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Research on Information Dissemination of Natural Disasters Based on System Dynamics

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In the information society, the spread of online public opinions on natural disasters has gradually become a new problem concerned by people. We analyzed the influencing factors of information dissemination, the characteristics of natural disaster information dissemination and the index elements of natural disaster grade evaluation. Then, a series of indicators and factors were selected, and combined with the characteristics of natural disasters, the influencing factors of natural disaster information dissemination were summarized and analyzed. After that, the system dynamics model of natural disaster information transmission was established. The basic data were determined by means of questionnaire survey and expert scoring, and the information transmission process of natural disasters was studied from the perspective of dynamic simulation. We believe that the information dissemination of natural disasters has an obvious life cycle, the duration of which is generally 15-20 days, and different levels of disasters have little impact on the information dissemination cycle.

Keywords: system dynamics, natural disasters, information dissemination, influence factor introduction, simulation analysis

1. INTRODUCTION

In recent years, global climate change has intensified and natural disasters have occurred frequently. With the continuous development of Internet technology, people's ability to acquire and transmit information is continuously enhanced. This is easy to form public opinion, and it will have a certain impact on the process of the incident. When natural disasters occur, how to guide relevant information, prevent and reduce the losses caused by the spread of these emergency information, and relieve the pressure of public opinion caused by the spread of information. These measures are of great significance to ensure the smooth progress of emergency rescue and management of natural disasters and to maintain the harmonious and stable development of society [1].

Scholars have made multi-level research and analysis on the network public opinion of natural disasters from different angles and with different methods. It mainly focuses on the study of communication theory, the study of emergency information dissemination, and the application of system dynamics in information dissemination. In the research of communication theory, DeFleur proposed different communication media, which have influence on the quality of information communication [2]; Cai and others put forward the characteristics of information communication with rapidity, diversity and complexity in the new era [3, 4]; Hu proposed a socialized information dissemination model [5]; Ma

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proposed that the diversity of individual characteristics would slow down the spread of rumors in the network [6]. On the research of emergency information dissemination, he found that the government has a strong guiding role in the direction of emergency information dissemination [7]; Zhao and others concluded that the government should choose the appropriate media to publish the truth according to the seriousness of the incident and the spread speed of rumors [8]; Tian and others found that the websites of the government and mainstream media are in the leading position in the network information dissemination [9]; Liu concluded that netizen behavior has the characteristics of observation, imitation and learning [10]. On the application of system dynamics in information dissemination, Zhang introduced the idea of system dynamics in the process of studying the government's ability to deal with network public opinion [11]; Liu and Zhang built a dynamic model of information dissemination about emergencies, and conducted simulation analysis [12, 13]; Xiang made a systematic analysis of the development process of Internet public opinion from four aspects of events, media, government and netizens by using system dynamics [14].

We use the mechanism of infectious disease model to analyze the process of natural disaster information transmission dynamically, and then uses the method of system dynamics to simulate the process of natural disaster information transmission dynamically. The research contents of this paper mainly include the influencing factors of natural disaster information transmission, the dynamic model of natural disaster information transmission system, and the analysis of natural disaster information transmission system.

2. METHODS

2.1 Analysis of Factors Affecting Information Dissemination of Natural Disasters

Through the analysis of the main influencing factors of information dissemination, the characteristics of natural disaster information dissemination and the evaluation index of natural disaster grade. We believe that the factors that affect information dissemination can be classified into four categories: the nature of information source events, the content of information, the channels of information dissemination, and the subjective factors of information audiences. Secondly, the characteristics of natural disaster information dissemination are analyzed. Natural disaster information and other emergency information have distinct particularity: the subject of natural disaster information dissemination is complicated, the channels of natural disaster information dissemination are diversified, and the content of natural disaster information dissemination is diversified and changeable. Finally, the evaluation index of natural disaster grade is analyzed. Different grades of natural disasters cause different losses to human society, which will inevitably lead to different attention to natural disaster events and different probability of related information dissemination. Feng and others pointed out in the comprehensive evaluation study of 9 indicators affecting the disaster grade that the cumulative contribution rate of casualties and economic losses in the disaster grade evaluation reached about 90% [15]. Based on this, in the subsequent research, the two indicators of casualties and economic losses are taken as the main factors affecting the natural disaster grade, and then the natural disaster grade is defined and judged.

