Control Mode of Public Emergency Response

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Abstract. Emergency is very difficult to be predicted since the social system has complex and comprehensive characters, so while a public emergency happens, a reasonable, efficient and timely response and control mode to be quickly selected is important to decrease the loss and to reduce the control cost. If the public emergency response agency doesn't rapidly forecast or estimate the potential loss, an ineffective control mode would be adopted, and the emergency diffusion situation couldn't be controlled, which would lead to the social instability. According to the different efficiency of response measure, the different control mode of public emergency response are classified into four types which are defined as lead-control mode, sync-control mode, delay-control mode and Invalid-control mode, respectively. The results show that the different cost is needed to control the emergency diffusion with different control mode, and the lead-control mode is the most efficient control model.

Keywords: Public emergency, Public emergency response, Control mode.

1 Introduction

While a public emergency happens, people's normal human life will be disrupted, and the lives and property would be threatened, Even that a host of social problems stimulated by the ripple effect of the event would lead to the social disharmony and the regional (or national) social chaos [1-3]. In the 21st century, the frequency of different event is increasing, and the impact scope and intensity is becoming more and more severity [4-6]. For timely responding to different event, and properly dealing with them, the national response plans of public emergency are established in few countries [7, 8]. Example, The National Response Plan (NRP) of United States being launched by Homeland Security of US in 2004, is an all-discipline, all-hazards plan that establishes a single, comprehensive framework for the management of domestic incidents. It provides the structure and mechanisms for the coordination of Federal support to State, local, and tribal incident managers and for exercising direct Federal authorities and responsibilities [9]; The Master State Plan for Rapid Response to

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Public Emergencies of China is launched by the State Council of the People's Republic of China in 2006, which principles are to improve China's capacity for safeguarding national security, social stability, and the public lives and property, timely responding the public all-emergencies, reducing the probability of the emergencies and their loss, and make economic and social development more people-oriented, comprehensive, balanced, and sustainable. Furthermore, many approaches about how to forecast and dealt with different emergencies are gradually developed [10]. However, the development of social system is an extremely complicated nonlinear dynamic process. The drive force and characteristic of any social emergency is different, especially in different time and space, so there can be no two social emergencies with the same causes, scale, character, and diffusion process, if it is possible, there are only similarity. For better response to a new social emergency, not only it is need to quickly find the appropriate plan from the emergency response plan, but also it is necessary to rapid adopt the appropriate control mode on the basis of the diffusion intensity and trend of the emergency under the emergency response plan guidance.

Those experiences are from dealing with many major emergencies, e.g. SARS (2003) and Wenchuan earthquake (2008) in China, let us know how to exactly and quickly get these emergency information, especially the precision location, characteristic, strength, and scope, are important to carry appropriate scheme into control the diffusion speed, reduce the death number and loss, and recover the damage. Only after these information are rapidly hold by the government response office, the timely and appropriate control measures could be established and adopt. If not, which would made the rescue measure become invalidation and lead to the damage scope enlarged, death number increased, the control cost increased, so much as lead to the regional or national society instability. Further more, despite all that a control measures may be carried into execution very quickly, there is still a certain amount of time lag for the real situation of emergency. In that case, it is the key issue of emergency response what control mode and how much strength are just right for effectively and quickly dealing with the emergency to minimize the loss. Based on the above mentions, the different control mode of public emergency response are developed in this paper, according to the different efficiency of response measure, which are defined as lead-control mode, sync control mode, delayed control mode and collapse control mode. In next contents, the four control modes of public emergency response will be discussed in detail, respectively.

