Research on the Influencing Factors of Resilience Development of Shortage Drug Supply Chain

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Abstract. In recent years, medical accidents caused by supply chain shortages have occurred frequently. Countries have proposed to improve the pharmaceutical supply chain and seek the resilient development of the domestic pharmaceutical supply chain. All countries have proposed to improve the pharmaceutical supply chain and seek the resilient development of the domestic pharmaceutical supply chain. Starting from the resilience development of the shortage drug supply chain, this paper conducts semi-structured interviews with relevant experts in medical institutions, production enterprises, circulation enterprises and other channels, as well as relevant practitioners in the first-line medical supply chain. In view of the different scenarios of supply chain disruption of shortage drugs, this paper makes a detailed analysis of the resilience development of the shortage drug supply chain from the aspects of external environment, channel risk, logistics guarantee, information chain, capital chain and production chain. By coding the influencing factors in the details, an open coding-spindle coding-selective coding is established. The DEMEL model is used to generate coding variables to obtain a direct impact matrix. By subjectiveizing the direct influence matrix, the comprehensive influence matrix is obtained. The study found that : (1) From the ranking of the factors that affect the resilience of the shortage drug supply chain, the government has a high degree of regulation and control over the shortage of drugs. The list of shortage drugs and the introduction of policies on drug supply directly affect the production process of shortage drugs. The stability of the entire supply chain plays a decisive role. (2) From the perspective of supply chain resilience, the key influencing factors are still capital flow and information flow. However, while paying attention to the internal information of the supply chain, it is still necessary to maintain sensitivity to external factors.

Keywords: shortage drug supply chain ; resilience ; grounded theory ; DEMATAL

1 Introduction

In the new era of economic globalization, global economic growth is sluggish, international trade is severely declining, and the pharmaceutical supply chain is the first to be affected by disruptions. In response to the phenomenon of supply chain fractures, the United States released a 100 day supply chain report in 2021, which emphasized the importance of the supply chain resilience system relationship for semiconductors, new energy batteries, rare earth minerals, and pharmaceuticals. Among them, the development of resilience in the pharmaceutical supply chain coincides with the "Healthy China 2030" policy, which has extremely high requirements for the pharmaceutical industry and supply chain.

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In 2020, the National Health Commission defined "shortage of drugs" as "drugs that have been approved for marketing by China's drug regulatory authorities, are clinically necessary and cannot be replaced or completely replaced, and are in short supply or unstable supply within a certain period of time or region." [1]. The modern pharmaceutical industry in China has a short development time, mainly focused on generic drugs, with a relatively low level of independent research and development. It still relies on the pharmaceutical level of other developed countries to gradually develop[2]. In the pharmaceutical industry, shortage of drugs is an important target that cannot be ignored. From the perspective of developed countries such as the United States, ensuring the supply of shortage drugs is a major livelihood project, and the causes of supply disruptions are complex[3]. Considering factors such as external environment, circulation enterprise processes, entrusted storage methods, and distribution management systems, various countries have proposed different policies to reduce the risk of pharmaceutical supply chain disruptions. Countries such as the Netherlands and Egypt have put forward different policy recommendations in the face of drug shortages in different situations [4-8].

Currently, China urgently needs to pay attention to the development factors of supply chain resilience for scarce drugs. In May 2022, the "Key Tasks for Deepening the Reform of the Medical and Health System in 2022" clearly stated that it will expand the scope of procurement, strengthen the ability to ensure drug supply, improve the collaborative monitoring mechanism for drugs, strengthen the graded response to drug shortages, and strengthen the construction of centralized production bases for small variety drugs (shortage drugs). The main procurement method for shortage drugs in China is centralized procurement.

Due to the fact that domestic research on the resilience of the shortage drug supply chain often starts from the details, scholars generally focus on a certain key point in the system, such as finance, channels, profit sharing, etc., and there is little literature that focuses on analyzing the overall supply chain system. Currently, many scholars are attempting to establish some transparency mechanisms through blockchain or information sharing, but resilience should be multifaceted, not just from the perspective of informatization, nor from any particular point. Based on this, this article conducts a systematic analysis from the perspective of the shortage of pharmaceutical systems. Conduct in-depth interviews and analysis on various levels of supply chain links, considering the resilience development from the industrial chain to the supply chain, and eager to find the influencing factors of the resilience development of domestic shortage drug supply chains.