2.2 Construction of Dynamic Model of Natural Disaster Information Dissemination System

(1) Assumptions

The following assumptions were put forward before the model was established: First, in the process of natural disaster information dissemination, it is assumed that the government's attention to natural disaster events and the attention of the public to natural disaster events have a positive correlation with the level of natural disasters. Second, after the occurrence of natural disasters, there is no coupling phenomenon between natural disaster-related information and other emergencies in the process of dissemination. Third, there are people in the judgment period in the process of information dissemination. Fourth, the number of people in the system will not change in the short term. That is, in the process of studying the information dissemination of natural disasters, we do not consider the changes in the number of people in the system due to factors such as birth rate, mortality, immigration and emigration. Then, the crowd in the natural disaster information system can be divided into three categories: information unknowns, information judges and stop disseminators.

(2) Establishment of system dynamics model

In order to establish a system dynamics model, the causal relationship of natural disaster information dissemination should first be analyzed. Then research the influencing factors of information dissemination, the classification standard of natural disaster grade index and the influencing factors of natural disaster information dissemination. On the basis of comprehensive consideration of the mutual influence between various elements in the system. The Vensim PLE software is used to give an intuitive description of the process of natural disaster information dissemination and diffusion, the measures taken by the government in the process of information dissemination, and the causality of other stages. The results are shown in Fig. 1.

Among them, the grade of natural disasters is determined by the economic losses caused by natural disasters and the casualties caused by natural disasters. However, Zhao and Ma put forward the concept of disaster loss rate of natural disasters in their research on the classification of natural disasters, and gave the calculation formula of disaster loss rate as follows: disaster loss rate of natural disasters = direct economic losses of natural disasters/total income of disaster areas the year before last [16]. Disaster loss rate simply defines the level of natural disasters from the economic aspect, which is obviously unreasonable. Therefore, we put forward the concept of cumulative disaster rate and studies the classification of natural disasters through the combined effect of cumulative disaster rate and disaster loss rate. Cumulative disaster rate = cumulative number of victims/numbers of permanent residents in the disaster area. The economic losses and casualties caused by natural disasters to human society are respectively expressed by disaster loss rate and cumulative disaster rate, and then the grade of natural disasters is defined.

From Fig. 1, we can see that there is a positive feedback loop and two negative feedback loops in the natural disaster information dissemination system. The number of information disseminators in the process of natural disaster information dissemination shows a dynamic relationship under the interaction of these three positive and negative feedback loops and other external related influencing factors.

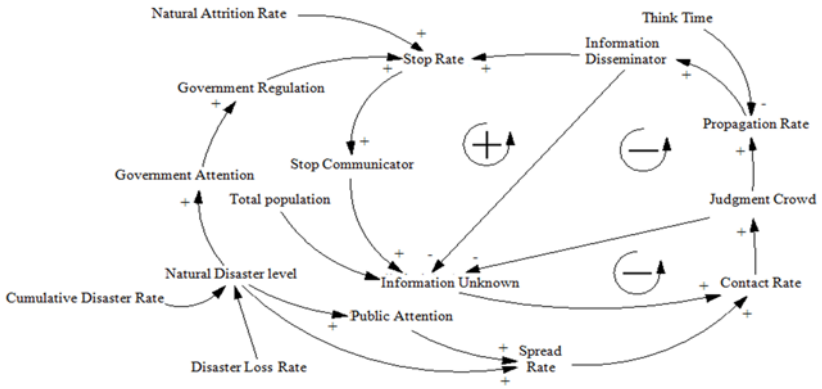

Fig. 1. Causality diagram of natural disaster information dissemination.

(3) Flow chart construction of natural disaster information dissemination

Fig. 1 cannot express the quantitative change relationship of each element in the system, nor can it analyze the impact of the change of one element of the system on the natural disaster information dissemination system. However, the system dynamics inventory flow diagram distinguishes the variables with different properties on the basis of the causality diagram, and quantitatively describes the relevant variables in combination with relevant data and equations. On the basis of the previous research, this paper constructs a flow chart as shown in Fig. 2 below to carry out a dynamic simulation of the change trend of each main variable in the system.

