

Research on Society Risk Evolution Mechanism and Counter Measures in Severe Emergency Infectious Disease — in the Case of H7N9 Avian Influenza

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Received 11 October 2014

Accepted 28 January 2015

Abstract

In this paper, the evolution and control of society risks caused by severe emergency infectious disease will be analyzed and studied. Firstly, the evolution chain of society risks caused by severe emergency infectious disease is constructed to analyze the evolution rule of society risks and identify the essential factors in counter measures. Then, the system dynamics model is established and employed to simulate the effects of society risk control with various countermeasures. Finally, based on the simulation results, a conclusion is drawn: improving medical treatment capacity, strengthening quarantine level under epidemic situation and enhancing the effectiveness of dealing with public opinions are effective in controlling society risks. Especially when the three aspects mentioned above are promoted at the same time, the society risk control can achieve a more notable effect.

Keywords: Severe emergency infectious disease; Society risk; Evolution; Counter measure; Disaster chain; System dynamics.

1. Introduction

In recent years, severe emergency infectious diseases broke out frequently, such as SRAS in 2003, H5N1avian influenza in 2009, eye disease in 2012, H7N9 avian influenza in 2010, etc. On one hand, the occurrence of epidemic poses threats to human health and life. On the other hand, the increasingly cumulative society risk caused by epidemic gives rise to various social riots and exerts immense adverse effects on social stability and economic order. Therefore, it is of great necessity to carry out research on evolution mechanism and countermeasures of society risk given rise by severe infectious disease. By analyzing the evolution process of society risk caused by severe emergency infectious disease, the basic rule of society risk evolution is grasped and the key elements during society risk evolution is identified. On this basis, the coping strategy is developed to improve the effectiveness of social risk

control and reducing the probability of society risk outbreak.

The dynamic evolution process of disaster has its own law and mechanism. Therefore, only by grasping the evolution law and mechanism of disaster can the social risk initiated thereof be reduced to a minimum. Over the past, enormous studies have been conducted on the evolution mechanism of flood, earthquake, extreme weather, drought and other natural disasters, focusing on forming a complete disaster chain and identifying potential risks through simulating the evolution process of disasters. In addition, a suitable method is necessarily proposed in studying the evolution mechanism of risk. Li etc. [5] made a cross coupling analysis of the over two thousand disasters from 2001 to 2010 by statistical method, and summarized the occurrence rule of disasters in recent ten years in our country. Peng [6] studied the influencing mechanism of gas seepage generated in

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sudden disaster by conducting the thermal coupling experiment. Wind [7] investigated the post-flood psychological health of community residents in the towns and countryside of Northern England, and studied the evolution rule of residents' mental health. He [8] proposed a chaotic differential evolution algorithm, providing a better method to predict the evolution process of flood disaster. Tinguaro, etc. [9] proposed a data-based bipolar intellectual decision support system prototype, where society risks after natural disaster were managed through the construction and application of induced rules. On the part of identifying and evaluating disaster risk, Du[10] and Birkmann [11] conducted some researches on identifying possible risks after natural disasters. Guikema [12] put forward a risk assessment system on natural disaster and concrete method based on a large amount of statistical data, and applied it in the field of infrastructure system. From the perspective of meteorology, geography, disaster science and environmental science, Zhang etc. [14] proposed a risk identification and assessment method of droughts based on GIS (Geographical Information Systems). Zio [15] described the issues concerning the post-disaster risk identification resulted from such disaster as nuclear and gas leak, and proposed a risk assessment and management framework. Jiang [16] utilized the fuzzy mathematics theory and method, and applied the fuzzy comprehensive evaluation method, fuzzy clustering and fuzzy similarity method into the risk identification, classification and assessment of floods, providing an effective method for risk management of flood disaster. In the field of risk coping strategy, Hu and Zhu [17, 18], with meteorological disaster as the research object, described the method of preventing disaster risk. Batabyal[19], targeting at financial risks of disaster, presented the theory of financial risk management caused by natural disaster and its warning model. Liu [20] put forward a decision analysis method of risk based on prospect theories, and applied it into the emergency response risk decision analysis. Huang [21] applied three risk analysis models of natural disaster into practical decision-making problems. On the basis of the utility function theory, Tamura [22] presented the risk analysis and decision model for natural disasters. At present, research on social risks mainly focuses on natural disaster itself. Nevertheless, studies on social risks caused by infectious disease are far from sufficient. Thus, this paper, with social risks caused by

major infectious diseases as the research subject, is to construct the evolution chain of social risk to describe its process, and on this basis, to identify the key elements of risk response strategy and simulate the effectiveness of risk control with different strategies by means of the system dynamics model. The finding obtained in this paper is of certain reference value to develop and implement the prevention and control plan of severe infectious disease.