2 Research Design

2.1 Research object

This paper mainly studies the resilience of the shortage drug supply chain, pays attention to the special supervision and management of the shortage drug supply chain, studies the sustainable supply of shortage drugs and the resilience influencing factors existing in the digital transformation and development period of commercial companies, and solves the problem of how stable the supply chain is. It is clear logic to interpret the policy status and resilience from the inside and outside of the supply chain system. In addition, through the analysis of the operation mode of the shortage drug supply chain system and the pilot results of the collection

innovation, combined with the analysis of the causes of the end interruption summarized by scholars, the core process topology relationship is established to form a theoretical framework.

2.2 Research methods

Decision making trial and evaluation laboratory (DEMATEL). The advantage of this method is to analyze the influencing factors of complex systems by applying hierarchical diagrams and matrices. By analyzing the mutual influence and direct influence relationship between the elements in the system, the core driving factors of the research problem are found on this basis, so that the importance of each influencing factor is clearly visualized.

2.3 Preliminary selection of influencing factors

Based on literature review, with the theme of "resilience of the pharmaceutical supply chain", 253 core articles were retrieved from relevant fields published in the China National Knowledge Infrastructure database, and key words were identified through article by article screening. Accompanied by a trilogy of talks, questions, and inspections, the experts were interviewed multiple times to understand the factors affecting supply chain resilience in the industry from various aspects such as pharmaceutical supply chain channels, the impact of centralized procurement on pharmaceuticals, and the turnover of pharmaceutical raw materials. From this, 24 common factors are obtained, namely the core influencing factors of the shortage drug supply chain system (see Table 1).

Table 1 Core influencing factors of shortage drug supply chain

main category	Subcategory	main category	Subcategory
External environment（E）	E1 Rapid-onset event	Stabilize the capital chain（W）	W1 Pharmaceutical commercial companies
	E2 Government support		W2 Funds refund
	E3 International environment		W3 Contractual agreements
	E4 Local Drug Catalogue		W4 Government project
Logistics guarantee（L）	L1 Transportation support	Channel risk（R）	R1 Agent channel is difficult to control
	L2 Production scheduling (long term)		R2 Commercial companies into the library selection
	L3 Production scheduling (short-term)		R3 Balance department funds with drugs
	L4 Warehouse drug expiration date		R4 Rebate settlement delay
Shared information（M）	M1 Market R & D control	Industrial production (S)	S1 Production line transformation
	M2 Medical Academic Conference		S2 Changes in quality standards
	M3 Refund information regulation		S3 Production license expired
	M4 New and old specifications change		S4 Raw material medicine monopoly

3 Evaluation of the main factors of DEMATEL

3.1 Calculation of comprehensive impact matrix

This study uses the DEMATAL method to analyze the interaction between 24 sub-category factors such as E1 rapid-onset event, E2 government support, E3 international environment, E4 local drug list, L1 transportation support, L2 production scheduling (long-term), L3 production scheduling (short-term), L4 warehouse drug expiration date, M1 market R&D control.

$$A = \begin{bmatrix} 0 & A_{12} & \cdots & A_{1n} \\ A_{21} & 0 & \cdots & A_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ A_{n1} & A_{n2} & \cdots & 0 \end{bmatrix} = \left(A_{ij}\right)_{n\times n} \quad (1)$$

$$N = \frac{A_{ij}}{\max\limits_{1\le i\le n} \sum_{j=1}^{n} A_{ij}} = \left(N_{ij}\right)_{n\times n} \quad (2)$$

$$T = N(I-N)^{-1} = \left(T_{ij}\right)_{n\times n} \quad (3)$$

$$D_i = \sum_{j=1}^{n} T_{ij}\ (1 \le i \le n, 1 \le j \le n) \quad (4)$$

$$C_i = \sum_{i=1}^{n} T_{ij}\ (1 \le i \le n, 1 \le j \le n) \quad (5)$$

$$M_i = D_i + C_i \quad (6)$$

$$R_i = D_i - C_i \quad (7)$$

3.2 Data processing

In order to eliminate the influence of subjective errors caused by scoring and the degree of experts ' understanding of research issues on the results, this study designed a matrix questionnaire of influencing factors, and invited a group of experts from research institutions, pharmaceutical companies, bioengineering enterprises, industry associations and other supply chain organizations to fill in. Among them, the expert scoring mechanism is shown in Table 2.

