Infectious Disease Risk Transmission Mechanism in Cold Chain Transportation Link and Simulation Study

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Abstract. In order to study the infectious disease risk propagation process and propagation mechanism in the cold chain transportation link, this paper, based on the accident causation theory, obtains the infectious disease risk propagation mechanism in the cold chain transportation process by constructing the cold chain transportation infectious disease propagation risk intensity system and the cold chain transportation infectious disease immunity evaluation index system; and applies the SIR viral propagation model to compute two parameter values of risk propagation of the Cold Chain Transport Company A as a case study, to Simulate the spreading process of infectious disease risk in the cold chain transportation network with Cold Chain Transportation Company A as the core, in addition, analyze the influence of each parameter of the risk spreading model on the spreading process by adjusting the values of each parameter.

Keywords: Cold chain transportation; Infectious disease prevention; Infectious disease risk transmission; SIR infectious disease modeling

1 Introduction

At present, China's cold chain transportation industry is in the stage of rapid development, the existing cold chain transportation facilities and equipment and management system has been unable to adapt to the current domestic situation. Some scholars have found that cold chain transportation has become a new type of carrier for virus transmission[1], and infectious diseases are often detected during the rampage of infectious diseases containing infectious viruses in the imported cold chain food, and on the outer packaging. Fresh food import and export enterprises have a greater impact on the cold chain market increased domestic demand [2], so in order to strengthen the management of infectious diseases in the cold chain transportation link, the study of the transmission mechanism of viral diseases in cold chain transportation is particularly important. Luo Jun et al[3] identified five major risks in the operation of food supply chain in China based on the perspective of systematic risk prevention, and elaborated on the management measures to prevent the risk of food supply chain from four aspects: food source control, supply chain reconstruction, informationization and cold chain logistics. Menglis et al[4] studied the risk of import and export cold chain logistics in terms of packaging, warehousing, barging and timeliness. Liu Guoxin[5] showed that if the source of food is not in place for the prevention and control of infectious diseases. Li Yating et al studied that the loading and unloading link in cold chain transportation is also one of the high-risk links to contaminate the transported materials. Zhao Mengmeng et al

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detected nucleotides of infectious viruses on top of the outer packaging of imported goods handled by staff during their research work on the source of the Qingdao outbreak. This is the first time in the world that an active virus has been successfully detected from a low-temperature environment, thus determining that infectious disease viruses can survive for a long time in a low-temperature environment. Although the research and application of cold chain transportation risk and infectious disease transmission mechanism have achieved certain results, the research on the transmission mechanism of infectious disease in cold chain transportation has not formed a more complete theoretical system. Therefore, this paper simulates the transmission mechanism of infectious diseases in cold chain transportation by establishing a model of infectious disease transmission in cold chain transportation and verifies it with examples.

2 Modeling of infectious disease transmission in cold chain transportation

2.1 Model building

The risk spreading model of the cold chain transportation system is based on the possibility of new crown infections after the raw materials are opened, and in the storage, cold chain transportation, and sales process after production, the outer package is directly contacted by the infected person or due to the irregularities in the disinfection of the refrigerated trucks, resulting in the contact between the outer package of the products and the refrigerated trucks, thus spreading to each sales outlet, and then spreading after contacting with the consumers.

The spread of infectious diseases in the cold chain transportation link, first of all, the goods from the beginning of the uninfected through the loading link, cold chain truck transportation link and unloading link and so on the delivery to the business due to the loading and unloading link of the goods to contact a large number of staff outside the package. And because of the infectious disease spreads extremely strong, in the middle of the personnel is easy to spread the infection, the personnel in the self-protection is not in place, it is more likely to be infected with infectious disease virus, and infectious diseases have a certain latent period, is not easy to be found. Moreover, enterprises may not monitor the situation when checking, which leads to the direct contact of these virus-carrying staff with the goods, resulting in the flow of goods that may carry infectious disease viruses, thus spreading them. In the case of cold chain trucks, it may be due to the fact that the poisonous work of the enterprises and the inspections are not put in place, which makes the cold chain trucks carry infectious disease viruses, which are infected to the goods during transportation, thus spreading the viruses. After the multi-layer transportation link finally arrives at the business point of sale, from the business start selling, carrying new crown goods sold to consumers, assuming that consumers buy the goods carrying infectious disease virus, and in the purchase and after the purchase did not take certain protective measures is infected with the probability of greatly increased, once infected, the infectious disease virus began to start the exponential diffusion of spreading in the crowd, to sum up the construction of the cold chain transport In summary, a diagram of the infection mechanism of infectious disease viruses in the cold chain transportation link is shown in Figure 1.

