Journal of Namibian Studies, 33 S2(2023): 1883–1902 ISSN: 2197-5523 (online)

Construction And Application Of Evaluation Index System For Pharmaceutical Supply Chain Resilience: A Delphi Study

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Abstract

The present study outlines a methodical methodology for developing an assessment index framework aimed at enhancing the resilience of the pharmaceutical supply chain. A preliminary version of the evaluation index system was established through a comprehensive review of literature and panel discussions. Two rounds of expert consultation were conducted using the Delphi method to finalize the indicators and their corresponding weights. The assessment criteria for pharmaceutical supply chain resilience comprises of ten primary indicators and sixty-two secondary indicators. These indicators encompass various facets such as the ability to design the supply chain, reserve resources, integrate processes, collaborate effectively, adopt eco-friendly practices, visualize data, and foster a culture of learning. The outcomes of the consultation conducted with experts reveal that the evaluation index system is reliable, as it demonstrates a significant level of attention, coordination, and authority among the experts. The determination of the weight of each indicator in the system was based on the relative significance of various factors in augmenting the resilience of the pharmaceutical supply chain. The development of an evaluation index system offers a systematic approach to evaluate and enhance the resilience of pharmaceutical supply chains, thereby providing a valuable scientific instrument. The results of this study hold potential value for various entities within the pharmaceutical industry, such as pharmaceutical companies, policymakers, and other stakeholders. Specifically, these findings may aid in the identification and resolution of potential weaknesses within the supply chain, the enhancement of management practices, and the fortification against external disruptions. Prospective investigations may center on the implementation of the assessment index system in practical scenarios, scrutinizing its soundness and dependability, and investigating methods to consistently enhance the robustness of pharmaceutical supply chains.

Keywords: Pharmaceutical supply chain, resilience, Delphi method, evaluation index system, risk assessment, emergency response, supply chain management.

Introduction

The pharmaceutical industry plays a crucial role in promoting public health and has a significant impact on the global economy. With the development of global economic integration, the pharmaceutical supply chain has become increasingly complex and vulnerable to various external shocks such as natural disasters, pandemics, and policy changes. To ensure the stability and resilience of the pharmaceutical supply chain, it is essential to establish a scientific evaluation index system and improve the management and supply chain management capabilities of pharmaceutical companies.

The construction of the pharmaceutical supply chain resilience evaluation index system is an important foundation for evaluating and preventing risks in the pharmaceutical industry. Many scholars have conducted research on the evaluation of the pharmaceutical supply chain, and the methods and indicators for constructing the evaluation index system of the pharmaceutical supply chain vary among different regions and economic development levels. In China, some researchers have studied the evaluation and control of drug circulation in specific regions, such as "Study on Factors Evaluation and Control of Drug Circulation in Shenzhen" (Song Hua & Yang Yudong, 2022) and "Research on Supply Chain Management of the Pharmaceutical Industry in Hubei Province" (Wang Guowen, 2020). However, a comprehensive and scientific evaluation index system that is in line with the characteristics of the pharmaceutical industry and the pharmaceutical supply chain has not yet been formed.

In this context, a study titled "Evaluation Index System of Pharmaceutical Supply Chain Resilience Based on Delphi Method" by Li Jing and Wu Yibin proposes a scientific evaluation index system that reflects the characteristics of the pharmaceutical industry and supply chain. The study is based on the Delphi method and adopts a multi-level and multi-dimensional evaluation index system, which includes 10 first-level indicators and 62 secondary indicators. The first-level indicators are divided according to the source of resilience and the operating environment, and can be classified into two categories: the ability to resist pressure and the index to rebound. The study evaluates the reliability of the index system and analyzes the content of the evaluation indicators, providing suggestions for the management of the pharmaceutical supply chain.

The study highlights the importance of improving the management and supply chain management capabilities of pharmaceutical companies to enhance the resilience of the pharmaceutical supply chain. The authors suggest that pharmaceutical companies should strengthen their management awareness, means of identification, and supervision mechanism, and continuously optimize the structure of the pharmaceutical industry. In addition, the government should strengthen policy coordination, improve the efficiency and rationality of supervision, and enhance the training of talents in medicine circulation and the supply chain management capabilities.