2. Society Risk Evolution Mechanism in Severe Emergency Infectious Disease

Social risk is defined as the possibility of giving rise to social conflicts and endangering social stability and order, namely, the possibility of social crisis outbreak. Once this possibility becomes a reality, social risk is transformed into social conflict, producing disastrous effects on social stability and order. During SARS and avian influenza outbreak, many events of social disruption effects due to epidemic situation broke out nationally, for example, many college students and migrant workers rushed to their hometown during SARS, which formed a so-called "homebound rush"; During avian influenza, some people deceived by rumors sparked a run on medical supplies, daily necessities, and some unscrupulous merchants seized the opportunity to bid up prices, disrupting social economic order; some lawbreakers began to publicize feudal superstitions, inciting a crowd riot. The cases cited above are all caused by the accumulation of social risks.

The social risk system (Fig. 1) mainly covers three basic elements: hazard-formative factor, hazard-inducing environment, and hazard-affected body. Take social risk caused by avian influenza as an example, the outbreak of avian influenza is the incident that touches off the generation and evolution of social risk, which is thus defined as hazard-formative factor. Hazard-formative environment falls into two types: natural environment and social environment. In terms of natural environment, epidemic spreads very rapidly because of bird migration in spring and fall, and meanwhile the warm and humid climate in spring also provides favorable conditions for the spreading of disease. In the part of social environment, most of poultry farms are short of necessary monitoring and prevention measures against new virus, and in addition, the spreading of rumors and psychological fear of human beings

accelerates the formation and accumulation of social risks. Hazard-affected body is mainly the human beings with psychological fear and vulnerability of social environment. When the number of residents with fear accumulates to a certain number, social risk will burst out, and then a variety of group social events will occur, causing negative influences on social development and stability.

The evolution chain of society risk caused by severe emergent infectious disease is shown in Fig. 2. When Bird flu outbreaks at a certain moment, social risk began to generate; as time passes by, the number of people infected and the death toll are on constant increase, and all kinds of rumors began to spread, causing the

psychological fear of residents to soar. In turn, the fear of residents also intensifies the spreading of rumors to a certain extent, making more people infected by rumors. Thus, social risks began to accumulate rapidly. The enlargement of social risk is mainly manifested in two aspects: intensifying of psychological fear of residents and the increasing number of people infected by rumors. Once social risk accumulates to a certain extent, social risk will burst out, giving rise to a series of mass events. Meanwhile, these group social events will in turn speed up the accumulation of social risks.

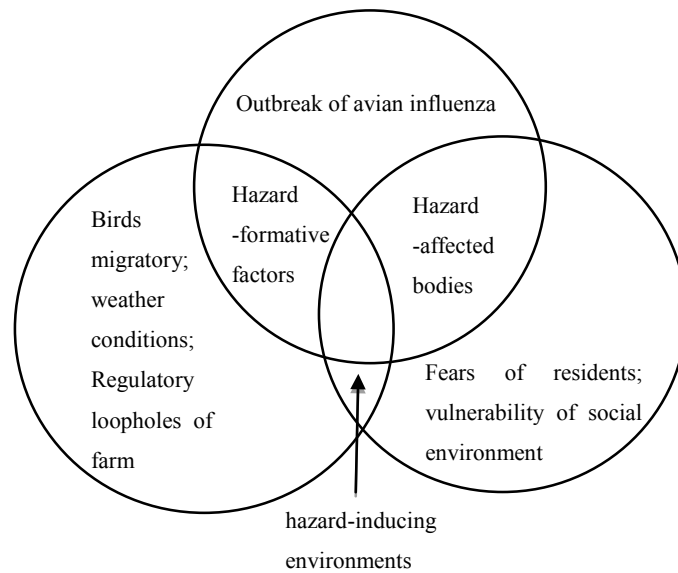


Fig. 1. Social risk system of avian influenza.