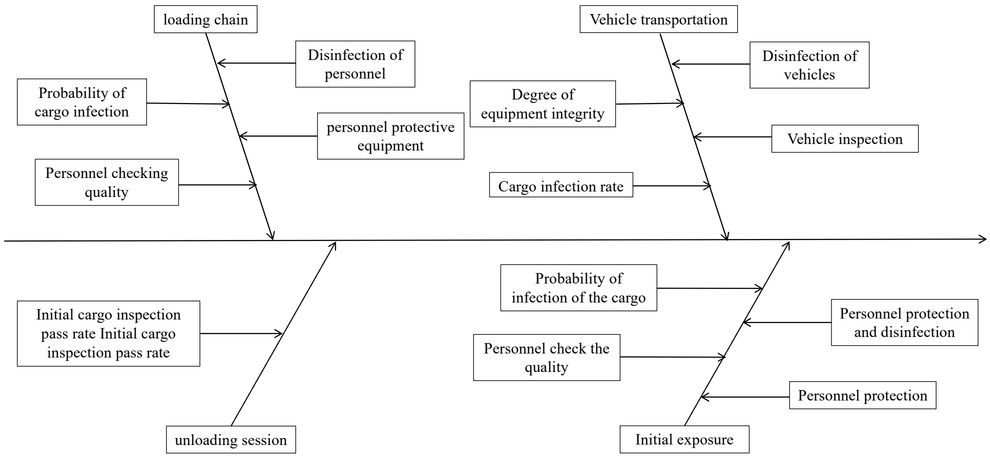

Fig. 1. Fish bone diagram of the transmission and infection mechanism of infectious disease viruses in cold chain transportation.

2.2 Initial simulation of the model

The results of a run assuming data applying the model constructed in the previous subsection are shown in Figure 2. and Figure 3.

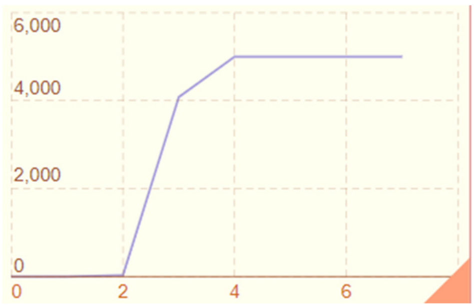

Fig. 2. Personnel infection results.

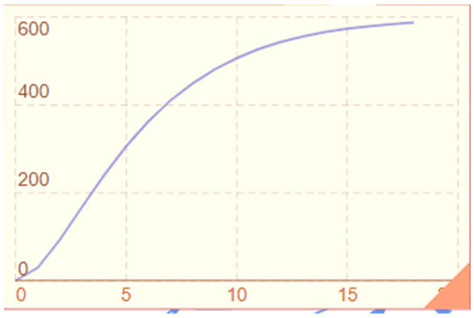

Fig. 3. Cargo infection results.

From these two charts, we can see that at different time points, when in time 2, due to the first batch of infected goods transported to the sales outlets, the infection of people began to increase violently, this is due to the infection of people infected with more factors, and the mobility of people is greater, as long as there is a person infected in the crowd, it will spread rapidly, making the infection of the crowd is constantly expanding. So once the goods reach the sales outlets and contact with the crowd began to spread after more difficult to control. While the goods in the cold chain transmission process is relatively single, we only need to control each link each operation can effectively avoid the spread of the risk of new crown pneumonia.

3 Case study

3.1 Evaluation indicator system establishment

After researching and combing the literature related to cold chain transportation risk and consulting with cold chain transportation practitioners and relevant experts, this paper selected 21 tertiary indicators from 4 secondary indicators of people, materials, management and environment to construct an evaluation index system for determining the intensity of the risk of spreading epidemics in cold chain transportation. Meanwhile, the evaluation index system of immunization capacity for the risk of infectious disease transmission in cold chain transportation is determined, including two secondary indicators of risk resistance capacity and risk recovery capacity, and nine tertiary indicators.