The study fills the gap in the evaluation index system of the pharmaceutical supply chain and provides a scientific and practical tool for the evaluation and prevention of risks in the pharmaceutical industry. The study also has certain limitations, such as the subjective evaluation of indicators and the need for further empirical research to revise and improve the index system.

The pharmaceutical industry is a highly regulated and complex industry, and the supply chain management of pharmaceutical products is crucial to ensure the safety and quality of drugs. The COVID-19 pandemic has exposed the vulnerabilities of the global pharmaceutical supply chain and highlighted the importance of resilience in the industry. The pharmaceutical supply chain is vulnerable to various external shocks, including pandemics, natural disasters, and policy changes, and the evaluation and prevention of risks in the pharmaceutical industry have become more critical than ever before.

Therefore, the establishment of a scientific evaluation index system for the pharmaceutical supply chain is an urgent task. The index system should reflect the characteristics of the pharmaceutical industry and supply chain and provide practical guidance for the management of pharmaceutical companies and the formulation of government policies. In addition to the evaluation of the pharmaceutical supply chain resilience, it is also necessary to strengthen the research on the construction of a sustainable and green pharmaceutical supply chain, which will contribute to the sustainable development of the pharmaceutical industry and the global economy.

Table 1. Antecedents of the Study

Antecedents of the Study	**Description**	**References**
Pharmaceutical Supply Chain	The study focuses on the evaluation of the resilience of the pharmaceutical supply chain, which refers to the ability of the pharmaceutical-related supply chain to withstand external shocks and rebound to normal operation.	(Liu, Jiang, & Zhao, 2022); (Li, Li, & Li, 2018)
Resilience	The ability to recover quickly from difficult situations, and to resist external shocks and disruptions.	(Yu, Li, Li, & Cheng, 2018); (Yang, Xie, & Zhang, 2021)
Delphi Method	A research method used to gather and analyze the opinions of experts through multiple rounds of questionnaires and feedback.	(Zhou, Zou, & Song, 2019); (Liu & Liu, 2015)
Supply Chain Management	The management of the flow of goods and services, including the movement and storage of raw materials, work-in-progress inventory, and finished goods from the point of origin to the point of consumption.	(Li, Ma, & Chen, 2021); (Wu, Xia, & Zhou, 2019)
Evaluation Index System	A set of quantitative and qualitative criteria used to evaluate the performance or effectiveness of an organization, system, or process.	(Guan, Wang, & Wu, 2021); (Ma, Cao, & Li, 2018)
Risk Management	The identification, assessment, and prioritization of risks, followed by coordinated and economical application	(Yao, Li, & Shao, 2019); (Liu, Song, & Zhang,

	of resources to minimize, monitor, and control the probability or impact of unfortunate events.	2019)
Green Supply Chain	A supply chain management approach that integrates environmental considerations into all stages of the product life cycle, from design to disposal.	(Li, Wang, & Zhang, 2017); (Wang, Wu, & Du, 2019)
Information Sharing	The exchange of information among different parties involved in a supply chain, including suppliers, manufacturers, distributors, and customers.	(Liu, Zhang, & Li, 2017); (Wang, Gao, & Zhu, 2018)
Coordination Ability	The ability of different parties involved in a supply chain to work together to achieve common goals, including joint planning, communication, and resource sharing.	(Wang, Qi, & Zhang, 2020); (Luo, Liu, & Huang, 2018)
Flexibility	The ability to adapt quickly to changing circumstances, including changes in demand, supply, and the operating environment.	(Guo, Li, & Li, 2020); (Wang, Li, & Zhu, 2021)
Simulation and Training	The use of computer-based simulations and training programs to improve the skills and knowledge of supply chain personnel.	(Liu, Zhang, & Liu, 2022); (Chen, Zeng, & Zhang, 2018)

The aforementioned table presents a comprehensive summary of the precursors to the present investigation concerning the assessment of resilience in the pharmaceutical supply chain. The tabular presentation comprises of ten distinct rows, each of which corresponds to a unique antecedent that has contributed to the evolution of the research.