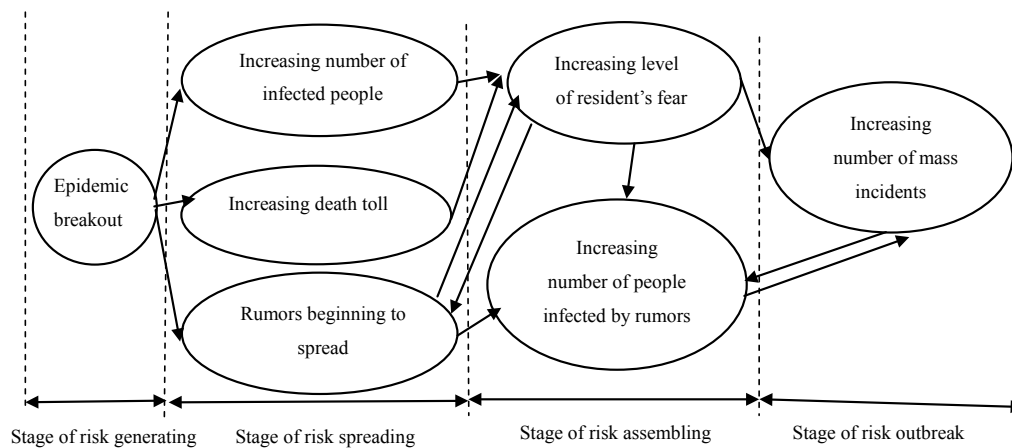


Fig.2. Evolution chain of social risk of avian in fluenza.

3. Running Head Society Risk Control Strategies of Severe Emergent Infectious Disease

3.1. Key elements of the strategy

From Fig. 1 and Fig. 2, it is known that there are primarily three influence factors in the formation and evolution of social risk: the death toll of infections, the spreading degree of epidemic and rumors. Therefore, "strengthening the medical treatment ability", "enhancing the quarantine level during epidemic situation" and "promoting the effectiveness of handling public opinion are the key elements in formulating the risk control strategy.

(1) Strengthening the medical treatment ability to reduce the mortality of patients. The purpose of strengthening the medical treatment ability is to save the life of infections and minimize the mortality rate. Once a person is found to infect with bird flu, he or she should be subject to early report, early quarantine and early treatment. Moreover, the development of vaccine and its application in clinical trials should be accelerated as soon as possible.

(2) Enhancing the quarantine level to prevent the further spreading of epidemic. Bird flu and SRAS has varied mode of infection. According to the existing studies, avian influenza can only be transmitted through "bird to bird" and "bird to human", excluding "person to person". However, in practice, once a bird-flu patient is diagnosed, quarantine treatment is conducted firstly, and meanwhile his or her contacts must be put in quarantine for a few days. When avian influenza outbreaks, the poultry farm and surrounding farms need to be disinfected and all the poultry therein should be killed, and vehicles carrying the livestock and poultry should be disinfected. Through controlling the infection source and cutting off the mode of infection, the epidemic will be prevented from spreading to the surrounding area.

(3) Handling public opinions effectively to reduce their impacts on the masses. People's fear of the epidemic is mainly because H7N9 avian influenza virus is a new one with few known information, which causes uneasiness over the mass psychology. Especially when the number of infections and the death toll continues to rise, people's fear will intensity and rumors begin to spread. Confronted with the above situation, a series of measures should be taken to clarify the rumors timely and effectively, crack down on such illegal activities as

spreading of rumors by network, publications and other means so as to reduce the effect of rumors on residents.

3.2. A system dynamics model over emergency infectious disease epidemic situation of social risk control effect

In order to display the effect of social risk control emergency strategy on emergency infectious disease in a more visual way, the system dynamics (SD) model is constructed to simulate the process of society risk control. The recovery rate, the source processing efficiency and the rumor clarification rate are optioned to represent the medical treatment capacity, the epidemic quarantine level and rumor processing effectiveness of emergency strategy, respectively. Take H7N9 outbreak in Shanghai as an example, based on the relationship between different variables, relevant parameters and formula are set as shown in Fig.3.

(1) Basic situation of the epidemic area. Shanghai city has an area of 8064.3 square kilometers and a total of 23.83 million populations. The area is distributed with dozens of poultry farms, with each producing about 200000 feather on average. By the end of July 16, 2013, a total of 30 H7N9 infected cases, including 11 death cases, has been reported in Shanghai. The mortality was 36.7%, slightly higher than the national average. According to the relevant statistics, during the outbreak, mass incidents caused by epidemic have up to dozens of times, which produced a huge influence on the normal life of residents and social stability.

(2) Medical treatment of avian influenza. H7N9 is a highly lethal avian influenza. If the patient fails to receive timely and effective treatment, their life would be threatened. Therefore, the recovery rate of avian flu is set as the index to evaluate the treatment, namely, the higher the treatment level, the better the medical effect on the avian influenza, and the lower the mortality rate. The infection probability of avian influenza through contact is 6.12% to 7.63%, so the parameter of the infection probability of avian influenza through contact is set as RANDOM UNIFORM (0.0612, 0.0763, 0.001). The infection rate refers to the number of newly infected patients per day, which is associated with the infection probability through contact and the number of people having contact with the virus. Thus, the infection rate of avian influenza is set as: the infection probability of avian influenza through contact* the number of people contacting the virus.