3.2 Case background

A Cold Chain Transportation Company is a comprehensive modern transportation company in a city which integrates cold chain storage and transportation, refrigerated warehouse, loading and unloading, container disassembling and assembling, railroad-owned container transportation as well as export trade of fruit juice. The company sits on a high standard constant temperature freezer warehouse can be loaded with about 50,000 tons of goods, of which the constant temperature warehouse can be loaded with 28,000 tons of goods, the temperature of the refrigerated warehouse between (0℃ ~ 5℃) can be loaded with 3,000 tons of goods, and the temperature of the freezer warehouse is between (-18℃ ~ -25℃) can be loaded with 25,000 tons. The company's annual storage and turnover of goods can be up to more than 1 million tons.

3.3 Determination of risk transmission parameters for cold chain transportation

3.3.1 Calculation of spreading intensity of infectious disease risk in cold chain transportation

Invite 15 management experts and leaders of A Cold Chain Logistics Co., Ltd. to compare the importance of the indicators affecting the risk of infectious diseases in cold chain transportation with our selected indicators using the 1-9 scale method, and use AHP to calculate the weight value of each indicator as follows.

$$R = (0\ 0.06\ 0.36\ 0.48\ 0.10)$$

$$S = RT = (0\ 0.06\ 0.36\ 0.48\ 0.10)(0.9\ 0.7\ 0.5\ 0.3\ 0.1)^T = 0.376$$

3.3.2 Calculation of immunization capacity against infectious disease risks in cold chain transport lines

Following the process of calculating the risk intensity of transportation above to calculate the immunity of the transportation process, the following results were obtained.

$$R_1 = (0.081\ 0.25\ 0.42\ 0.263\ 0.135)$$

$$R_2 = (0.075\ 0.243\ 0.398\ 0.273\ 0.167)$$

$$S_1 = R_1T = (0.081\ 0.25\ 0.42\ 0.263\ 0.135)(0.9\ 0.7\ 0.5\ 0.3\ 0.1)^T = 0.55$$

$$S_2 = R_2 T = (0.075\ 0.243\ 0.398\ 0.273\ 0.167)(0.9\ 0.7\ 0.5\ 0.3\ 0.1)^T = 0.535$$

3.3.3 Calculating parameter values for the risk propagation model

Firms are infected by risk because they work with firms that are already infected but cannot resist the risk. Therefore the risk infection probability β and μ can be found by the following equation(1)(2).

$$\beta = R(1 - S_1) \tag{1}$$

$$\mu = RS_2 \tag{2}$$

The values of R,S_1,S_2 are brought into the formula to obtain the values of the parameters of this risk propagation model, as shown in Table 1.

Table 1. Risk propagation model parameter values.

Parameter	β	μ
numerical value	0.169	0.201

3.4 Simulation Analysis

3.4.1 Analysis of simulation results

In accordance with the cold chain transportation network system established in the previous section, Matlab software will be used to simulate the risk infection probability β and the probability of immunity μ of the cold chain transportation network with Cold Chain Transportation Company A as the core, combined with the SIR model and the risk infection probability β and the probability of immunity μ of the cold chain transportation network calculated in the previous section. At the same time, the total number of enterprises is assumed to be 20, and the starting infected enterprise is set to be 1. The magnitude and law of the influence of each parameter on the process of spreading the risk of infectious diseases in the cold chain transportation are analyzed by the changes caused after changing the values of some parameters. At the beginning moment, the number of enterprises infected with risk is set as 1, β=0.269, μ=0.201. In by assuming that the total number of node enterprises N=20, the simulation results obtained are shown in the following figure 4.

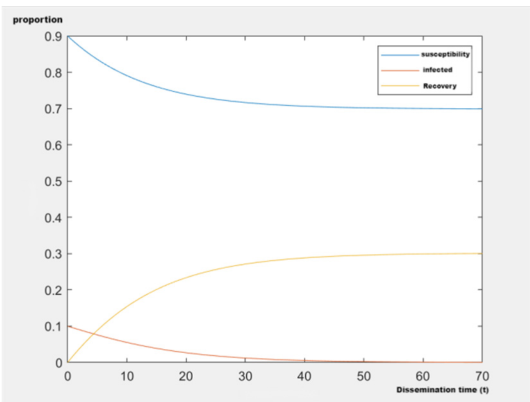

Fig. 4. A. Schematic diagram of the risk spread of the epidemic in the cold chain transportation network.

It is evident in Figure 4 that when a node in this network generates a risk to become an initially infected node, the risk of infectious disease will spread rapidly throughout the network. We can also clearly observe that the infected nodes in the network are growing until the moment of t=30 reaches to about 0.3, and then begins to turn into a steady state.