Table 2 Expert evaluation semantic scale

semantic variable	no effect	Minor impact	Less impact	general influence	Strong influence	strongly influenced
scale	0	1	3	5	7	9

Comprehensive influence matrix. The comprehensive influence matrix is further calculated on the normalization matrix :

$$T =$$

0.064	0.114	0.119	0.127	0.144	0.137	0.147	0.112	0.123	0.130	0.126	0.119	0.152	0.143	0.130	0.142	0.114	0.124	0.091	0.113	0.124	0.119	0.077	0.115
0.096	0.077	0.131	0.139	0.143	0.158	0.168	0.124	0.135	0.135	0.131	0.123	0.166	0.150	0.136	0.155	0.126	0.137	0.102	0.118	0.129	0.124	0.081	0.121
0.084	0.105	0.068	0.116	0.118	0.125	0.134	0.096	0.113	0.113	0.109	0.102	0.133	0.131	0.113	0.130	0.104	0.106	0.076	0.090	0.094	0.096	0.082	0.098
0.072	0.078	0.089	0.067	0.097	0.110	0.118	0.083	0.093	0.106	0.095	0.089	0.130	0.122	0.105	0.116	0.105	0.113	0.078	0.097	0.100	0.089	0.063	0.091
0.057	0.055	0.064	0.069	0.054	0.085	0.094	0.071	0.067	0.066	0.075	0.064	0.086	0.085	0.071	0.073	0.059	0.065	0.049	0.058	0.068	0.065	0.050	0.073
0.063	0.068	0.071	0.083	0.104	0.067	0.110	0.079	0.074	0.074	0.076	0.078	0.103	0.094	0.092	0.088	0.072	0.100	0.055	0.065	0.074	0.065	0.054	0.080
0.060	0.065	0.068	0.073	0.093	0.104	0.065	0.076	0.070	0.070	0.066	0.075	0.098	0.089	0.075	0.084	0.069	0.089	0.052	0.061	0.071	0.062	0.052	0.076
0.071	0.077	0.073	0.086	0.087	0.098	0.100	0.054	0.070	0.069	0.086	0.081	0.112	0.097	0.082	0.077	0.068	0.104	0.064	0.067	0.093	0.096	0.092	0.076
0.071	0.084	0.102	0.101	0.102	0.121	0.123	0.075	0.064	0.098	0.094	0.075	0.115	0.100	0.091	0.114	0.083	0.084	0.070	0.081	0.100	0.103	0.077	0.118
0.074	0.080	0.091	0.103	0.097	0.109	0.111	0.070	0.101	0.060	0.089	0.097	0.110	0.101	0.086	0.109	0.078	0.086	0.059	0.071	0.081	0.084	0.066	0.080
0.070	0.083	0.081	0.080	0.103	0.115	0.110	0.075	0.091	0.084	0.067	0.087	0.128	0.134	0.104	0.100	0.103	0.112	0.071	0.103	0.092	0.081	0.069	0.103
0.060	0.065	0.062	0.073	0.087	0.105	0.107	0.070	0.071	0.071	0.067	0.047	0.105	0.097	0.076	0.072	0.063	0.071	0.053	0.076	0.080	0.083	0.060	0.071
0.077	0.084	0.108	0.115	0.139	0.138	0.140	0.090	0.093	0.112	0.122	0.088	0.092	0.144	0.119	0.123	0.091	0.127	0.076	0.109	0.093	0.087	0.074	0.097
0.076	0.090	0.087	0.094	0.117	0.130	0.125	0.108	0.118	0.110	0.121	0.087	0.131	0.088	0.118	0.122	0.110	0.112	0.089	0.115	0.112	0.087	0.068	0.091
0.068	0.080	0.078	0.103	0.118	0.110	0.112	0.078	0.088	0.081	0.090	0.083	0.118	0.123	0.066	0.110	0.100	0.087	0.061	0.086	0.074	0.070	0.058	0.080
0.074	0.087	0.098	0.104	0.097	0.095	0.104	0.077	0.101	0.101	0.076	0.076	0.110	0.115	0.106	0.069	0.079	0.085	0.060	0.084	0.073	0.070	0.058	0.079
0.055	0.060	0.063	0.074	0.076	0.107	0.108	0.064	0.066	0.072	0.095	0.063	0.081	0.107	0.098	0.080	0.052	0.079	0.082	0.092	0.067	0.062	0.053	0.092
0.048	0.052	0.054	0.059	0.092	0.089	0.090	0.083	0.056	0.056	0.066	0.062	0.090	0.075	0.068	0.063	0.055	0.048	0.047	0.055	0.065	0.062	0.048	0.057
0.055	0.060	0.055	0.059	0.072	0.077	0.085	0.077	0.064	0.064	0.067	0.062	0.070	0.076	0.062	0.064	0.085	0.070	0.035	0.084	0.066	0.056	0.048	0.058
0.065	0.071	0.074	0.080	0.102	0.113	0.108	0.083	0.077	0.070	0.074	0.067	0.106	0.112	0.097	0.106	0.097	0.111	0.086	0.055	0.084	0.067	0.057	0.070
0.065	0.077	0.074	0.080	0.094	0.099	0.101	0.089	0.077	0.069	0.086	0.095	0.100	0.091	0.082	0.098	0.075	0.090	0.057	0.068	0.058	0.097	0.086	0.090
0.059	0.065	0.067	0.072	0.072	0.082	0.091	0.069	0.070	0.069	0.066	0.061	0.077	0.081	0.074	0.084	0.061	0.075	0.052	0.060	0.106	0.049	0.087	0.083
0.078	0.092	0.089	0.116	0.126	0.133	0.135	0.111	0.106	0.085	0.124	0.103	0.134	0.132	0.120	0.104	0.098	0.122	0.084	0.097	0.123	0.125	0.057	0.100
0.094	0.102	0.127	0.128	0.139	0.153	0.150	0.115	0.125	0.123	0.135	0.114	0.148	0.146	0.133	0.130	0.116	0.134	0.092	0.121	0.134	0.135	0.106	0.083

