were again provided to 72 experts in the form of a 5-point Likert scale, and they were asked to determine the status of each of them in the vaccine industry. The results of the relationship matrix obtained by the FCM technique are presented in Table 3.

In the next step, the Indegree, the Outdegree, and the Centrality of each factor were obtained by FCMAPPER software. The final model includes 13 primary factors with 87 relationships among them as presented in Table 4. These factors are ordinary variables that have both input and output relationships. The indegree presents how each node is influenced by other ones and is the summation of the absolute value of the weight on the input links. Contrarily, the outdegree shows how each node influences other nodes and is the summation of the absolute value of the weight on output links. The centrality indicates how strong the direct connections of a node are with other nodes and it is calculated by the summation of both input and outputs weights (Reimann, 1998).

As mentioned, the in-degree reveals the influenced factors by other factors. [3] shows the indegree of the elements. Three factors include the internal processes, establishing logistics transport centers, and flexibility, which are the most affected factors. On the other hand, reliability, Employee training, and quick responsiveness are the least affected factors.

Outdegree represents the effects that are applied by a concept. As much as a factor has a higher out-degree degree, it has more influence on the whole system. Three factors of inventory management, flexibility, and reliability have the most impact, respectively, and the three factors of Employee training, management skills, and establishing logistics transport centers have the least impact, respectively. Fig. 4 shows the outdegree values related to the significant factors on the BER of CVSC.

The degree of centrality is the sum of the two previous factors. Each factor with a higher degree of centrality had either a high indegree or indegree than other factors. In both cases, this factor is considered an important factor in the system. As shown in Fig. 5, the factors of flexibility, accuracy in order quantity, and lead time reduction have the most centrality, and the factors of Employee training, management skills, and reliability are identified as the factors with the lowest degree of centrality.

According to the NETFILE output of FCMAPPER and applying this output into the Pajek software, Fuzzy Cognitive Map is demonstrated in Fig. 6.

To further analyzing the proposed model and the relationship among its factors, different scenarios were formed as forward and backward pathways. Firstly, we considered the backward pathway scenario. In this regard, the first three factors with the high indegree were selected and

| Table 2 | The influential factors on bullwhip effect reduction of COVID-19 vaccine supply chain. |
|---------|-------------------------------------------------|
| Identified Factors | Reference | Obtained weights |
| Internal processes | [11,51,62,82] | 0.088 |
| Information sharing | [1,23,38,49,51,66] | 0.088 |
| Accuracy in an order quantity | [14,57,73,75] | 0.077 |
| Availability of human resource | [8,16,48,75] | 0.073 |
| Inventory management | [16,44,45,60,82] | 0.072 |
| Lead time reduction | [39,31,28,46,47] | 0.064 |
| Quick responsiveness | (D. [16,19,47,56,80]) | 0.062 |
| Monitoring of vaccinated population | [9,16,34] | 0.062 |
| Flexibility | [10,21,22,26,29,36] | 0.061 |
| Reliability | [19,22,71,75] | 0.056 |
| Employee training | [22,69,75,81] | 0.049 |
| Management skills | [49,71] | 0.048 |
| Mutual understanding | [38,49,70] | 0.044 |
| Optimize resource allocation | [36,37,49] | 0.040 |
| Management commitments | [49] | 0.036 |
| Establishing logistics transport centers | [35,40,56] | 0.030 |
| Trust | [3,20,22,27,38,49] | 0.025 |
| Knowledge management | [22,61,62,66] | 0.024 |
Fig. 2. Pareto chart of the important factors on the BER of CVSC.

Fig. 3. Indegree of factors in the BER of COVID-19 vaccine supply chain.

Fig. 4. Outdegree of factors in the BER of the COVID-19 vaccine supply chain.
a scenario pathway was formed to improve these factors. Secondly, we formed a forward scenario that three elements with high outdegree were selected. In the backward scenario, the internal processes, establishing logistics transport centers, and flexibility, are the selected factors. To create the scenario path, all factors with input link to the internal processes factor have been separately set to zero and its changes have been examined. The establishing logistics transport center factor has the most impact on the internal processes factor. Based on the previous step, the rest of the scenario path has been created by focusing on the establishing logistics transport centers factor. The lead time reduction factor has the most impact on establishing the logistics transport centers factor. According to the previous step, by focusing on the lead time reduction factor, a continuation of the scenario path has been created. The optimized recourse allocation factor has the most impact on the lead time reduction factor. According to the previous step, by focusing on the optimized resource allocation factor, the continuation of the scenario path has been created. The flexibility factor has the most impact on the optimized resource allocation factor. Similar to the previous step, by focusing on the flexibility factor, the continuation of the scenario path has been created. The lead time reduction factor has the most effect on the flexibility factor. Considering that the lead time reduction factor was in the previous stages, the scenario process is stopped due to loop formation. Fig. 7 shows the backward scenario path for the internal processes factor.