The initial precursor pertains to the worldwide COVID-19 outbreak, which has underscored the significance of robust supply chains within the pharmaceutical sector. The second antecedent pertains to the escalating need for pharmaceutical goods, which can be attributed to demographic shifts, heightened life expectancy, and the surging incidence of chronic ailments. The third antecedent pertains to the intricate nature of the pharmaceutical supply chain, which encompasses a multitude of stakeholders and processes, rendering it susceptible to potential disruptions.

The escalation of competition and globalization within the pharmaceutical industry has resulted in amplified supply chain risks, thus constituting the fourth antecedent. The regulatory landscape in the pharmaceutical sector is a dynamic antecedent that has significant implications for the resilience of the supply chain. The pharmaceutical industry is placing greater emphasis on sustainability and environmental responsibility, which represents the sixth antecedent.

Literature

The study on the evaluation index system of the pharmaceutical supply chain involves several variables that have been studied extensively in the literature. The following section reviews the relevant theories and literature of these variables.

1. Supply Chain Resilience Supply chain resilience is a critical variable in this study. According to Liao et al. (2021), supply chain resilience refers to the ability of a supply chain to recover from disruptions and continue to function effectively. This concept has been widely studied in the literature, and several theories have been developed to explain it. One of these is the resource-based view (RBV) theory, which suggests that firms that possess unique resources and capabilities are more resilient to disruptions than those that do not (Ekanayake et al., 2021). Another theory is the dynamic capabilities theory, which suggests that firms that are better able to adapt to changes in the environment are more resilient (Yang et al., 2022).

2. Emergency Preparedness Emergency preparedness is another critical variable in this study. It refers to the ability of an organization to prepare for and respond to emergencies effectively (Wei et al., 2023). The literature on emergency preparedness has identified several factors that contribute to it, including the level of resources available, the quality of training and education, and the effectiveness of communication and coordination (An et al., 2023). The analytic network process (ANP) and extension cloud models (ECM) have been used to assess the resilience of safety systems at subway construction sites (Guo et al., 2020).

3. Supply Chain Disruptions The pharmaceutical supply chain is vulnerable to various disruptions, including natural disasters, pandemics, and supply chain management issues (Liu Jingyi, 2022). Disruptions in the supply chain can have significant consequences for pharmaceutical companies, including increased costs, reduced revenue, and damage to reputation (Chen & Yin, 2023). The literature on supply chain disruptions has identified several strategies for mitigating their effects, including developing contingency plans, improving supply chain visibility, and diversifying suppliers (Hsu et al., 2022).

4. Supply Chain Governance Supply chain governance refers to the management of relationships between suppliers and buyers in a supply chain (Liu Jingyi, 2022). Effective supply chain governance is critical for ensuring the resilience of the pharmaceutical supply chain. The literature on supply chain governance has identified several strategies for improving it, including developing supplier relationships based on trust and collaboration, using performance metrics to assess supplier performance, and developing risk management strategies (Liu Jingyi, 2022).

5. Coordination Ability Coordination ability is another critical variable in this study. It refers to the ability of different actors in the supply chain to work together effectively (Liao et al., 2021). The literature on coordination ability has identified several factors that contribute to it, including the quality of communication and information sharing, the effectiveness of decision-making processes, and the level of trust between actors in the supply chain (Liao et al., 2021).

6. Rebound Ability Rebound ability refers to the ability of a supply chain to recover quickly from disruptions and return to normal operations (Yang et al., 2022). The literature on rebound ability has identified several factors that contribute to it, including the level of preparedness, the effectiveness of response mechanisms, and the quality of contingency planning (Yang et al., 2022).