Centrality and cause. The centrality and cause degree are obtained, as shown in figure 1.

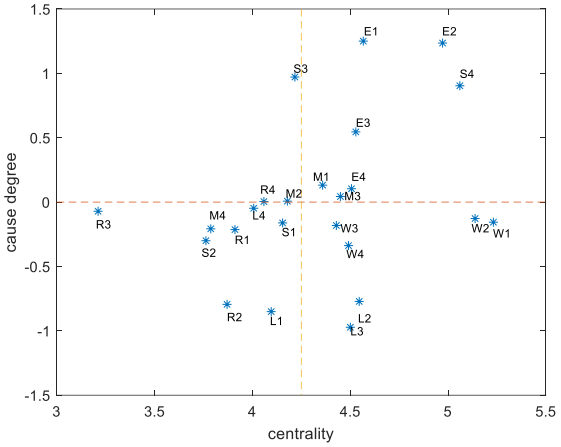

Fig.1 Causality diagram of influencing factors of resilience in shortage drug supply chain

3.3 Result analysis

(1) Analysis of the influencing factors of each index.

According to ranking, there are 10 reasons, ranking from high to low : E1 rapid-onset event, E2 government support, S3 production license expired, S4 raw material monopoly, E3 international environment, M1 market R&D control, E4 local drug catalogue, M3 refund information regulation, M2 medical academic conference, R4 rebate settlement delay. From the ranking of the factors that affect the resilience of the shortage drug supply chain, the government 's regulation and control of the shortage drug is high, and the list of shortage drugs and the introduction of policies on drug supply directly affect the production process of shortage drugs. The stability of the entire supply chain plays a decisive role. The implementation of information standardization makes the supply chain of shortage drugs maintain overall coordination and promotes the stable adjustment of drugs, which is an important factor to promote the stable supply of national shortage drugs.

(2) Centrality analysis of influencing factors of each index.

The greater the centrality, the greater the impact. From ranking, it can be seen that the top 5 factors of centrality are W1 pharmaceutical commercial companies, W2 fund return, S4 raw material medicine monopoly, E2 government support and E1 rapid-onset event. It shows that from the perspective of supply chain resilience, the key influencing factors are still capital flow and information flow, while E2 government support and E1 rapid-onset event ranking 4 and 5 indicate that the external environment is still the most important factor affecting the resilience of the shortage drug supply chain. While paying attention to the internal information of the supply chain, it is still necessary to remain sensitive to external factors.

(3) Causality diagram analysis.