Next, respectively, make the value unchanged value increased; value increased value unchanged. Analyze the change in the number of infected node enterprises in these two cases.

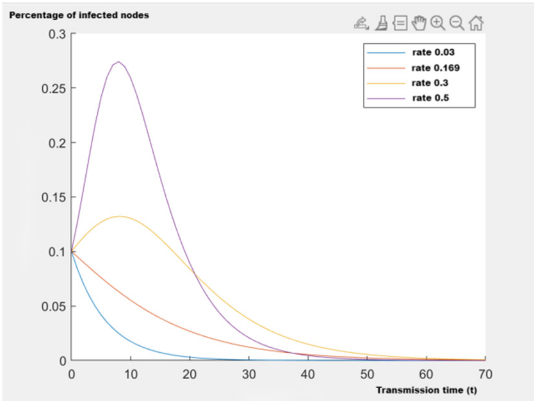

Fig. 5. Other things being equal, the simulation of the change in the infection rate.

In the figure 5. $\mu = 0.201$ and β is in the order of 0.03, 0.169, 0.3, 0.5. From the figure it can be seen that as the contagion rate increases, the number of infected nodes increases at the moment of t=10 as the risk propagates through the network. When the contagion rate is less than the recovery rate, the number of infected nodes decreases gradually. When the contagion rate is greater than the recovery rate, the number of infected nodes will first gradually increase, and then the number of infected nodes will gradually become less as the infected node enterprise gradually recovers from the cure. It can also be seen that the larger the contagion rate is, the faster the propagation rate is.

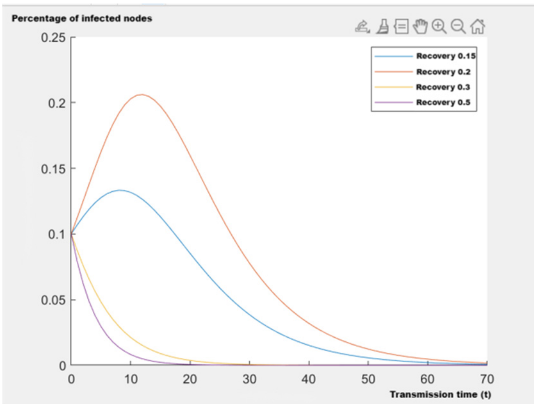

Fig. 6. Other things being equal, the simulation of the recovery rate changes.

In the figure 6. β= 0.169, μ in the order of 0.15, 0.2, 0.3, 0.5. It can be seen from the figure that as the recovery rate increases, the number of infected nodes in which the risk of infectious diseases spreads in the cold chain transportation network decreases and the risk stops spreading more quickly. As the recovery rate gradually approaches the infectious rate, the number of infected nodes increases over time because they cannot be better controlled. With the change of time, after a considerable period of time, the number of infected nodes will be controlled and gradually decrease until eliminated.

4 Conclusions

Through the previous model construction and simulation analysis, the following conclusions can be drawn:

When a company in the cold chain transportation network system has a risk and becomes a new risk source, the infectious disease virus will spread rapidly to the whole cold chain transportation network in a short time, and it will be difficult to control its spreading trend. For the company that found the infectious disease virus during self-testing, it should quickly activate the emergency plan, investigate the influencing factors of the risk points within the enterprise and in each transportation link, and take corresponding measures to make the risk in a controllable state, and quickly track and control the infected goods or people to avoid further expansion of the infection. For the existence of infection risk enterprises, should be early preparation, the establishment and improvement of emergency response to infectious diseases and risk early warning mechanism as well as continuous dynamic monitoring of cargo information, so as to reduce the probability of infection, increase the recovery rate of the purpose of enterprises in a safer state.

References

[1] Ivanov, D .: Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case . Vol. 136(2020)

[2] Galanakis, C M .: The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis.Vol.9, pp. 523. Foods, (2020).

[3] Jun, L. Wenjie,Z .: Study on risk identification and management strategies of China's food supply chain. Vol.34, pp. 205-207. Logistics Technology, (2015).

[4] Lisi, M .: Identification and control of logistics risks of Vietnamese lychees exported to China. Vol.12, pp. 49-52. Practice in Foreign Economic Relations and Trade, (2020)

[5]Guoxin, L .: Infectious viruses are frequently detected in imported cold-chain food, and how to ensure the safety of cold-chain food consumption. Vol.11, pp. 40-45. Meat Industry, (2020)