The pharmaceutical supply chain refers to the whole process of pharmaceutical products from raw material procurement, production, warehousing, transportation to consumers (patients), covering the production, circulation, sales and final use of pharmaceutical products, involving pharmaceutical production enterprises, pharmaceutical business enterprises , pharmaceutical distribution companies and medical service institutions and many other stakeholders. With the continuous reform of the medical and health system, the structure of the pharmaceutical industry, and the distribution system of pharmaceutical products, and affected by the particularity of pharmaceutical products, the pharmaceutical supply chain is gradually showing a flat feature, and any weak link may cause abnormal operation of the entire supply chain. In recent years, public health emergencies (such as the new crown epidemic) and vicious emergencies in the pharmaceutical supply chain (such as the Changchun fake vaccine incident , etc.) have occurred from time to time, and it is particularly urgent to improve the supply chain resilience management capabilities of the pharmaceutical industry that is in transition . In the field of supply chain management, the proportion of research related to resilience is relatively small. Summarizing the resilience referred to in various fields, most of them focus on the ability of the system to "absorb" and "adapt" to disruptive events, while "recovery" is considered to be a key part of resilience.

At present, the pharmaceutical supply chain resilience evaluation index system has not yet been established, the industry lacks systematic resilience identification methods and scientific and objective judgment basis, and the resilience management ability of each link in the pharmaceutical supply chain is insufficient. In order to promote the healthy development of the pharmaceutical industry, improve the ability of pharmaceutical companies to resist sudden shocks, improve the production and distribution of pharmaceutical products, and improve the operational efficiency and competition level of pharmaceutical companies, this paper uses the literature research method and the Delphi method to construct a pharmaceutical supply model. The chain resilience evaluation index system provides a reference for the resilience management of the pharmaceutical supply chain.

Methods

This study employed literature research and the Delphi method as its research methodologies. The objective of the literature review was to conduct an examination and assessment of prior research endeavors pertaining to pharmaceutical supply chain management and resilience management within the contemporary era. The aim was to establish a fundamental structure for the appraisal index system for pharmaceutical supply chain resilience. The aforementioned task was accomplished by conducting searches on prominent databases including CNKI, VIP, and Wanfang. The research team formulated a preliminary assessment criterion system after conducting the analysis, which was subsequently shared with experts for consultation.

The Delphi method is a frequently employed research technique that entails leveraging the expertise and experience of a panel of specialists to gradually arrive at consensus on intricate issues characterized by significant levels of ambiguity and uncertainty (Wang Chunzhi, 2011). The Delphi consultation process involved the participation of 20 experts in the present investigation. The panel of experts was composed of individuals from diverse sectors of the pharmaceutical supply chain, encompassing managers from pharmaceutical companies, medical institutions, and regulatory departments, as well as academic researchers.

The process of conducting research encompassed multiple stages. Initially, a preliminary index system for assessing the resilience of pharmaceutical supply chains was established via comprehensive literature review and collaborative deliberations. The aforementioned system comprised of 13 primary indicators and 66 secondary indicators. A consultation questionnaire was developed for experts based on this particular system. The survey comprised of four sections, namely: an overview of the study's context and objectives, the fundamental details of the specialists, their acquaintance with the consultation issue, and the primary content of the consultation survey.

The consultative procedure was conducted in two phases. During the initial phase, specialists were requested to evaluate the significance of every indicator using a 5-point scale and offer their feedback for revision. Following the feedback of the experts in the initial round, the questionnaire was revised and subsequently administered in a second round. The statistical findings from the initial round were appended for purposes of reference, subsequent to which the specialists were requested to re-evaluate the indicators.

The statistical analysis of the data obtained from the expert consultations was conducted utilizing the SPSS25.0 software. The present study involved the computation of various coefficients, namely the coordination coefficient, authority coefficient, positive coefficient, and coefficient of variation, to assess the significance of individual indicators. The objective was to develop a conclusive assessment framework utilizing expert viewpoints that exhibited a tendency towards consistency and dependability.

To sum up, the present study employed literature research and the Delphi method as research methodologies. The development of the preliminary evaluation index system involved a comprehensive review of relevant literature, followed by group discussions. Expert consultations were then carried out using a consultation questionnaire that was designed based on the aforementioned system. The data collected from the consultations underwent statistical analysis using SPSS25.0 software in order to establish the final evaluation index system.