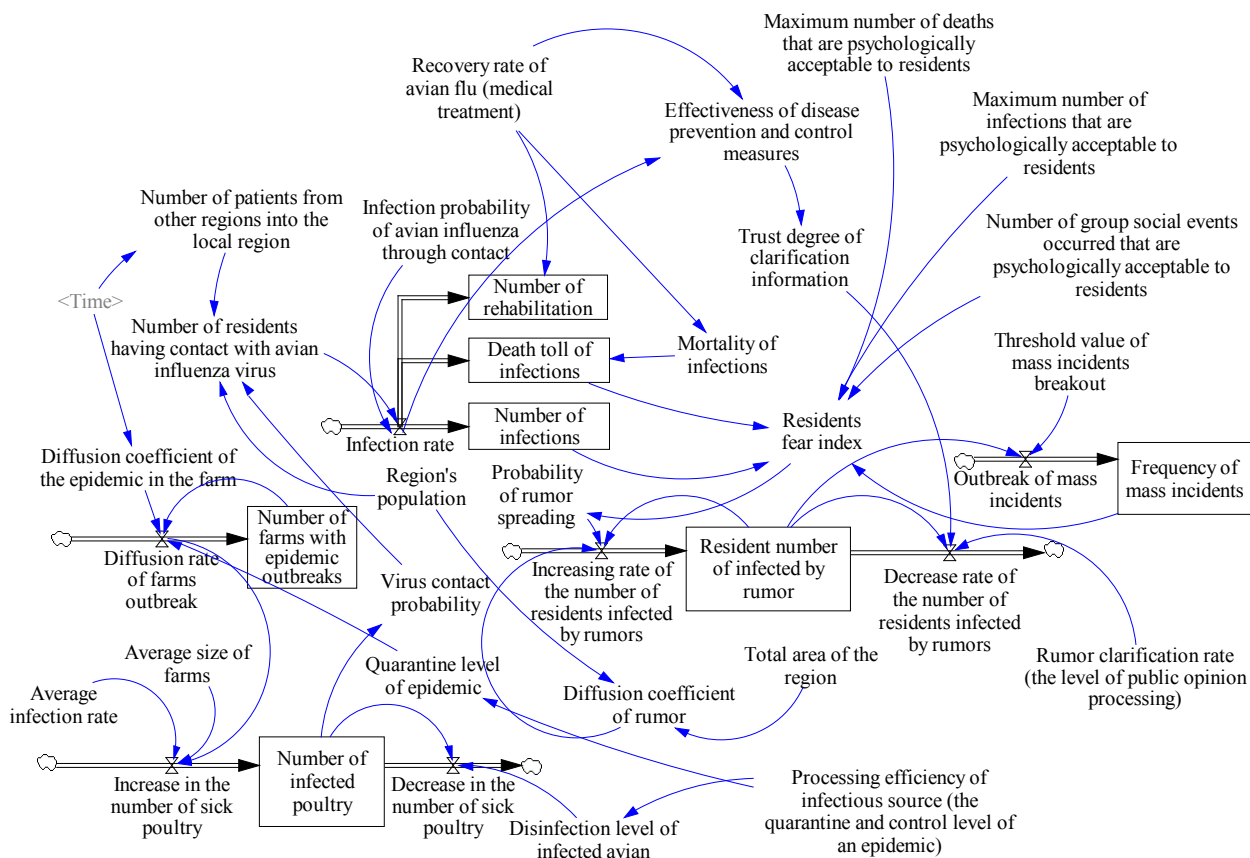


Fig. 3. System dynamics model of social risk control of disease epidemic situation.

(3) Epidemic quarantine and control. The infection mechanism of H7N9 avian influenza is different from that of SARS. It has not confirmed that H7N9 avian influenza can be transmitted by "person to person". The major infection source of H7N9 avian influenza is the bird and poultry with avian influenza virus. The epidemic quarantine and control, on one hand, is to disinfect the farm where avian influenza breaks out so as to reduce the probability of human exposure to the infection source. On the other hand, disinfection of the ground and vehicles used in the farm in epidemic area should be strengthened to cut off the transmission route of virus and reduce the diffusion rate of virus.