2 Lead-Control Mode

Lead-control mode referred in this paper is that while the emergency happens, on the basis of the location, characteristic, strength and scope of emergency, the emergency response agency rapidly forecasts the possible diffusion speed and loss extent of the emergency and implement an optimal response mode which will greatly control the farther deterioration of emergency and minimize the loss in time. So, the lead-control mode is one of the most efficient public emergency response modes, that is to say,

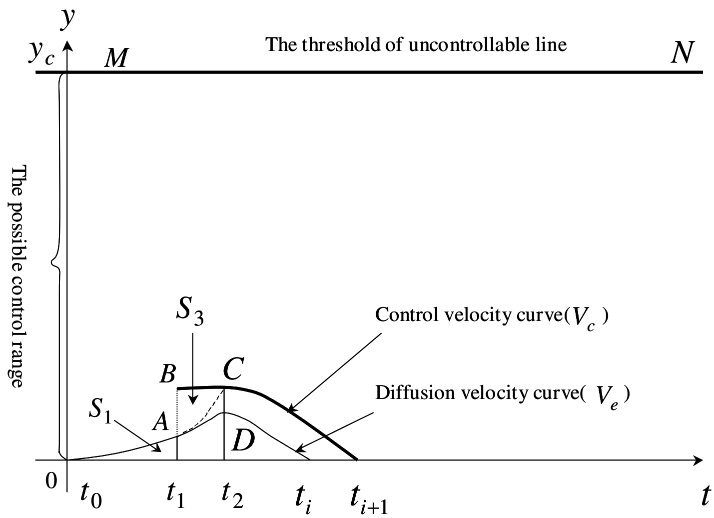

Fig. 1. The control process with lead-control mode

which is an intelligent control model. The control process with lead-control mode can be expressed as fig.1.

In fig. 1, y -axis is the speed includes response control speed and emergency diffusion speed; t -axis is the time of the emergency diffusion and controlled; MN is assumed to be the threshold of uncontrollable line; the across point y_c with y -axis and MN is the max velocity of emergency diffusion which could be controlled; V_c is the control velocity curve; the surrounding area with t -axis and V_c is the control capacity which expresses the control cost; V_e is the diffusion velocity curve; the surrounding area with y -axis and V_e is the diffusion extent which expresses the loss; t_0 is the time of the emergency occurred; t_1 is the time of control measure carried out by public emergency response agency. The control process for emergency with the lead-control mode can be divided into the following stages.

2.1 Knowledge and Forecast Stage

The public emergency response agency rapidly know the emergency information of where, what, why and how, and forecast its possible diffusion trend and diffusion velocity from t_0 to t_2 . During the stage ($t_0 \sim t_1$) of knowledge and forecast, the diffusion acceleration (a_e) of emergency has showed an upward trend, the diffusion velocity has increased from 0 to $V_{e_{t1}}$, and the diffusion extent has increased from 0 to

S_1 ($S_1 = S_{\text{diffusion}_{t_1}}$). The emergency has been diffusing and worsening from t_0 to t_1 because this is a knowledge and forecast stage and not an implement control stage.

2.2 Full Control Stage

The emergency diffusion velocity and diffusion extent would increase to $V_{e_{t_2}}$ and $S_{\text{diffusion}_{t_2}}$ from t_1 to t_2 , respectively, on the basis of forecast result with the emergency information of where, what, why and how. In order to full controlling the emergency diffusion state in the shortest possible time, the control initial velocity $V_{c_{t_1}}$ ($(V_{c_{t_1}} = V_{c_{\max}}) > V_{e_{t_2}}$) at t_1 has to be carried out by the emergency response agency and has been maintaining until t_2 (see fig. 1). To the moment t_1, $dV_{e_{t_1}}$ equals 1 and a_e begin to decrease from the maximum; to the moment t_2 , $dV_{e_{t_1}}$ decreases to 0, $V_{e_{t_2}} = V_{e_{\max}}$ and $(S_{\text{control}_{t_{1-2}}} - S_{\text{diffusion}_{t_{0-2}}} = S_3) > S_1$, the diffusion acceleration a_e becomes to 0, and the control acceleration a_c also decreases from 0 to negative. That is to say, the worsening state of emergency diffusion be converted to full controlled state during the control stage ($t_1 \sim t_2$).

2.3 Appease Stage

Because the optimal control measure is adopt in the control stage, the diffusion velocity decreases to 0 at the moment t_i , and the control velocity also decreases to 0 at the moment t_{i+1} which mean the emergency has been fully appeased, and the social stability comes back to the original state.