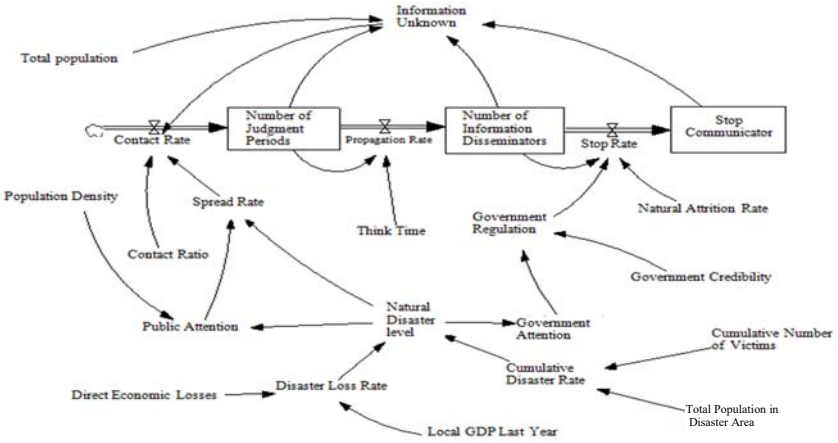

Fig. 2. Flow chart of natural disaster information dissemination.

Among them, the contact rate refers to the number of netizens who contact information related to natural disasters in a unit time. Propagation rate refers to the number of netizens who pass the information judgment period and then transmit relevant information within a unit time. Stop rate refers to the number of people who stop transmitting information related to natural disasters due to natural loss or the influence of government policies per unit time.

(4) Variable equation and initial value setting

From the previous analysis, it can be found that the system dynamics model of natural disaster information transmission mainly includes 24 variables. Among them, the horizontal variables mainly include number of populations in judgment period, the number of information disseminators and the number of stopped disseminators. Rate variables mainly include contact rate, propagation rate and stop rate. Auxiliary variables mainly include 8 variables such as natural disaster level, spread rate, public attention, government attention and disaster loss rate. Constants mainly include 10 variables such as total population, population density, direct economic losses, cumulative number of victims and government credibility.

In this study, the total population base in the system is set to 300 million. The initial number of people, information disseminators and stopped disseminators in the initial judgment period of natural disaster information dissemination is 0, which gradually changes with the process of natural disaster information dissemination. According to the general process of natural disaster emergency management and the characteristics of natural disaster information dissemination, the time of the model is set to 30 days and the step length is 1 day. In order to make the model more intuitive and clearer, the initial values in the article will be rounded on the basis of relevant data. The contact rate of natural disaster information will be affected by many factors. And considering the rapid development of the network, the rapid spread of the network and the increasing popularity of the network. Therefore, the initial contact rate of system natural disaster related information is set to 0.8. However, the impact of natural disasters in society is generally relatively large, so people pay relatively high attention to relevant information, and the natural wastage rate of information disseminators is relatively low without other influences. Therefore, the initial value of natural wastage rate is set to 0.01 here. Based on the relevant data of the Ya'an earthquake in Sichuan. The direct economic losses of natural disasters are set at 10 billion, the GDP in the year before the local disaster is 39.8 billion, the total number of people in the disaster area and the cumulative number of victims in the disaster area are 1.5 million and 380,000.

Under a certain social ideology and education level, we believe that people's judgment time for information related to natural disasters and their public trust to the government have certain stability. Therefore, in the process of setting the initial value of the government's credibility and the public's judgment time for natural disaster information, we use the method of questionnaire survey to obtain the relevant basic data. Furthermore, the relevant arithmetic operation is taken as the initial data value of the article. In the process of research, 400 questionnaires were sent out and 350 were recovered, with a questionnaire recovery rate of 87.5%. After statistics and removal of questionnaires containing missing values, the number of valid questionnaires was 300. Then SPSS software was used to carry out relevant descriptive statistical analysis.

On the issue of trust in access to information related to natural disasters. We found that in terms of trust in information related to natural disasters, people mainly choose official and online information, and about half of them believe in official information. Therefore, in the research process of natural disaster information dissemination, the initial value of government public trust in the system is set to 0.5.

As shown in Table 1, in the investigation of the judgment time of natural disaster information, we found that most people would first make a subjective judgment on the

received information before transmitting the related information, and the most people choose to transmit the related information within 18-24 hours. Therefore, the judgment time of most people on the related information of natural disasters is about 1 day. Then, in this study, the initial value of natural disaster information judgment time is set to 1 day.

Table 1. Judgment time of natural disaster information.