Results

The present study proposes an evaluation index system for assessing the resilience of pharmaceutical supply chains.

The establishment of the evaluation index system for pharmaceutical supply chain resilience was informed by expert consultation results. This system comprises 13 first-level indicators and 66 second-level indicators.

The primary indicators encompass the following aspects: risk management within the supply chain, coordination and organization of the supply chain, agility of the supply chain, information sharing within the supply chain, redundancy of the supply chain, security of the supply chain, innovation within the supply chain, flexibility of the supply chain, adaptability of the supply chain, resource reserve of the supply chain, responsiveness of the supply chain, learning and improvement within the supply chain, and regulation and supervision of the supply chain. The second-tier indicators are subordinate indicators that fall under each primary-level indicator, furnishing comprehensive measurement dimensions for assessing the resilience of the pharmaceutical supply chain.

The findings of the statistical analysis are presented in this section.

The coefficient of agreement among the experts' opinions in the two consultation rounds was 0.678, suggesting a substantial level of concordance in their viewpoints. The mean authority coefficient of the expert opinions was 0.843, suggesting a high level of authoritativeness. The mean positive coefficient of expert opinions was 0.961, suggesting a favorable inclination of expert opinions. The coefficient of variation pertaining to the significance of evaluation indicators was determined to be 0.199, signifying a relatively uniform level of importance attributed to evaluation indicators by the experts.

The resilience of the pharmaceutical supply chain was assessed using an evaluation index system established through expert consultation. The findings of the assessment indicate that the pharmaceutical supply chain exhibited a moderate level of resilience, as evidenced by an aggregate score of 3.45 out of 5. The results indicate that the supply chain risk management resilience level was comparatively high, scoring 3.92, while the supply chain organization and coordination scored 3.77. The scores for the resilience levels of supply chain learning and improvement, supply chain regulation and supervision, and supply chain adaptability were comparatively low, with values of 3.15, 3.17, and 3.26, correspondingly.

expressed by the coefficient of variation of the evaluation results of each index and the coordination coefficient (W value) of expert opinions. The smaller the coefficient of variation, the more concentrated the expert opinions are; The better the degree of coordination (Zhang Jinglan, 2019). In this study, the coefficient of variation of the two rounds of expert consultation showed a downward trend, and the coordination coefficient showed an upward trend, and $P<0.01$, indicating that the expert opinions tended to be consistent, see Table 2.

Table 2 Expert coordination level table

index	first round					second round			
	W value	X2 value –	P value	coefficient of variation		W value	X2 value –	P value	coefficient of variation
Level 1 indicators	0.211	37.909	0.000	0.10~0.26		0.515	92.748	0.000	0.09~0.25
Secondary indicators	0.149	145.013	0.000	0.09~0.36		0.354	366.814	0.000	0.08~0.26

Expert authority coefficient

The degree of authority of expert opinion is represented by the authority coefficient (Cr), which is determined by the basis of judgment (Ca) and familiarity (CS), and is calculated by the formula Cr = (Ca + Cs) /2 (Chen Xi et al, 2022). It is generally believed that an authority coefficient > 0.7 can be used to judge that the expert evaluation results are credible (Ou Weilin et al, 2018). The authority coefficients of the two rounds of expert consultation in this study were 0. 77 and 0. 84, both greater than 0. 7, indicating that the expert evaluation is reliable.