The infection treatment efficiency index is introduced to indicate the quarantine and control level of an epidemic. There is a positive correlation between the infection treatment efficiency and the control level of epidemic situation. According to relevant statistical data, it can be obtained: the disinfection level of

infected avian = 50000 * processing efficiency of infectious source (the quarantine and control level of an epidemic). The diffusion coefficient of epidemic occurred in a farm refers to the number of newly infected farms nearby at unit time when bird flu hits one farm, which is mainly infected by the characteristics of avian influenza virus and bird migration. Avian influenza often take place at the beginning of the spring or autumn until the rising or falling temperature is unsuitable for virus survival as time passes by. In addition, migratory birds are obviously seasonal. Thus, spring and autumn are two high-occurrence seasons of bird flu. The diffusion coefficient of epidemic taken place in a farm changes with time when the climate is warming or cooling, and the scale of bird migratory gradually decreases until the end. It can be concluded that the diffusion coefficient of an epidemic is in a negative correlation with time. According to relevant statistical data concerning the spreading of H7N9 bird flu in Shanghai, the independent variable "time" is set to

fit the diffusion coefficient of the farm with epidemic: the diffusion coefficient of the epidemic in the farm = $\text{MAX} \left((1.8254 * (1 / (1.4525 * \text{Time} + 1)) - 0.000256 * \text{Time}), 0 \right)$.

The increase rate of farms with epidemic outbreak is the number of newly infected farms at unit time, which is associated with the diffusion coefficient, the quarantine level and the number of farms infected. The increase rate of farms with epidemic outbreak = the diffusion coefficient of epidemic in the farm * (1 - the quarantine level of epidemic) * the number of farms with epidemic outbreaks. According to the occurred cases, most of patients have contact with poultry before infection, so the probability of infection is related with the number of resident who is exposed to the infection. Based on actual data, the equation is obtained: the probability of infection through contact = the number of infected poultry * $0.85 * 10^{-11}$, the number of residents having contact with avian influenza virus mainly includes local ones and those coming from other places. So the number of residents having contact with avian influenza virus = the total population in the area * probability of people having contact with virus + the number of patients from other regions into the local region.

(4) Social risk processing. Relevant parameters of social risk comprise the number of rumors, the number of residents infected by rumors and the number of group events, etc. Among them, the resident fear index refers to the fear of ordinary residents for epidemic situation, the number of infections and the number of group social events caused by epidemic. It can be expressed as the following equation: the residents fear index = $0.2 * \text{frequency of mass incidents} / \text{the number of group social events occurred that are psychologically acceptable to residents} + 0.4 * \text{the number of infected people} / \text{maximum number of infections that are psychologically acceptable to residents} + 0.4 * \text{deaths} / \text{maximum number of deaths that are psychologically acceptable to residents}$. The psychological fear index of residents is between [0, 1], the greater the index, the more fear the residents have psychologically. We use questionnaire to determine the coefficients mentioned in the equation above. In this paper, the number of maximum acceptable group social events is set 100, the number of maximum acceptable infections is set 100 and the number of maximum acceptable deaths is set 50.

The number of residents infected by rumors is connected with the spreading rate of rumors, the number of rumors and the effectiveness of rumor processing. The increase rate of residents infected by rumors = probability of rumor spreading * diffusion coefficient of rumor * (1 + 0.002 * the resident number of infected by rumor) / (1 + the resident number of infected by rumor). Decreasing the number of residents infected by rumors is mainly achieved by eliminating the rumor influence by clarifications. The effectiveness of rumor refuting is mainly concerned with the rumor clarification rate and the trust degree of residents for clarification information. The rumor clarification rate refers to the ratio between the number of rumors clarified and the number of spreading rumors, the greater the rate is, the more people will be affected. The trust degree of clarification information mainly lies in the effectiveness of epidemic prevention and control measures, namely, the more effective the epidemic prevention and control measures is, the greater the trust degree of residents have. The decrease rate of the number of residents infected by rumors = rumor clarification rate (the level of public opinion processing) * the resident number of infected by rumor * the trust degree of clarification information. The frequency of mass incidents is the main criteria to evaluate the control level of social risks, which is mainly related to the number of residents infected by rumors. According to the survey, we find the threshold value of mass incident outbreak is 30000 persons average, meanly that it will break out once the number of residents infected by rumors exceeds the threshold.

3.3. Social risk control effect under different conditions

In initial state, supposing the number of farms with epidemic outbreak is 1, the simulation step size is 1 day and the end time is 100 days, the system dynamics model is then used to simulate the change of social risks under different medical treatment level, epidemic quarantine control level and effectiveness of public opinion handling. According to the actual prevention and control situation of avian influenza in Shanghai, in the situation 0, the three exogenous variables, including the recovery rate, source processing efficiency and rumors clarification rate, are assigned as 0.66, 0.6 and 0.7 respectively, which are then used in the system dynamics model for simulation. As the simulation

results are basically consistent with actual data, this model is proven to be effective and the 3 exogenous variables are set as the initial parameters.