3 Sync-Control Mode

Sync-control mode referred in this paper is that while the emergency happens, on the basis of the location, characteristic, strength and scope of emergency, the emergency response agency rapidly estimates the emergency state and carries out control measure to deal with the emergency in time. The significant difference between lead-control mode and sync-control mode is that, in the fist control stage, lead-control mode adopts the maximum control velocity through forecasting the potential diffusion speed and damage extent of the emergency, but sync-control model adopts gradually increasing the control velocity from $V_{c_{t_1}}$. The control process with the Sync-control mode can be divided into the follows stage (see fig. 2).

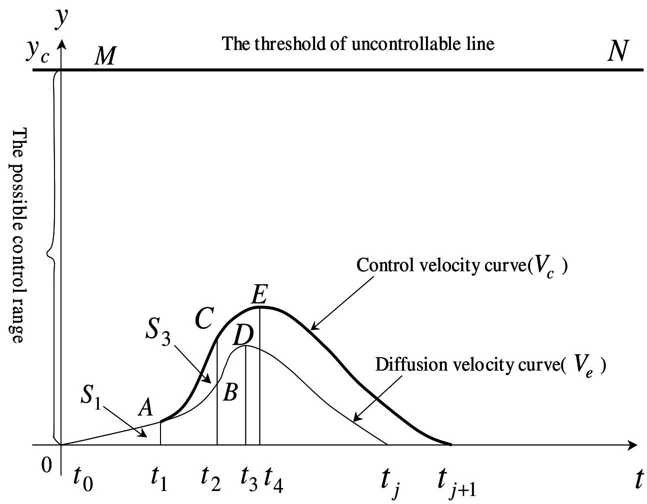

Fig. 2. The control process with sync-control mode

3.1 Knowledge and Estimate Stage

The public emergency response agency rapidly knows the emergency information of where, what, why and how, and estimates its current state. During the stage ($t_0 \sim t_1$) of knowledge and estimate, the diffusion acceleration (a_e) of emergency has showed an upward trend, the diffusion velocity has increased from 0 to $V_{e_{t1}}$, and the diffusion extent has increased from 0 to S_1 ($S_1 = S_{\text{diffusion}_{t_1}}$). The emergency has been diffusing and worsening from t_0 to t_1 because this is a knowledge and estimated stage and not an implement control stage which is same as the first stage of lead-control mode.

3.2 Dominant Control Stage

The control measure is carried out by the public emergency response agency in dominant control stage which control initial velocity $V_{c_{t_1}}$ equals the diffusion velocity $V_{e_{t1}}$ at t_1, and begins to increase with the acceleration a_c (> a_e). From the fig. 2, we can see, to the moment t_2, the control velocity increased to $V_{c_{t2}}$; the diffusion velocity increased to $V_{e_{t2}}$; $dV_{c_{t2}}$ and $dV_{e_{t2}}$ all equal 1, and $V_{c_{t2}} > V_{e_{t2}}$; the a_e and the a_c are all to the maximum and begin to decrease; and the control capacity over the diffusion extent than S_3 , $S_3 = S_1$ and $S_{\text{control}_{t1-2}} = S_{\text{diffusion}_{t0-2}}$. That is to say, the accelerated state of emergency diffusion is controlled at moment t_2 .

3.3 Full Control Stage

The diffusion acceleration (a_e) has decreased from the maximum to 0 during the period of $t_2 \sim t_3$. To the moment t_3, a_e decreases toward to negative, $dV_{e_{t3}}$ decreased to 0, which is to say the diffusion velocity increases to the maximum ($V_{e_{\max}}$). The control acceleration (a_c) has decreased from the maximum to 0 during the period of $t_2 \sim t_4$. To the moment t_4, a_c decreases toward to negative, $dV_{c_{t4}}$ decreases to 0, and the control capacity ($S_{\text{control}_{t1-4}}$) is more than the diffusion extent ($S_{\text{diffusion}_{t0-4}}$), which means the partial controlled state of emergency changed to the full controlled state.