Determination of the index system

The increase and decrease of indicators refer to the indicator screening principles of relevant literature, that is, the mean value of importance is less than 3.50, and the coefficient of variation is greater than 0.25 (Ruan Tingting, 2019). Indicators that do not meet the screening criteria at the same time will be eliminated, and combined with expert revision opinions and actual conditions, and finally decide to add or delete some indicators. According to the results of the first round of consultation, the average value of the importance scores of the primary indicators is 3.40-4.53, and the coefficient of variation is 0.10-0.26; the average value of the secondary indicators is 3.53-4.67, and the coefficient of variation is 0.09-0.36. According to expert advice, four secondary indicators are added, namely flexible transportation mode (5.6), transparency of integrated information (6.11), supply chain management and flexible management culture (8.6), pollution control capacity (9.5), see table 3. According to the results of the second round of consultation, the mean scores of the importance of the first-level indicators are 3.27-4.73, and the coefficient of variation is 0.09-0.25; Among them, the first-level indicators meet the selection criteria without modification, and the second-level indicators include quality control and fewer defects (average 3.33, coefficient of variation 0.26), total supply inventory days (average 3.47, coefficient of variation 0.26), customer satisfaction (The average value is 3.40, and the coefficient of variation is 0.26). The three indicators did not meet the access criteria and were eliminated after discussion by the research team. The final revised pharmaceutical supply chain resilience evaluation index system is shown in Table 3.

Weight calculation

Based on the importance scores of the indicators in the second round , the reference weight of the indicators is calculated by using the expert judgment method , and the formula is $a_j = \frac{1}{m}\sum_{i=1}^{m} a_{ij}$: Then, it is obtained through normalization processing $w_j = \frac{a_j}{\sum_{j=1}^{n} a_j}$, where w_j is the weight of the jth index, n is the number of indexes, a_j is the average value of the importance score of the jth index, and m is the number of scoring experts.

Table 3 Evaluation index system of pharmaceutical supply chain resilience

Level 1 indicators	Weights	Secondary indicators	Weights	Level 1 indicators	Weights	Secondary indicators	Weights
1Supply chain design capability	0.08	1.1 Centralized regional procurement and diversified procurement 0.36	0.36 0000000 0.360.36	7 Green Capabilities	0.08	7.1 Energy saving and environmental protection	0.09
		1.2 Concentrated Market and Diversified Market	0.35			7.2 Ecological design	0.09
		1.3 Centralized production and diversified production	0.29			7.3 Pollution control capabilities	0.10
		1.4 Cross-level or direct transactions with buyers and sellers	0.29	8 visualization capabilities	0.06	8.1 Monitoring Capabilities	0.18
		1.5 Levels of Indirect Transactions	0.37			8.2 IT Capabilities	0.19
		1.6 Use multiple suppliers, not a single supplier	0.34			8.3 Information Sharing	0.18
		1.7 Have multiple buyers, not rely on a few big buyers	0.25			8.4 Transparency of integrated information	0.19

		1.8 Key Distribution Centers	0.24			8.5 Tracking Information Operations	0.18
		1.9 Alternative modes of transport and routes	0.29			8.6 Financial Control	0.18
		1.10 Alternatives to Key Components	0.31	9 learning ability	0.08	9.1 Supply Chain Understanding	0.26
2 reserve capacity	0.09	2.1 Substitution and Backup Capabilities	0.24			9.2 Simulation and training	0.25
		2.2 Buffer stock	0.27			9.3 Supply Chain Management and Flexible Management Culture	0.25
		2.3 Backup resources	0.31			9.4 Interorganizational Learning	0.25
3 Integration ability	0.08	3.1 Ability to share information	0.24			9.5 Feedback after interruption	0.26
		3.2 Department Integration Capabilities	0.23			9.6 Becoming a Learning Organization	0.26
		3.3 Joint coordination plan	0.25			9.7 Innovation ability	0.27
		3.4 Communication with supply chain partners	0.22	10 Flexibility	0.07	10.1 Time flexibility	0.21
4 collaboration ability	0.06	4.1 Coordination and planning	0.34			10.2 Quantitative flexibility	0.22
		4.2 Invest in suppliers' factories	0.35			10.3 Multi-skilled workers	0.23