3.3.1. Impact of medical treatment ability on risk society control

On the premise that other conditions remains unchanged, the medical treatment level is improved,

with the recovery rate grew by 10% and 20% respectively. That is to say, in situation 1, the recovery rate = 0.73; in situation 2, the recovery rate = 0.89; in situation 0, the recovery rate is the initial parameter. The simulation results are shown in the Fig. 4 to Fig. 6 below.

As shown in Fig. 4 to Fig.6, with the improvement of medical treatment level, the recovery rate of infections was improved, the psychological fear index

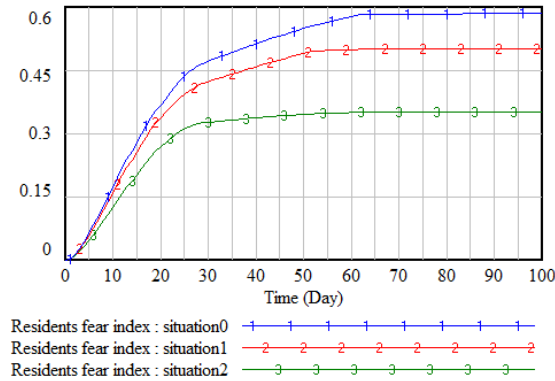


Fig.4. Impact of different medical treatment level on residents fear index

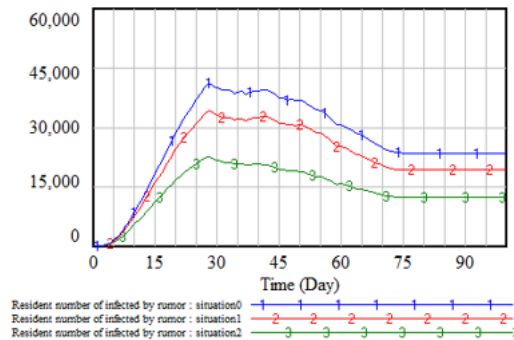


Fig.5. Impact of different medical treatment level on the number of residents infected by rumor.

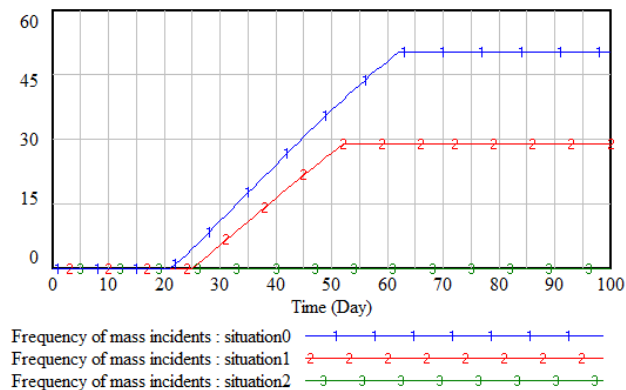


Fig.6. Impact of different medical treatment level on the frequency of mass incidents.

of residents leveled off after rising to a certain degree. Compared with the initial stage, the number of residents affected by rumors shows a downward trend, the frequency of mass incidents is fewer, indicating a more obvious effectiveness in social risk control.

3.3.2. Impact of the quarantine and control level of an epidemic on society risk control

On the premise that other conditions remains unchanged, the control level of an epidemic is improved, the processing efficiency of infection source is increased by 10% and 20% respectively. That is to

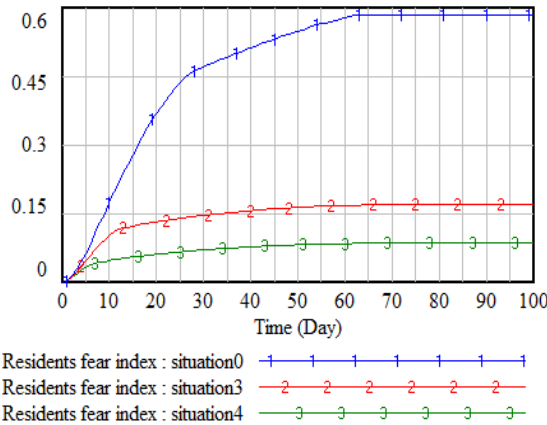


Fig.7. Impact of different quarantine and control level on residents fear index

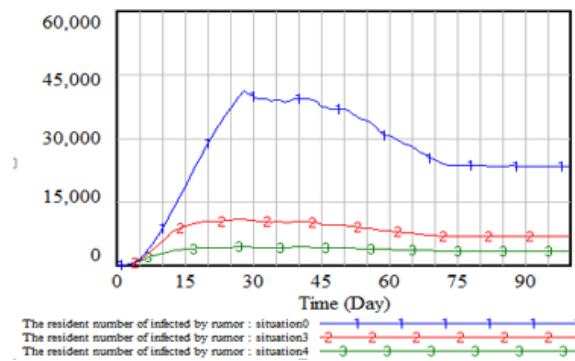


Fig.8. Impact of different quarantine and control level on the number of residents infected by rumor.