		Frequency	Percentage	Effective percentage	Cumulative percentage
Effective	Within 0-6 hours	44	14.7	14.7	14.7
	Within 6-12 hours	50	16.7	16.7	31.3
	Within 12-18 hours	56	18.7	18.7	50.0
	Within 18-24 hours	120	40.0	40.0	90.0
	After 24 hours	30	10.0	10.0	100.0
	Total	300	100.0	100.0	

In addition, the equation setting and construction ideas for other horizontal variables and auxiliary variables are as follows:

Number of Populations in Judgment Period = INTEG (Contact Rate-Propagation Rate, 0)
Number of Information Disseminators = INTEG (Propagation Rate-Stop Rate, 0)
Number of Stop Disseminators = INTEG (Stop Rate, 0)
Number of Unknown Information = Total Population-Number of Information Disseminators-Stop Disseminators-Number of Judgment Periods

Construction idea: since the total population in the system is constant, the number of information unknowns will show a dynamic change with the changes of judges, disseminators and stoppers in the process of natural disaster information dissemination.
Natural disaster loss rate = Direct Economic Losses/Local GDP Last Year
Cumulative disaster rate = cumulative number of victims/total population in disaster area
Natural disaster level = (Cumulative Disaster Rate + Disaster Loss Rate) ∗ 10

Construction idea: The degree of natural disasters is the result of cumulative disaster rate and disaster loss rate in disaster areas. In order to enhance the sensitivity of the system, this paper takes the real number within 1-10 as the grade of natural disasters.
Natural disaster information dissemination rate = 0.5 ∗ Public Attention + 0.05 ∗ Natural Disaster Level

Construction idea: the rate of natural disaster information transmission is determined by the public's attention and the level of natural disasters, and both are positively correlated with the rate of transmission. Among them, the mass attention and the weight of the impact of disaster level on the transmission rate are obtained through expert scoring.

Government Regulation Strength = 0.5 ∗ Government Credibility +0.5 ∗ Government Attention
Public Attention = 0.06 ∗ Natural Disaster Level + 0.4 ∗ Population Density
Construction idea: the weight is also obtained by experts' scoring method.
Government Attention = Natural Disaster Level / 10
Contact Rate = Information Unknown ∗ Contact Rate ∗ Propagation Rate
Propagation Rate = Number of Judgment Periods / Think Time

Stop Rate = Number of Information Disseminators ∗ (Natural Attrition Rate + Government Regulation)

3. ANALYSIS

3.1 Effectiveness Analysis of Natural Disaster Information Dissemination Model

The change of the number of information disseminators has a great impact on the process of natural disaster information dissemination. Therefore, we first analyzed the variation trend of the number of information disseminators through systematic simulation, and the variation trend is shown in Fig. 3.

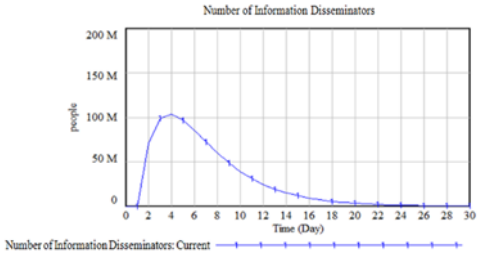

Fig. 3. Change trend of number of information disseminators.

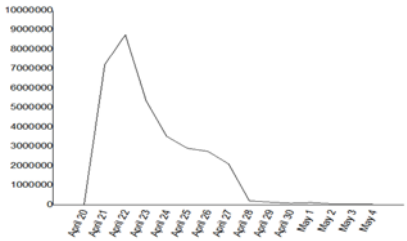

Fig. 4. Variation of the number of microblogs in Ya'an earthquake with time.

Meanwhile, according to the 2013 Ya'an earthquake public opinion report. In the process of people's dissemination of Ya'an earthquake-related information, 59% of the information came from microblogs, 34% from news, and the remaining 7% from other information interaction platforms. The dissemination trend of relevant information in microblog can represent the dissemination trend of relevant information about natural disasters in the whole society to a certain extent. We collected the number of microblogs about Ya'an earthquake published between April 20, 2013 and May 4, 2013, in order to make a simple analysis on the trend of the spread of Ya'an earthquake information, as shown in Fig. 4.

By comparing and analyzing the change trend of the number of natural disaster information disseminators in Fig. 3 and the spread trend of Ya'an earthquake microblog information in Fig. 4. We find that although the description objects are different, the simulation results are basically in line with the spread trend of real microblog information. In other words, the system dynamics model established in this paper is effective and feasible in studying natural disaster information dissemination.