3.4 Appease Stage

The appease stage has the similarity between the sync-control mode and the lead-control model. The diffusion velocity decreases to 0 at the moment t_j, and the control velocity also decreases to 0 at the moment t_{j+1}, which also mean the emergency has been fully appeased, and the social stability comes back to the original state.

4 Delay-Control Mode

Delay-control mode referred in this paper is that while the emergency happens, the emergency response agency rapidly carries out control measure to deal with the emergency, but the control initial velocity ($V_{c_{t1}}$) is too small, even close to 0, so the control initial velocity is assumed to 0 at the t_1 moment. The control process with the Delay-control mode can be divided into the follows stage (see fig. 3).

4.1 Knowledge Stage

The public emergency response agency rapidly knows the emergency information of where, what, why and how, but doesn't estimates its current state accurately. During the knowledge stage ($t_0 \sim t_1$), the diffusion acceleration (a_e) of emergency has showed an upward trend, the diffusion velocity has increased from 0 to $V_{e_{t1}}$, and the diffusion extent has increased from 0 to S_1 ($S_1 = S_{\text{diffusion}_{t_1}}$). The emergency has been diffusing and worsening from t_0 to t_1, which is same as the first stage of lead-control mode and sync-control mode.

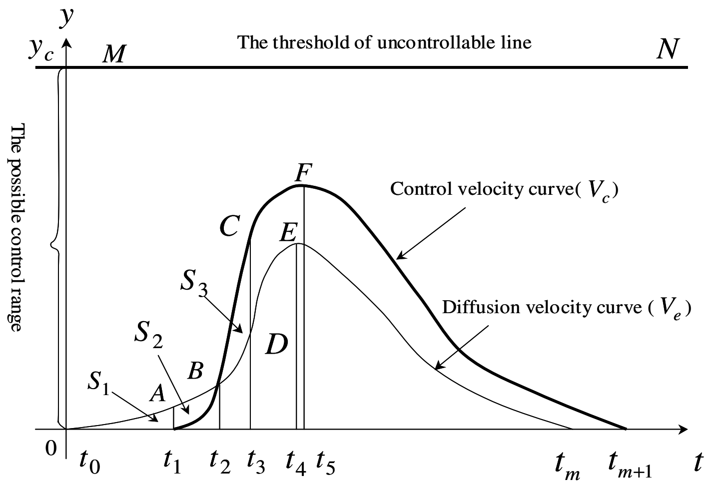

Fig. 3. The control process with delay-control mode

4.2 Partial Control Stage

The control measure is carried out by the public emergency response agency in partial control stage, in which the control initial velocity ($V_{c_{t_1}}$) equals 0 and increases with control acceleration (a_c ($> a_e$)) at the moment t_1. From the fig. 3, we can see, to the moment t_2, the control velocity increased from 0 to $V_{c_{t_2}}$, the diffusion velocity increased to $V_{e_{t_2}}$, and there is $V_{c_{t_2}} = V_{e_{t_2}}$. During the partial control stage, the diffusion extent increased from S_1 to $S_1 + S_2$ ($t_1 \sim t_2$), and the control capacity increased to $S_{\text{control}_{t_{1-2}}}$, but there is ($S_1 + S_2$) $> S_{\text{control}_{t_{1-2}}}$. That is to say, the diffusion state is only partially controlled, but which whole state is still show a worsening trend.

4.3 Dominant Control Stage

To the moment t_3, the control velocity increased to $V_{c_{t_3}}$, the diffusion velocity increased to $V_{e_{t_3}}$, the $dV_{c_{t_3}}$ and $dV_{e_{t_3}}$ all equal 1, which means the diffusion acceleration a_e and the control acceleration are all to the maximum and begin to decrease; the control capacity over the diffusion extent than S_3, the $S_3 = S_1 + S_2$ and $S_{\text{control}_{t_{1-3}}} = S_{\text{diffusion}_{t_{0-3}}}$ which means the accelerated state of emergency diffusion is controlled at moment t_4, so the stage ($t_2 \sim t_3$) is called the dominant control stage in the sync-control mode.

