Risk Analysis and Emergency Control of Epidemic Public Health Emergencies Based on Disaster Chain Network Model

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Abstract
In recent years, with the development of society and the acceleration of urbanization, all kinds of health and safety events have gradually moved closer to the chain structure, and the losses caused by the chain effect are huge. Based on the theory of disaster chain, the paper expounds the following effects of public health emergencies triggered by COVID-19, and constructs a series of disaster chain structure, and carries out risk analysis from the nodes and sides of the disaster chain. The influence degree of each secondary disaster caused by COVID-19 is analyzed, and the key nodes with the greatest impact are obtained, and effective emergency prevention and control measures for key nodes are put forward. The relevant research provides scientific methods and reference basis for the emergency management of infectious diseases and public health events.

Keywords-*disaster chain theory; public health emergencies; COVID-19; risk analysis; emergency control*

1. INTRODUCTION

In recent years, with the development of society and the continuous improvement of people's safety consciousness, public health and safety emergencies have become the focus of attention. Among them, public health safety is the basis for ensuring people's happy life, social stability and national economic stability. In June 2020, President Xi Jinping once again emphasized the importance of public health safety at the symposium held by experts and scholars, and put forward the establishment of a strong public health system to provide a strong guarantee for safeguarding people's health [1].

From the 1957 H2N2 virus, the 1968 Hongkong flu, hepatitis A in 1988, the SARS virus in 2003, the hand foot mouth disease in 2008, the influenza H1N1 in 2009, COVID-19 in the end of 2019, we can see that the treatment of epidemic diseases is imminent. The epidemic is characterized by strong infectivity and wide transmission channels. Once spread, the casualties and property losses caused will undoubtedly be huge, and it is also likely to cause people's panic and social unrest. At the same time, the workload and cost of medical rescue, personnel resettlement and subsidies in the later stage are huge [2].

The control of public health emergencies is a long-term focus of our country. Following the outbreak of COVID-19, the call for emergency prevention and control in this area has reached a climax. The development of the epidemic has led to the shutdown or closure of many enterprises and factories, the failure of colleges and universities to start school as expected, the closed management of people's life, and a serious impact on the mental health of everyone affected. At present, although the epidemic situation is handled properly, the emergency management of public health events in China is still relatively weak compared with the emergency management in other directions. This paper will provide a new research method, expand a new idea for future research in this direction and improve the construction of emergency prevention and control system.

S. A. R. Khan et al. (Eds.): ICMSSE 2022, AHCS 12, pp. 143–149, 2023.
https://doi.org/10.2991/978-94-6463-056-5_20

2. COMPLEX NETWORK MODEL BASED ON DISASTER CHAIN THEORY

2.1. Formation mechanism of disaster chain

The formation of disaster chain is the result of the interaction of initial disaster, secondary disaster and many influencing factors. Scholar Shi Peijun [3] proposed that disasters are the result of three factors: disaster pregnant environment, disaster causing factors and carriers. Disaster pregnant environment is divided into natural ecological environment and humanistic social environment. Natural ecological environment includes climate, region and hydrological conditions, while humanistic social environment refers to legal system, culture, social politics and economic environment. The classification of disaster causing factors is mainly summarized as man-made, nature, technology, politics and economy. The ultimate role of disasters is divided into natural resources, people, equipment and facilities, politics and economy. According to the nature, disasters include natural disaster events, accident disaster events, health and safety events and social security events [4]. The formation mechanism of disaster chain can be shown in Fig. 1.

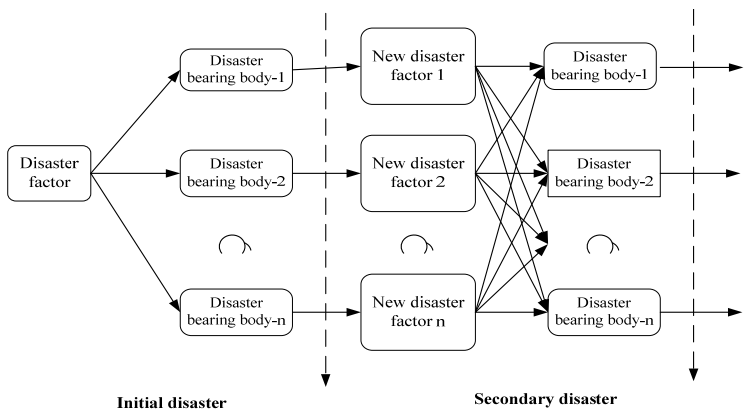

Figure 1. Formation mechanism of disaster chain

2.2. Complex network structure characteristics of disaster chain

According to the development reasons of the disaster chain, disaster chains are divided into five types: ①causal disaster chain; ②homogeneous disaster chain; ③recurring disaster chain; ④mutually exclusive disaster chain; ⑤ even-row disaster chain[5].Due to the wide classification of disaster chains and complex causes, these different factors often interact to form a huge disaster network, which has no fixed form, and even most of them are combined by different forms of disaster chains to form a complex network model. Therefore, the network model of disaster chain can be regarded as a directional evolution graph formed by N nodes and e edges. A node represents a disaster event, and each edge between two adjacent nodes represents an inducing pathway. The arrow is the evolution direction of one disaster inducing another disaster. The network structure can be shown in Fig. 2.