3.2 Overall Analysis of Natural Disaster Information Dissemination System

The VENSIM software is used to simulate and analyze the whole natural disaster information transmission system. The change trend of the number of three categories of people in the natural disaster information dissemination system is shown in Fig. 5.

As can be seen from Fig. 5, there are obviously three key nodes in the process of natural disaster information dissemination. Therefore, the process of natural disaster information dissemination is divided into four stages.

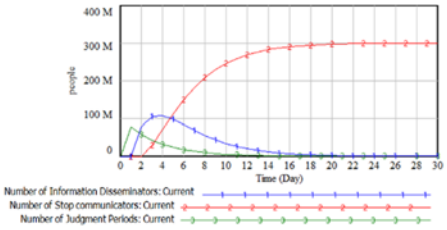

Fig. 5. Information dissemination process of natural disasters.

On the first day of natural disaster information, the number of information disseminators at this stage is very small. So, this stage can be said to be the accumulation stage of natural disaster information dissemination.

On the second day of natural disasters, the number of people in the judgment period began to decline, and the number of information disseminators began to rise gradually. And after the second day of natural disasters, the number of information disseminators will exceed the number of people in the information judgment period. We call this stage the growth period of information dissemination of natural disasters.

From the third day of natural disaster information dissemination, the number of information disseminators gradually exceeded the number of people in the judgment period. Until the fifth day of natural disasters, the number advantage of information disseminators began to be gradually occupied by stopped disseminators. Therefore, the 3rd-5th day of natural disaster information dissemination is called the outbreak period of natural disaster information dissemination.

According to Fig. 5, after the fifth day of natural disasters, the number of stopped disseminators in the natural disaster information dissemination system began to gradually occupy the dominant advantage. The number of information disseminators began to gradually decrease. Therefore, the fifth day of natural disasters and beyond is called the recession phase of the dissemination of natural disaster information.

3.3 Impact of Government Public Credibility on Information Dissemination of Natural Disasters

Government credibility is an important factor that determines the degree of government regulation and control of natural disaster information dissemination [17]. We used the control variable method to control the size of other research factors unchanged. By adjusting and controlling the level of government credibility, the influence of government credibility on various level variables in the system was observed. Through the questionnaire survey, the initial value of the government credibility is set as 0.5. In the simulation process of this system, the government credibility is set as 0.8 when it increases, and 0.2 and 0.4 when it decreases.

From Fig. 6 below, we can see that the level of the government credibility has little influence on the number of people in the judgment period. However, it has obvious influence on the number of information disseminators and the number of people who stop disseminating information. Although the influence of government credibility on the overall trend of the change in the number of stopped disseminators is not great, it has a great influence on the change rate of the number of stopped disseminators. The higher the government credibility is at the same time, the more the number of stopped disseminators in

the system will be. Eventually, when the natural disaster information is transmitted for about 20 days, it will be basically the same as the total population in the system. In a word, the public trust of the government plays a very helpful role in regulating and controlling the dissemination of natural disaster information in the society.

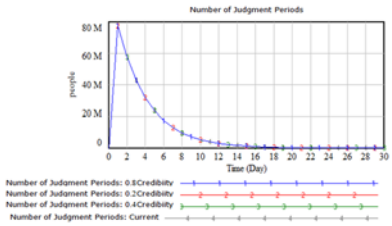

Fig. 6. (a) Effect of public reliability on judgment period.

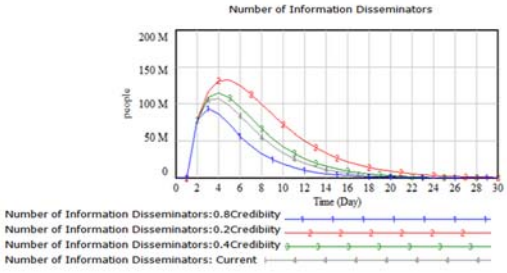

Fig. 6. (b) Effect of public reliability on disseminators.

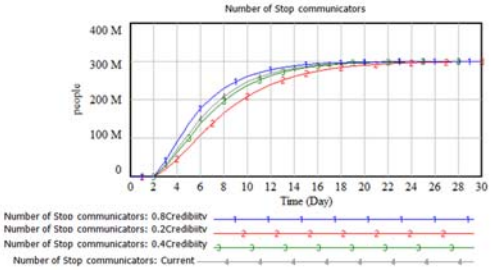

Fig. 6. (c) Influence of public credibility on disseminators.