According to Figure 1, it can be found that E1 rapid-onset event, E2 government support, E3 international environment, S4 raw material medicine monopoly, M1 market R&D control, E4 local drug catalogue, M3 payment information regulation are the important factors. W3 refund information regulation, W4 government project, W2 funds refund, W1 pharmaceutical commercial company, L2 production scheduling (long-term) and L3 production scheduling (short-term) are important result factors ; S3 Production license expired, R4 Rebate settlement delay and M2 Medical Academic Conference are the reasons for low importance. S3 production license expired, R4 rebate settlement delay, and M2 medical Academic Conference are the causal factors of low importance; R3 Balance department funds with drugs, M4 new and old specifications change, L4 warehouse drug expiration date, S2 changes in quality standards, R1 agent channel is difficult to control, S1 pharmaceutical commercial companies, R2 commercial companies into the library selection, L1 transportation supportare low importance outcome factors. From the perspective of causality, the external environment, stable capital chain, logistics guarantee, sharing information and industrial production are the influencing factors with high importance. Among them, the external environment and stabilize the capital chain are the key influencing factors in the resilience of the shortage drug supply chain.

According to the analysis results of Table 3, we further get the relationship between the six system dimensions. It can be found that the external environment and industrial production are the active influencing factors, and other factors mainly affect the resilience of the shortage drug supply chain around these two system dimensions. The results are consistent with the factor relationships obtained from the preliminary analysis of literature in this article. Among them, the impact of stable funding chains and channel risks on the resilience of the shortage drug supply chain is more complex, and further analysis is needed to draw a hierarchical diagram of the shortage drug supply chain.

Table 3 The analysis results of the system dimension in the shortage drug supply chain

	influencing factor system	influence degree		influenced degree		centrality		cause degree	
	dimension	numeric value	rank	numeric value	rank	numeric value	rank	numeric value	rank
E	External environment	3.411	1	2.206	6	5.617	1	1.205	1
L	Industrial	2.120	5	3.090	1	5.211	4	-0.969	6

	production								
M	Shared information	2.557	4	2.914	2	5.472	2	-0.357	4
W	Stabilize the capital chain	2.77	2	2.519	3	5.292	3	0.255	3
R	Channel risk	1.904	6	2.423	4	4.327	6	-0.519	5
S	Industrial production	2.689	3	2.303	5	4.992	5	0.386	2

From a macro perspective, the external environment and industrial production play a decisive role in the protection of the pharmaceutical supply chain. In terms of the degree of influence, in addition to the external environment and industrial production, the stability of the capital chain is an active factor for other influencing factors. It can be considered that for the entire supply chain, its importance is the first. In the face of the ups and downs of the domestic economic situation, the flow of funds between pharmaceutical companies should maintain a green and healthy state. When maintaining a healthy supply chain situation, sharing information is also a factor that cannot be ignored. For any part of the members of the pharmaceutical supply chain organization, only closely linked can we minimize the unexpected situation caused by external environment, industrial production and other factors. Sharing information plays an absolute role in the smooth flow of the supply chain. In the process of investigation, many enterprises also said that scheduling needs diversified information intersection to provide intelligent and comprehensive services for production and transportation.

4 Conclusion

This paper takes the shortage drug supply chain system as the research object, and focuses on the problem of how to maintain the stability and resilience of the national shortage drug supply chain. The grounded theory method is used to interview the heads of different pharmaceutical enterprises. Following the logic of ' thinking-behavior-result ', the influencing factors of the resilience of the shortage drug supply chain are summarized and deduced. The theoretical model of the influencing factors of the resilience of the shortage drug supply chain system is constructed from six dimensions : external environment, logistics guarantee, information sharing, stable capital chain, stable capital chain, channel risk and industrial production, and DEMATEL method is used. This paper identifies and calculates the influencing factors of the operation of urban logistics system from three aspects: centrality, causality and causality diagram. A total of 13 key factors are obtained, which are: rapid-onset event, government support, international environment, raw material medicine monopoly, market R&D control, local drug catalogue, refund information regulation, contractual agreements, government project, fund refund, pharmaceutical commercial companies, production scheduling (long-term), production scheduling (short-term), etc. Among them, the external environment and stable capital chain are the two main factors that determine the degree of development of urban logistics. In the supply cycle of shortage drugs, it is necessary to have a certain sensitivity to domestic government policies, pay attention to all problems in the production chain, focus on supporting the cooperative relationship with commercial companies, and improve the smooth operation of manufacturers.

Due to the limitation of resources and energy, the scope of enterprises interviewed in this paper is narrow, and the score is relatively subjective, which has certain limitations and lag. In future research, more sufficient indicators will be selected to obtain scores, in order to more accurately obtain the influencing factors of different types of shortage drug supply chains, and further improve the resilience of domestic shortage drug supply chains.

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