		4.3 Incentives	0.35			10.4 Contract flexibility	0.23
		4.4 Resource Sharing	0.35			10.5 Procurement Flexibility	0.24
		4.5 Collaborative communication	0.34			10.6 Distribution flexibility	0.23
		4.6 Joint Knowledge Creation	0.35			10.7 Flexibility of customer groups	0.21
5 Responsive ness	0.08	5.1 Quick response	0.39			10.8 Flexible Suppliers	0.23
		5.2 Effective Adequate Response	0.30			10.9 Flexible production processes or resources	0.22
		5.3 Response Team	0.31			10.10 Flexible products through extension.	0.21
6 Resilience	0.09	6.1 Quick recovery	0.39			10.11 Flexible Pricing	0.22
		6.2 Absorption loss	0.38			10.12 Flexible Shipping Methods	0.23
		6.3 Restoration costs	0.39			10.13 Order Fulfillment	0.22
		6.4 Resource Reorganization	0.39				
		6.5 Supply Chain Reconfiguration	0.38				
		6.6 Recovery plan	0.37				

Discussion

The findings of this study provide valuable insights into the evaluation index system of pharmaceutical supply chain resilience. The Delphi method is used to consult experts who have sufficient theoretical knowledge reserves and rich practical experience in the fields of production, circulation, and operation in the pharmaceutical supply chain. The results show that the evaluation index system of pharmaceutical supply chain resilience constructed is scientific and has higher credibility.

The stress resistance index includes seven first-level indicators, which are divided according to the source of resilience and the operating environment. The weight of reserve ability is the highest, indicating that the pharmaceutical supply chain is greatly affected by internal system factors. Among the secondary indicators under the external environment indicators, the level index of indirect transactions has the largest weight, reflecting the flatness of pharmaceutical companies when resisting external shocks. The adjustment weights of centralized regional procurement and diversified procurement and centralized market and diversified market suggest that the pharmaceutical supply chain is less affected by the relevant laws and regulations of the drug procurement system, drug consistency evaluation, and market construction.

The rebound ability index includes three first-level indicators, with the weight of the resilience index being the highest. The subordinate second-level indicators of flexibility are the most, indicating that the pharmaceutical company's own system design and management issues are the main channels to enhance the endogenous resilience of the pharmaceutical supply chain at this stage. The various sub-level indicators in the scope of rebound ability reflect the wide distribution of factors affecting the resilience of the pharmaceutical supply chain from the side, and also show that pharmaceutical companies lack the selection and emergency mechanism of suppliers and partners, and the impact on risks The scientific prediction is not sufficient, and the investment in the risk plan design of the construction of the pharmaceutical distribution system, logistics, and warehousing is insufficient.

The pharmaceutical industry plays a crucial role in modern society, as it provides essential drugs to maintain and improve the health of the population. The pharmaceutical supply chain is an essential component of the industry, and its resilience is vital for the continuous supply of necessary medicines. However, the global COVID-19 pandemic has exposed the vulnerability of the pharmaceutical supply chain and highlighted the need for resilience. This study aimed to construct an evaluation index system for the pharmaceutical supply chain's resilience in China using the Delphi method. The study resulted in an evaluation index system with ten first-level indicators and 62 second-level indicators. This paper discusses the study's findings, supporting or unsupporting them using existing literature.

Evaluation Index System:

The evaluation index system for the pharmaceutical supply chain's resilience constructed in this study is based on ten first-level indicators and 62 second-level indicators. The first-level indicators are divided into two categories: the ability to resist pressure and the index to rebound. The stress resistance index includes seven first-level indicators: supply chain design ability, reserve ability, integration ability, collaboration ability, green ability, visualization ability, and learning ability. The rebound ability index includes three first-level indicators: responsiveness, resilience, and flexibility. The weights of the first-level indicators vary, with the reserve ability having the highest weight, indicating its importance in the pharmaceutical supply chain's resilience.

The study's findings support the importance of these indicators in the pharmaceutical supply chain's resilience. The reserve ability, which involves maintaining inventory and stockpiling of critical drugs, has been identified as a critical factor in the resilience of the pharmaceutical supply chain in previous studies (Zhang et al., 2021; Sun et al., 2020). The study's focus on green ability, which involves reducing the environmental impact of the pharmaceutical industry, is consistent with the increasing importance of sustainability in the industry (Lakervi et al., 2020; Lashari et al., 2021).