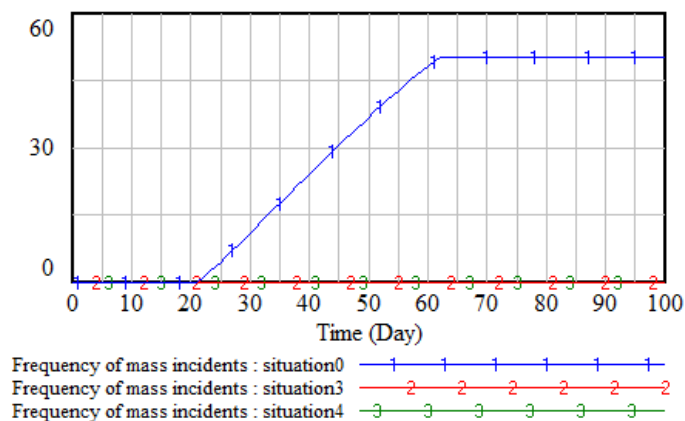


Fig.9. Impact of different quarantine and control level on the frequency of mass incidents.

say, the processing efficiency of infection source is set as 0.66 in situation 3, 0.72 in situation 4 and the initial parameters in situation 0. The simulation results are shown in Fig. 7 to 9 below.

As shown in Fig. 7 to Fig. 9, with the improvement of processing efficiency of infection source, the rise of residents fear index gradually leveled off and the number of residents infected by rumors is on the decrease, thus group social events will not occur basically.

3.3.3. Impact of the rumor processing level on risk society control

On the premise that other conditions remains unchanged, the efficiency of public opinion processing is improved, with the rumor clarification rate increased by 10% and 20% respectively. That is to say, the rumor processing efficiency is 0.77 in situation 5, 0.84 in situation 6 and is the initial parameter in situation 0. The simulation results are shown in Fig. 10 to Fig. 12.

As the rumor clarification rate rises, the inflection point of resident fear index becomes low gradually, the increase rate of the number of residents infected by

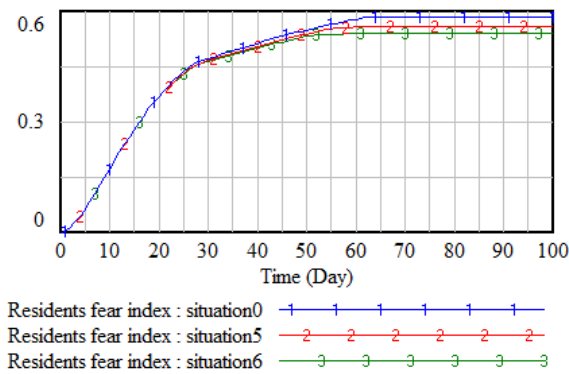


Fig.10. Impact of different rumor processing level on residents fear index.

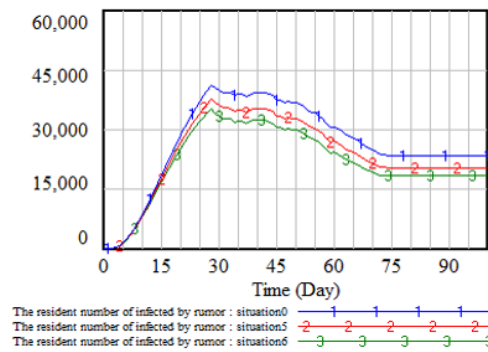


Fig.11. Impact of different rumor processing level on the number of residents infected by rumo.

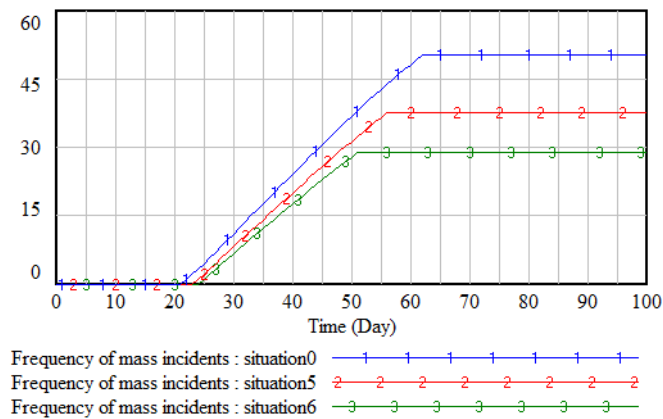


Fig.12. Impact of different rumor processing level on the frequency of mass incidents.

rumor is slowing, and the frequency of less mass incidents is decreasing. The above results indicate that social risks can be controlled, but the control effect is still not ideal.