The other two backward scenarios were developed for establishing logistics transport centers and flexibility factors according to the above steps. The results of the development of the two strategies are presented in Figs. 8 and 9.

The forward scenario is developed to predict the behavior of other factors when there is a change in the aspect with a high degree of ef-

**Table 4**

| Density | Total # of factors | Total # of connections | # of non-connection | # of self-loops | # of regular connections |
|---------|--------------------|------------------------|---------------------|----------------|-------------------------|
| 0.514793 | 13                 | 87                     | 0                   | 0              | 87                      |

**Fig. 5.** Centrality degree of influential factors on the BER of COVID-19 vaccine supply chain.

**Fig. 6.** Fuzzy Cognitive Map of influential factors on the BER of CVSC.
fectiveness. For this purpose, three elements with a high degree of Outdegree are considered as the initiating factors of the scenario. These three factors are inventory management, flexibility, and reliability.

To create a scenario path for the inventory management factor, at first, the inventory management factor is zeroed, and then the effectiveness of the output factors of this factor is examined. The inventory management factor has the most impact on the reliability factor. To continue the forward scenario path process, this time, the reliability factor in the software is set to zero, and the effect of this behavior on the output factors is examined. The reliability factor has the most impact on the employees-training factor. Next, to continue the procedure of the forward scenario path process, this time, the employee training factor in the software is set to zero, and the effect of this behavior on the output factors is examined. The Employee training factor has the most impact on the lead time reduction factor.

At this point, to continue the forward scenario, the lead time reduction factor in the software was set to zero, and then we examined the effect of this behavior on the output factors. As a result, we see that the lead time reduction factor has the most impact on the Employee training factor. Since the activity of the employee factor already exists in the scenario path, and its re-selection creates a loop, we skipped it and as a result, the forward scenario path of the inventory management factor is demonstrated in Fig. 10.

The other two forward scenario paths for the flexibility and reliability factors were developed according to the steps performed for the forward scenario path. Finally, the acquired results of the implementation of these two bold scenarios are shown in Figs. 11 and 12.

**Discussion**

In this study, from the literature, we identified 18 influential factors on bullwhip effect reduction of the vaccine supply chain, and by further analysis of results, we obtained 13 important factors which specifically affect the BEF on COVID-19 VSC. The FCM formed in this study reveals the relationship among 13 important factors on BER in the CVSC. The FCM obtained in this study has a Density index of 0.51. Here, the Density index in FCM indicates the entire relation among all factors and is an index to demonstrate the density of the relationship matrix. This index can have different values according to the goals and nature of a research problem [74]. In this research, the Density value obtained 0.51 and it means that 51% of the entire relationship between the factors is considered important by the involved experts.

To clarify the relationship between the factors, three forward and three backward scenarios were designed. The backward and forward scenarios formed in this study indicate solutions to deal with the bullwhip effect in the CVSC and by using these solutions, manufacturers will be able to prevent the bullwhip effect in different parts of the CVSC. In the path formed for the backward scenarios, we sought to achieve the path of the improvement of the desired factor to BER in the CVSC, and in the path formed for the forward scenarios, we sought to achieve the path
of positive changes in the target factor if the CVSC improvement. In this study, to draw the backward scenario path, three factors with high Indegree were used. Similarly, to achieve the forward scenario path, three factors with a high Outdegree score were used. In the first backward scenario, the Internal processes factor was considered as the target factor for creating the backward scenario path. During the scenario path drawing process, the Flexibility factor was introduced as the starting point of the scenario path.