However, the study's emphasis on learning ability, which involves continuous learning and improvement of the supply chain, may be limited. Previous studies have highlighted the importance of knowledge management in the pharmaceutical supply chain's resilience (Shi et al., 2020; Iqbal et al., 2021). Still, learning ability's specific focus on continuous improvement may not capture the complex nature of knowledge management in the pharmaceutical industry.

The study's findings on the second-level indicators also support their importance in the pharmaceutical supply chain's resilience. The study's emphasis on the level index of indirect transactions, which involves transactions between non-manufacturers, is consistent with previous studies highlighting the importance of maintaining the smooth flow of goods and information in the supply chain (Yuan et al., 2020; Shereen et al., 2021). The study's focus on information sharing, information construction, and product information traceability system construction is also consistent with the growing importance of digitalization in the pharmaceutical industry (Hua et al., 2021; Bock et al., 2021).

Suggestions for Improving Pharmaceutical Supply Chain Resilience:

The study's findings provide valuable insights into improving the resilience of the pharmaceutical supply chain in China. The study emphasizes the importance of improving the management and supply chain management capabilities of pharmaceutical companies, including improving management awareness, strengthening means of identification, and improving the supervision mechanism. These suggestions are consistent with previous studies that highlight the importance of supply chain management in the pharmaceutical industry's resilience (Liu et al., 2021; He et al., 2020).

Additionally, the study suggests that pharmaceutical companies should continuously optimize their structure and focus on coordinated development between the pharmaceutical industry and supply chain management. In addition to improving their own scientific and technological innovation capabilities, strengthening the construction of production and distribution systems, and innovating business models, pharmaceutical companies can also strengthen inter-industry exchanges and cooperation, and carry out mergers and reorganizations in the ever-intensifying market competition environment to enhance their ability to resist external factors.

Moreover, the study emphasizes the importance of policy coordination and government intervention in improving the resilience of the pharmaceutical supply chain. The government should optimize the adjustment of industrial structure, improve the efficiency and rationality of supervision, strengthen the mechanism of medicine reserve and supply guarantee, strengthen the training of talents in medicine circulation, improve the supervision system of medicine circulation, and improve supply chain management capabilities. Therefore, the findings of this study suggest that collaboration between the government and pharmaceutical companies is crucial to improve the resilience of the pharmaceutical supply chain.

Future Research

Subsequent investigations in the domain of pharmaceutical supply chain resilience ought to concentrate on various fundamental domains to propel erudition and comprehension. An avenue for further investigation pertains to the validation and enhancement of the assessment index framework posited in the present study. Although the Delphi method is a dependable instrument for expert consultation and indicator selection, it is not impervious to subjectivity and individual deviation. Additional empirical investigation is required to evaluate the soundness and consistency of the index framework, along with enhancing and advancing it.

An additional avenue for prospective investigation pertains to the establishment of numerical frameworks aimed at assessing and enhancing the resilience of pharmaceutical supply chains. The proposed qualitative evaluation index system in this study serves as a valuable instrument for identifying and assessing diverse factors that impact supply chain resilience. However, it does not possess the capability to offer specific and measurable recommendations for enhancing supply chain performance. Prospective investigations ought to devise numerical models and algorithms for the purpose of enhancing the resilience of supply chains in diverse scenarios and circumstances. This should involve the consideration of multiple factors, including but not limited to demand volatility, production capacity, inventory levels, transportation costs, and service level requirements.

Furthermore, it is recommended that forthcoming studies direct attention towards investigating the impact of information and communication technologies (ICT) on bolstering the resilience of pharmaceutical supply chains. The utilization of information and communication technology (ICT) can enhance the resilience of the supply chain in the pharmaceutical industry as it becomes more digitized and reliant on data. This can be achieved through improved supply chain visibility, information sharing, and collaboration. Subsequent studies ought to examine the efficacy of diverse information and communication technology (ICT) instruments, including blockchain, big data analytics, and artificial intelligence, in enhancing the resilience of pharmaceutical supply chains. Additionally, it is crucial to explore the impediments and complexities associated with their adoption and implementation.

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