3.3.4. Impact of coordination strategy on social risk control

Collaborative strategy is to control the social risks caused by epidemic through improving the medical treatment capacity, quarantine level and rumor clarification level at the same time. Suppose that the

above three aspects are increased by 10% and 20%, respectively. That's to say, in situation 7, the recovery rate = 0.73, the processing efficiency of infection source = 0.66, the rumor clarification rate = 0.77; in situation 8, the recovery rate = 0.8, the processing efficiency of infection source = 0.71, and the rumor clarification rate = 0.84; in situation 0, they are all the initial parameters. The simulation results are shown in Fig. 13 to Fig. 15.

As shown in Fig. 13 to 15, the higher level the ability of collaborative strategy, the lower the increase rate of resident fear and the number of residents infected

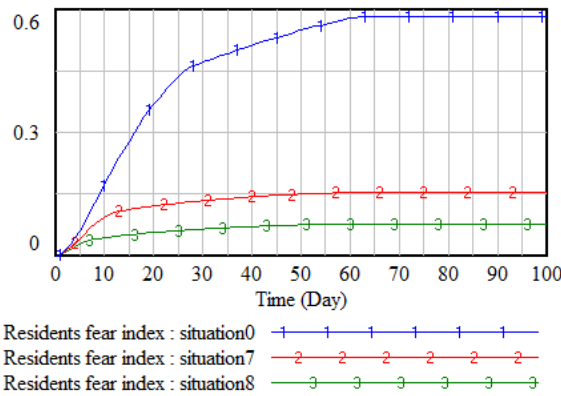


Fig.13. Impact of different collaborative strategies on residents fear index.

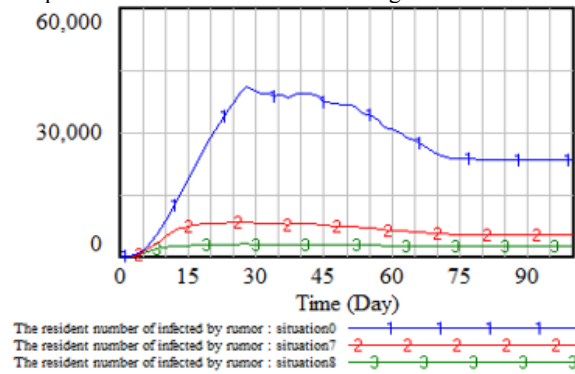


Fig.14. Impact of different collaborative strategies on the number of residents infected by rumor.

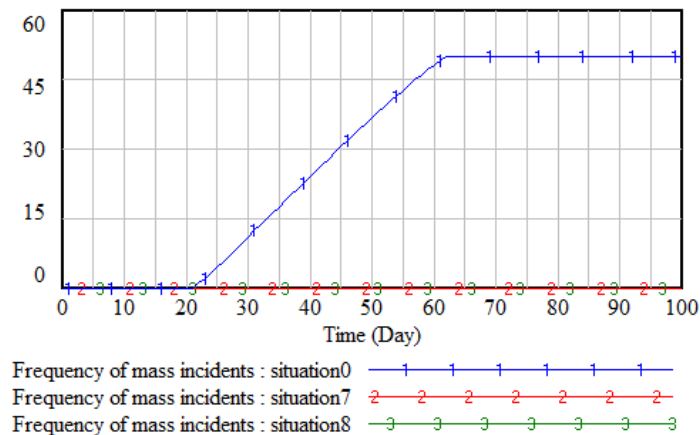


Fig.15. Impact of different collaborative strategies on the frequency of mass incidents.

by rumors and the more effective the social risks control. Compared with the coping strategy aiming at improving a single aspect, the collaborative strategy can realize effective control over all indexes related with social risks, thus obtaining more obvious control effects. Therefore, in the actual operation, collaborative strategy should be given priority to cope with social risks caused by severe emergent epidemics.

4. Conclusion

This paper is mainly aimed at studying the key components, generation and evolution process of social risks caused by severe emergent epidemic, and simulating the effect of social risk control with different strategies by means of the system dynamics model. The simulation results indicated that it is effective to control social risks through improving the medical treatment ability, strengthening the quarantine control level and enhancing the effectiveness of public opinion handling, especially when the above-mentioned three aspects are strengthened at the same time.

Acknowledgements

This Paper was supported by the Key Program of National Social Science Foundation of China (No. 12AZD109) and the National Natural Science Foundation of China (No. 71171202).

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