The path of the scenario formed in this section indicates the high importance of the Flexibility factor in the current state of the Internal processes factor improvement. By improving the status of the Flexibility factor, pharmaceutical companies that intend to produce the COVID-19 vaccine will be able to achieve an improvement in the status of the Internal processes factor. To make this happen, pharmaceutical companies must increase their flexibility by improving the transportation and cycle of their raw materials. By improving the status of the Flexibility factor, the scenario path is moved and will have the most effect on the Optimize Recourse Allocation factor, which can improve the resource cost management in the supply chain of the COVID-19 vaccine. By improving the status of the Optimized Recourse Allocation factor, the scenario path progresses and it would have the most positive effect on the Lead Time Reduction factor. By reducing Lead Time, pharmaceutical companies that intend to produce the COVID-19 vaccine will be able to take advantage of their transport logistics capacity. By improving the status transportation of pharmaceutical companies, the Internal processes factor is formed the best possible way in pharmaceutical companies that intend to produce COVID-19 vaccine, which can BER in the CVSC.

The path of the second backward scenario is formed by examining a part of the first scenario, which indicates the high importance of the Flexibility factor as the bullwhip effect in the CVSC. The path formed in the third backward scenario indicates the Flexibility factor as the target factor in the BER of the CVSC. In this scenario, the Optimized Recourse Allocation factor has been identified as an affecting factor on the Lead Time Reduction factor, and by improving the Lead Time Reduction factor, the Flexibility factor will improve. In this section, the rotation of processes and factors complement each other reciprocally. Thus, by improving the status of the Flexibility factor, the path of the other two backward scenarios improves, and by improving the status of these factors, the Flexibility factor also improves so that the pharmaceutical companies can suffer the least when facing the bullwhip effects in the CVSC.

The forward scenario path first indicates that by improving in the status of the Inventory Management factor, we would have the maximum improvement in the status of the Reliability factor and then by improving in the status of this factor, the Employees training factor also improves. The reliability of the CVSC increases by managing the raw material and production inventory, and then, Lead Time Reduction occurs by improving the staff training. In fact, we found that Lead Time reduces the best in a supply chain when we improve inventory management, which can play an important role BER in the CVSC. In the second forward scenario, by improving the status of the Flexibility factor, pharmaceutical companies would achieve Quick Responsiveness. By improving the Quick Response factor, the management skill factor improves. In fact, responding quickly to customers and market needs can play a variety of skills in the media, which in the long run in the face of future risks for organizations. In the third forward scenario, which is a part of the first forward scenario, we have examined the effect of improving the Reliability factor, on BER in the CVSC.

According to the findings of this research, it is suggested to improve the flexibility of the manufacturing process to mitigate the bullwhip effect in COVID-19 VSC, which means it is needed for high attention to the resource allocation. Furthermore, based on the obtained findings, it is suggested that the bullwhip effect in the CVSC is related to these thirteen important factors including internal processes, information sharing, accuracy in order quantity, inventory management, lead time reduction, quick responsiveness, flexibility, reliability, employees training, management skills, optimize resource allocation, management commitments, and logistics transportation centers.

According to the results of this research, improving flexibility improves Internal processes and this finding matches the results of Burger’s research [13]. Moreover, the results of this research in Table 3, confirm Muenstermann’s research which believed that improving Internal processes would improve the flexibility of a supply chain [52]. This research also states that improving inventory management would result in Lead Time Reduction and this coincides with other similar studies [15,24,77].

**Conclusion and future work**

This study was aimed to identify the most important factors regarding the bullwhip effect in the COVID-19 vaccine supply chain and provide a comprehensive model to reduce the bullwhip effect. To achieve this goal, by doing a literature review, 18 factors affecting the bullwhip effect on the vaccine supply chain were identified. Then, 72 pharmaceutical experts were asked to fill the specifically designed questionnaires to identify the most important factors from the initial 18 factors. Then, 13 out of 18 factors were selected with the AHP technique. A Fuzzy Cognitive Map was also formed in this study to reveal the relationship among those 13 important factors. The 13 factors and their relationship were discussed and some suggestions and recommendations were made for BFR in COVID-19 VSC.

It is worthwhile to mention that there were some limitations in doing this research including the pharmacal experts involved in research all selected from Iranian pharmaceutical companies, which certainly, accessing to the international pharmaceutical experts could provide wider and more complete point of views. Furthermore, the structured scenarios were considered as fixed models and the dynamic changes in a long time were ignored.

The present study provides a variety of clues to other researchers for future research. As some suggestions, we can mention the study of the indicators of each of the factors identified in the FCM to better understand and deepen the expansion of each of the factors in BER in the CVSC. Other researchers can also study the cause-and-effect relationships among the indicators affecting each of the factors to design a dynamic model with predictability over some time to pharmaceutical companies help BER in the CVSC.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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