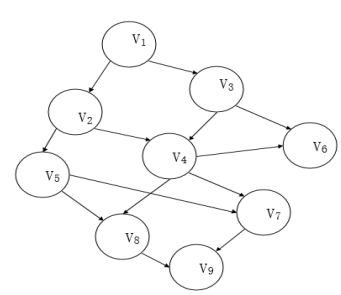

Figure 2. Network structure of disaster chain

2.3. Theory and application of disaster chain network model

2.3.1. Vulnerability analysis based on network nodes

a) Point centrality: In this disaster chain network diagram, the number of ways leading to the occurrence of the disaster event is called the penetration of the event. The greater the penetration, the more ways the event occurs, and the more difficult it is to control the event. If the occurrence of an event causes other disaster events to occur, the number of ways to cause other disaster events is called the occurrence of the event. The value of out degree is the number of other disaster events pointed to by the node. The greater the occurrence, the more serious the consequences caused by this event, and the

more it needs to be controlled. This event is also a key node in the network diagram.

b) Intermediary centrality: The higher the number of times a node acts as an intermediary, the greater its intermediary centrality, indicating that it plays a key role in communicating with other points. Then, for the calculation of intermediary centrality, starting from the definition of intermediary, centrality refers to the number of shortest paths passing through node v. assuming that the intermediary of node V needs to be calculated, based on the shortest path basis, there is the following formula:

$$C_B(v) = \sum_{j \neq v \neq k} \frac{\sigma_{jk}(v)}{\sigma_{jk}} \tag{1}$$

As in (1), σ_{jk} represents the number of shortest paths from node j to node K, $\sigma_{jk}(v)$ represents the number of times node v passes in the shortest path from node j to node k.

2.3.2. Vulnerability analysis based on network edge

In the complex network model, the importance of an edge can be measured by its vulnerability. For the vulnerability of the middle edge of the disaster chain, the comprehensive indicators can be expressed by the following formula:

$$V_{i \in (1,k)} = B_i L_i / H_i \tag{2}$$

As in (2), k is the total number of edges in the whole disaster chain network model; i represents the i-th side; B_i is the edge intermediate number of the ith edge; L_i is the average path length of the network after removing the ith edge; H_i is the connectivity of the network after removing the i-th edge.

a)Edge intermediate number: Intermediate number is divided into edge intermediate number and point intermediate number, which is used to measure the importance of nodes or edges in the network. The larger the intermediate number, the wider the influence range of the edge or point, which is positively correlated with vulnerability.The calculation formula of edge intermediate number is:

$$B_i = \sum_{j,k} g_{jk}(i) \tag{3}$$

As in (3), $g_{jk}(i)$ is the number of times the shortest path between nodes J and K passes through edge i.

b)Average path length: The average value of the distance between any two nodes is defined as the average path length of the network, which is recorded as L, and its calculation formula is:

$$L = \frac{1}{N(N-1)} \sum_{i \neq j} d_{ij} \tag{4}$$

As in (4), N is the number of nodes in the network, and d_{ij} is the shortest path of i and j nodes.

The average path length of the network expresses the propagation speed of the network. Therefore, if we compare the changes of the average path length of the network after removing each side in the disaster network structure, the larger the average path length becomes, the greater the harm of this side and the higher the corresponding vulnerability.

c)Edge connectivity: In the complex network structure model, the connectivity of connected graph is called connectivity, which is divided into edge connectivity and point connectivity. Only edge connectivity is considered here. The corresponding calculation formula is:

$$H = \frac{N_i}{N} \tag{5}$$

As in (5), N is the total number of nodes in the network, and N_i is the number of nodes that can be connected in the network model after removing the i-th edge.

3. CASE ANALYSIS: TAKING COVID-19 AS AN EXAMPLE

In December 2019, a sudden virus quietly began to spread from Wuhan to the whole country. As of May 12, 2021, the cumulative number of confirmed diagnoses recorded was 103932 and 5851 were imported from abroad, including 98506 cured and 4858 dead. In addition to the direct impact on people's life safety, it has also caused a heavy blow to people's life, physical and mental health and even the whole society.