4.4 Full Control Stage

To the moment t_4, the diffusion acceleration (a_e) decreases from 0 to negative, $dV_{e_{t4}}$ decreased to 0, that is to say, the diffusion velocity increased to the maximum ($V_{e_{\max}}$). To the moment t_5, the control acceleration (a_c) decreases from 0 to negative, $dV_{c_{t5}}$ decreased to 0, that is to say, the control velocity increased to the maximum ($V_{e_{\max}}$), and the control capacity ($S_{\text{control}_{t1-5}}$) is more than the diffusion extent ($S_{\text{diffusion}_{t0-5}}$), which means the partial controlled state of emergency changed to the full controlled state, so the stage ($t_3 \sim t_5$) is called the full control stage in the delay-control mode.

4.5 Appease Stage

The appease stage in delay-control mode also has the similarity with the sync-control mode and the lead-control model. The diffusion velocity will decrease to 0 at the moment t_j, and the control velocity will also decrease to 0 at the moment t_{j+1}, which mean the emergency has been fully appeased, and the social stability comes back to the original state.

5 Invalid-Control Mode

Invalid-control mode referred in this paper is that while the emergency happens, the emergency response agency doesn't rapidly and exactly estimates how much loss will be possible caused, but only simply know what happened, which results in a ineffective control measure adopted. During the whole process of invalid-control mode, the control velocity (V_c) has been always less than the diffusion velocity (V_e), and the control capacity has been also less than the diffusion extent. The control process with the Sync-control mode can be divided into the follows stage (see fig. 4).

5.1 Knowledge Stage

During the knowledge stage ($t_0 \sim t_1$), the diffusion acceleration (a_e) of emergency has showed an upward trend, the diffusion velocity has increased from 0 to $V_{e_{t1}}$, the diffusion extent has increased from 0 to S_1 ($S_1 = S_{\text{diffusion}_{t_1}}$), and the emergency has

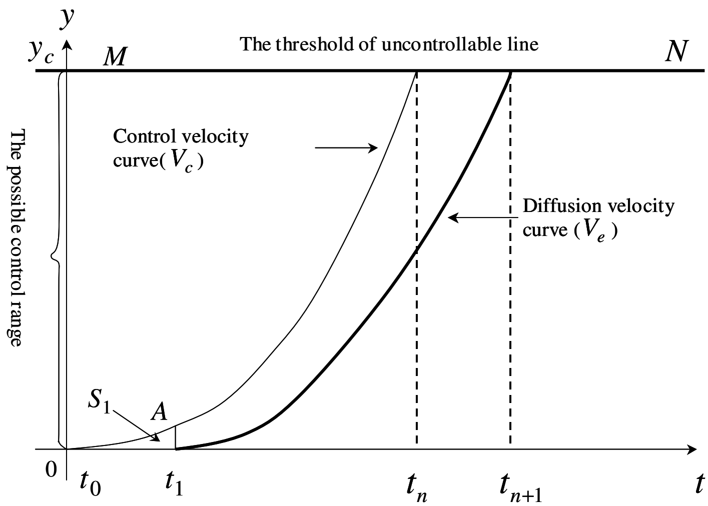

Fig. 4. The control process with invalid-control mode

been diffusing and worsening from t_0 to t_1. To the moment t_1, the control measure adopted by the emergency response agency, but which is an ineffective control measure.

5.2 Lose Control Stage

Because the acceleration of control velocity (V_c) has been always less than the acceleration of diffusion velocity (V_e), the diffusion velocity ($V_{e_{t_n}}$) increased to the max value (y_c) at the moment t_n that could be controlled before the control velocity ($V_{c_{t_n}}$) at the moment t_{n+1}, which means the control capacity (S_{control}) has been also less than the diffusion extent ($S_{\text{diffusion}}$) during the stage (t_1 ~ t_n). Once the emergency diffusion extent is more than the threshold can be controlled, the emergency diffusion situation would become uncontrollable, and which would led to the regional (even national) society system change to instable and chaos.