3.4 Impact of Natural Disaster Grade on Information Dissemination of Natural Disasters

In order to more intuitively show the impact of natural disaster level on the process of natural disaster information dissemination. On the basis of previous research, the natural disaster flow chart in Fig. 2 is simplified. Because the natural disaster level is determined by the disaster loss rate and cumulative disaster rate, and there is a direct functional relationship. Then after a simplified model, given an initial value of the natural disaster level, the overall quantitative change trend of the three groups of people in the system will not be affected in the process of natural disaster information dissemination. Therefore, the initial value of the natural disaster grade is given as 6 on the basis of the research on the classification of natural disaster grade. In the process of system simulation, the increase value of natural disasters is set as 8. The decrease value of natural disasters is set as 2 and 4. Then, the system changes under different scenarios are simulated and analyzed respectively. After simulation, the change trend of the number of people in the system is shown in Fig. 7.

The analysis found that the higher the level of natural disasters, the faster the change trend of the number of related groups in the system in the transmission process. The natural disaster level does not have much influence on the transmission cycle of relevant information, and even the higher the disaster level, the shorter the relative time for transmission

of relevant information. In general, the time people pay attention to natural disaster information usually lasts for 15-20 days.

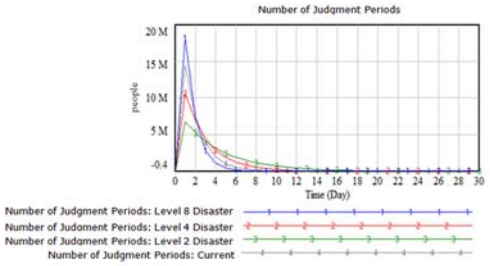

Fig. 7. (a) Effect of grade on judges.

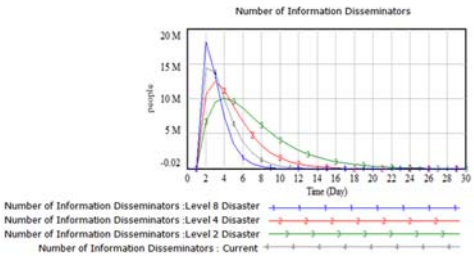

Fig. 7. (b) Effect on disseminators.

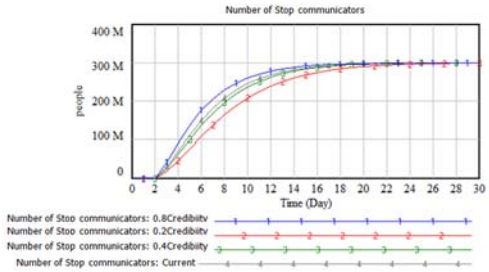

Fig. 7. (c) Effect of rank on stopping disseminators.

4. RESULT

We took the natural disaster information dissemination process as the research object. The method of system dynamics was used to construct a dynamic model for simulation and analysis, and the dynamic process of natural disaster information dissemination was analyzed. Then, the influence of relevant system elements on the process of natural disaster information dissemination was studied. Through research and analysis, the article mainly draws the following conclusions:

First, the process of natural disaster information dissemination has obvious life cycle. Among them, the first day of natural disasters is the budding period. The second day of information dissemination is the growth stage of information dissemination. The 3rd-5th day of natural disaster information dissemination is the stage of natural disaster information outbreak. The 5th-20th day after the occurrence of natural disasters is the declining stage of natural disaster information dissemination.

Second, the level of natural disasters will not affect the duration of natural disaster information dissemination. Different levels will only affect the change rate of natural disaster information disseminators and the peak value of the number of information disseminators.

Third, the government's public credibility plays a positive role in guiding information disseminators to stop the dissemination of information related to natural disasters. The higher the public credibility, the greater the rate of information dissemination will stop.

5. CONCLUSION

Based on the above research, we put forward the following policy recommendations. First, in the budding and growing stage of natural disaster information dissemination, actively respond to and accurately release information related to natural disasters. Second, during the outbreak stage of natural disaster information dissemination, government units and public figures are combined to actively guide the dissemination direction of natural disaster information. Third, in the declining stage of natural disaster information dissemination, statistics and release of losses caused by natural disasters shall be made in a timely manner, and progress in post-disaster recovery and reconstruction shall be reported in real time. Fourth, strengthen the supervision of the masses over the government's public power and strive to enhance the government's social image.

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