3.1. Analysis and construction of disaster chain

a)Pregnant disaster environment: The outbreak of the new crown comes on the eve of the Spring Festival. Subsequently, with the continuous discovery of new crown cases, all localities also took different degrees of closure measures. In just a few months, major transportation systems have been closed, and travel modes such as railway, expressway, aviation and waterway have been completely closed.

b)Disaster causing factor: Disaster causing factors mainly include the following things: closure of enterprises and factories, inconvenient travel, suspension of classes in Colleges and universities, illness or casualties.

c)Disaster bearing body: The disaster bearing body mainly includes the following things: the normal operation of society and economy.

Based on the above analysis of the impact factors on COVID-19 epidemic situation, the COVID-19 disaster

chain shown in the figure below is constructed. The figure is shown in Fig. 3.

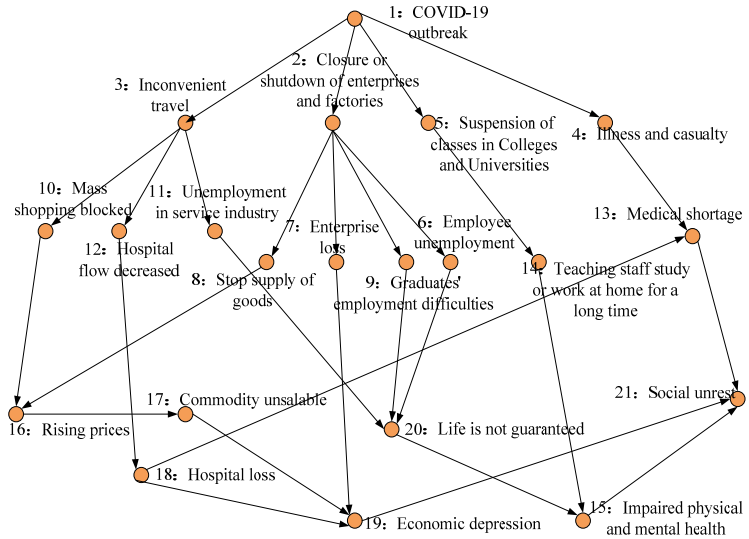

Figure 3. COVID-19 disaster chain network structure

3.2. Access analysis of disaster chain

Taking the above disaster chain as an example, Pajek software is used to calculate its entry, exit and the number of subnet nodes.

According to the above table, in the COVID-19 disaster chain, from the perspective of access, the three problems of economic depression, social unrest and lack of guarantee of life are more involved, and there are more ways to induce events, which is more difficult to control than other disaster events. The closure or shutdown of enterprises and factories and the inconvenience of people's travel are frequent, resulting in the largest number of secondary disasters and the most serious consequences. From the number of subnet nodes in the network diagram, the number of subnet nodes that enterprises and factories are closed or shut down and people are inconvenient to travel is the largest, causing the most disaster events and the greatest risk.

Considering comprehensively, in the whole network model, the control of disaster events should start from the closure of enterprises and factories and the inconvenience of people's travel. However, since the occurrence of these two events is irreversible during the outbreak of the epidemic, we can start from the number of subnet nodes controlling these two events, that is, take measures to reduce the consequences of these two events. At the same time, COVID-19 outbreak is a first-class disaster event, and the prevention of initial disasters should be focused on.

3.3. Analysis of disaster intermediary centrality

In the paper, Pajek software is used to draw the network model diagram of intermediary centrality according to the number of times each node acts as a bridge on the shortest path between any two points, and the specific values are given, as shown in Fig. 4. The larger the point, the greater the intermediary centrality.

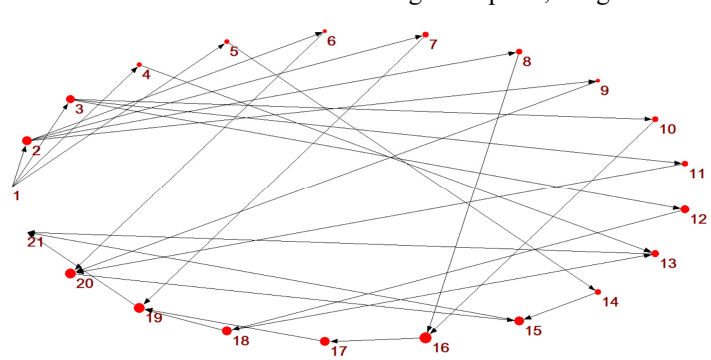

Figure 4. Intermediary centric network model

Since the beginning and end of the disaster chain can not play the role of "intermediary", in which the intermediary centrality is always 0, it is not considered when analyzing the data results. According to the calculation and analysis results, the points with the highest intermediary centrality are 16 and 20, that is, rising prices (0.024) and lack of guarantee of life (0.022), which means that most of the links between any two other disaster events need to go through these two events, and the fermentation of these two events will

affect the pointed end between the other two points. Therefore, the emergency management of this type of disaster has countermeasures, and the way to cut off these two events can be considered in the suggestions.