6 Results and Discussion

The lead-control model, sync-control model, delay-control model and invalid-control model are discussed in the above mentions which shows the different control cost is need to control the emergency diffusion with different control mode, and the loss and impact caused by the emergency are different. According to integrate analyzing fig.1-4, these results can be obtained: 1) emergency has shown the worsening trend during the stage (t_0 ~ t_1); 2) the emergency diffusion period and caused loss, and the control period and control cost, all are delay-control model > sync-control model > lead-control mode; 3) whether each one of the delay-control model, sync-control model and lead-control mode are adopted by the public emergency response agency, the emergency diffusion velocity and strength could be full controlled before which increases to the uncontrollable threshold; 4) If the public emergency response agency doesn't rapidly forecast or estimate the potential loss caused by the emergency on the basis of the emergency information of where, what, why and how, even doesn't know them, the inefficient control measure would be adopted, and the emergency diffusion situation couldn't be controlled, which would lead to the social instability; 5) the lead-control model not only need take the shortest time to full control the emergency diffusion situation, but also make the loss and control cost minimize, however, which had to rapidly finish the forecast and analysis in the stage ($t_0 \sim t_1$).

In fact, whether the emergency would happened is very difficult to be predicted, so the optimal control mode adopted has directly impact on the response plan is success or fail. Then how control mode is optimal? From the above analysis, it can be concluded that whether the emergency information of location, characteristic, cause, strength can be rapidly known, and the potential change trend can be quickly forecasted, directly lead to the selected control measure is appropriate or inefficient, so we can say if these works have rapidly completed in the first control stage ($t_0 \sim t_1$) of certain control mode which may be called the optimal control mode to deal with the emergency. At the same time, since the social system often has the complex and comprehensive characters, and the research of four control modes is in the mechanism stage and still in the first instance, which result in many problems need to investigate in the next work. For example, how many drive forces and how to cause the emergency are very difficult to be estimated, and how much control capacity need to full control the emergency diffusion is also very difficult to be forecasted in a short period of time. However, A lot of experience in history emergency could be used for testing these control modes in future works, so these control modes of public emergency response in this paper would provide an efficient tools to help the public emergency response agency select the optimal control measure in the emergency process. In sum, with the development of forecast technology and methods, we believe that the correctness and speed of forecasting and estimating for emergency possible diffusion trend, extent and loss, will be quickly advanced, and the lead-control model will eventually become the universal emergency mode.

References

1. Niu, W.Y.: The social physics: subject significance and application value. Science (Shanghai) 54(3), 32–35 (2001) (in Chinese)
2. Niu, W.Y.: The social physics and the warning system of China's social stability. Bulletin of the Chinese Academy of Sciences 1, 15–20 (2001) (in Chinese)
3. Fan, Z.M., Niu, W.Y.: A new mechanism model for controlling the stability of social system. Systems Engineering – Theory & practice 27(7), 69–76 (2007) (in Chinese)
4. Fan, Z.M., Liu, Y.J., Wang, Y.L., Li, D., Fu, Y. (Translator & eds.): The Progress of Social Physics. Niu, W.Y (Editor in chief). Series of Social Physics, vol. 1. Science press, Beijing (2007) (in Chinese)

5. Wu, Z.Z., Liu, M.: Gradation and categorization system of emergency plan for major accidents and their main contents. China safety science journal 13(1), 15–18 (2003) (in Chinese)
6. Wang, C., She, L.: Research on the early-warning management mode of society important sporadic event. Wuhan University of technology (Social science edition) 18(1), 26–29 (2005) (in Chinese)
7. Niu, W.Y.: The Social Harmony Equation Based on Social Physics. Bulletin of the Chinese Academy of Sciences 23(4), 343–347 (2008) (in Chinese)
8. Fan, Z.M., Niu, W.Y., Gu, J.F.: Response model and control pattern of the social emergency. China soft Science 8, 85–93 (2007) (in Chinese)
9. U.S. Department of Homeland Security: National Response Plan, `http://www.scd.state.hi.us/documents/nrp.pdf`
10. The State Council of the People's Republic of China: The Master State Plan for Rapid Response to Public Emergencies of China is launched, `http://www.gov.cn/yjgl/2006-01/08/content_21048.htm`