3.4. Vulnerability analysis of disaster chain edge

According to the disaster chain network model, the number of edges, average path length and connectivity are calculated by formulas (3), (4) and (5), and the calculation results of these three indicators are brought into formula (2) to obtain their vulnerability. According to the calculation results, it can be seen that the vulnerability of edges 1→2, 1→3 and 19→21 are strong, and their vulnerability are 26.58, 21 and 19.62 respectively. The edge with greater vulnerability or the source of the disaster chain has a high degree of association with multiple nodes and plays an important role in the network diagram of the whole disaster chain. If the links of these edges are artificially intervened to disconnect the edge with greater vulnerability, the whole disaster chain can be destroyed and most of the secondary disasters can be cut off. On the contrary, the vulnerability of edges 1→4, 1→5 and 4→13 are 6.45, 6.71 and 8.60 respectively. These edges have small vulnerability, weak correlation with other nodes and weak importance.

Therefore, in the emergency prevention and control of the disaster chain, vulnerability has guiding significance for the decision-making of disaster prevention and reduction: first, edge 1→2, in the case of infectious disease outbreak, such disaster events can not be avoided. The best solution is to control the development of the epidemic from the source and reduce the number of enterprise factory closures, or reduce the impact of this event; Second, edge 1→3, that can not be avoided, but the impact can be reduced; Third, edge 19→21, in the case of major epidemic or other extremely serious public health, the state or government needs to issue corresponding economic policies to protect the national economy.

4. COMPREHENSIVE EMERGENCY CONTROL SUGGESTIONS

The serious harm caused by epidemic emergencies has brought great challenges to emergency management. Its complex causes and scope of danger force the emergency management to be continuously improved according to the changes of the situation in order to deal with public health events of different nature and types. The suggestions are as follows.

4.1. Prevention of epidemic emergencies

According to the previous description of the number of sub network nodes of the network model, the initial disaster is a first-class disaster, which is the key object of prevention. Take measures to prevent the initial disaster and cut off the development path of all secondary disasters from the root. Do a good job of prevention before the disaster comes. No matter what kind of disaster environment, the most effective preventive measure is to strengthen prediction supervision and normalized management. Build an intelligent data platform to improve the level of early warning decision-making; At the same time, strengthen the normalization management of early warning work.

4.2. Establish an economic response mechanism

According to the disaster chain network model node analysis results, the most in-depth disaster event economic depression and the most central disaster event price rise, life can not be guaranteed, and the edge economic depression → social unrest with high vulnerability obtained from the edge vulnerability analysis, it can be seen that the analysis results are related to the economy. Therefore, an economic response mechanism can be established to prevent and reduce the occurrence and harm of these disaster events. Accelerate the commercialization of the Internet and the cultivation of emerging industries, provide more choices for people's livelihood and provide new support for the national economy. To solve the problem of short-term price rise, the most important thing is to ensure emergency resources in advance to prevent supply interruption and low inventory.

4.3. Stabilize social order

Considering from subjective factors, an important factor causing social unrest during the occurrence of infectious disease emergencies is the incorrect guidance of social public opinion. The fermentation of negative public opinion will affect the mental health of the light, and cause the panic of the masses. If this panic is not dredged, the serious consequences can lead to social unrest. Because we need to maintain physical and mental health, enhance the sense of responsibility and establish an online intervention mechanism; Secondly, the stability of social order needs to correctly guide public opinion, strengthen information communication, positively guide and transmit positive energy.

5. CONCLUSION

- Aiming at the severity of the consequences of infectious disease emergencies, the paper realizes the construction of the complex network model of disaster chain, and calculates and

analyzes the node related parameters and edge vulnerability of the network structure. It is concluded that the disaster events with the greatest impact are social unrest and economic depression.

- Based on the key events obtained from the analysis results, specific countermeasures and suggestions are put forward to prevent or mitigate the impact of key disaster events, and the importance of improving the early warning ability with establishing the economic response mechanism in the emergency management of infectious diseases are clarified. In the process of emergency management, public opinion guidance and maintaining physical and mental health should be placed in an important position to appease the people and maintain social stability.

Future research should further strengthen the investigation, refine the disaster chain model, and continue to deepen the disaster chain risk assessment algorithm.

ACKNOWLEDGMENT

This work was financially supported by the PhD Research Startup Foundation of Shandong Technology and Business University (No. BS201522).

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