Expression and Deduction of emergency scenario based on scenario element model

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ABSTRACT
In the context of an era filled with frequent occurrence of emergencies, it is urgent to carry out effective treatment. The existing studies focus their research on general rule of emergency evolution, ignoring the consideration of concrete composition of scenario, while the formulation of contingency plan based on the real evolution process of the emergency is rare. In this paper, the basic model of scenario elements is proposed firstly. Next, from the perspective of evolution and disposal of emergency, the framework of scenario for emergencies and emergency disposal is put forward, which paves the way for depiction and scenario analysis of emergency. Finally, this paper takes the stampede as an example, dividing the scenario of emergency and its components, namely scenario elements, and representing the evolution scenario of stampede by scenario elements model. Our method takes advantage of scenario elements model to provide support for the formulation and evaluation of emergency exercise.

Short Paper –Analytical Modeling and Simulation
Proceedings of the ISCRAM 2015 Conference - Kristiansand, May 24-27
Palen, Büscher, Comes & Hughes, eds.

Keywords
Emergencies, Contingency plan, Scenario, Evolution of scenario, Scenario Element.

INTRODUCTION

With the ever-growing climate change and enhanced economic activities, emergencies occurred frequently on a global scale, which brought tremendous threat to human life and property safety. Sufficient ability for emergency response and handling is critical for a country, in particular for countries like China. At present, China's emergency response and disposal practice mainly stays on the macro level, such as theoretical policy or general strategy research, and the emergency exercise model is simple and not systematic. The existing emergency plans are seldom based upon the evolution path of real emergency accidents, and lack quantitative analysis and scientific modelling. There is neither an effective nor an integrated method to assess the rationality of an emergency plan.

Research on the evolution process of a single emergency event has been elaborated. Disaster chain is a specific model to describe one disaster(Li 2010).Combine scenario analysis and probability theory to acquire the method to get the scenario probability and analysis model(David 2002). Their studies cover disaster monitoring, disaster alleviation, disaster dispose and disaster recovery of an emergency event (Shi 1996), and lots of valuable results are obtained. Situation analysis is supposed to improve the decision ability from the expert(Pierre 1985).Situation analysis is also defined as a research on changing process of a complex environment and internals from the decision maker and planning department(Vaner 1996).Scenario is similar to the situation, but easier to classify and separate the element than situation.

Current studies mainly focus on general analysis of common regularity of emergency evolution, but the overall is without considering of the deduction rules and concrete composition of the scenarios of occurrence and development. Besides, it can't reveal the actual evolution of emergencies .However, scenarios are the temporal and spatial carrier of emergencies, which are constituted by various scenario element (factors, resources and information). Some academics conclude that the fastest way to make the emergency decision available is base it on the emergency plan (Raskob 2008). A procedure to find a special rule and inherent law, which exists in different kinds of emergencies and one emergency, can transform into a series emergencies as a chain reaction (Yuan and Fu, 2008). A producing rule implement when working on situation inference rules summarizes the evolutionary process of situation, the research achieve classification of the secondary cases and derivatives cases.

However, most of the existing research stays at the level that only involves a general analysis of the evolution rule of a simple emergency. A method to frame the deductive rules of emergencies and build a scenario elements system is strongly needed, which should be based on the evolutionary process of actual emergencies to assess emergency plan and carry out the emergency exercise.

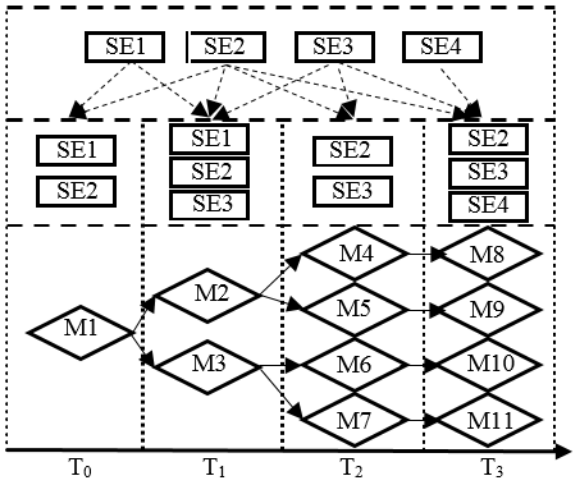
Based on the 'public safety triangle' (Fan and Liu,2009)model, the interaction in the evolution process of any emergency accident is incorporated in the emergency theory in this paper. We will develop a framework to represent this interaction, as well as to describe the evolution rules and underlining disciplines of emergencies based upon a thorough analysis of existing emergency plans.

This paper will present scenario element theory, which is a deduction model for emergency scenario based on components as well as its change in scenario, and build a scientific framework of emergencies and emergency disposal for practical purposes. In addition, this paper takes stampede in high density of population areas as an example, making a systematic division for specific disasters, emergency scenarios and its components of scenario element. Next, the unified expression of the stampedes and contingency plans are given, effectively corroborating the practicability and scientific based on the above theory and finally providing powerful support for the formulation and evaluation of emergency plans and emergency drilling.

EXPRESSION OF SCENARIO ELEMENT MODEL IN EMERGENCY SCENARIO

Emergencies are characterized by the feature of time and location. The emergencies would involve sequentially according to their occurrence time and location. Scenario elements are inseparable basic factors to form the scenario (shown in Figure 1). An emergency can be expressed qualitatively from three perspectives, including its cause, carrier and environment, and if combined with the background information and resources of solutions, an emergency is affirmed to contain Hazard Element, Bearing Element, Condition Element and Resource

Element which will be represented by H, S, C and R, respectively.



Note: SE=Scenario Element; M= Scenario; T= time series

Figure 1 Scenario Element and Scenario of Emergency

Hazard element refers to the scenario element that describe the causes of the emergencies. For instance, the earthquake wave in earthquakes, the over-crowdedness in the stampede accident, and the rainfall in the floods all indicate the Hazard element in certain type of emergency incident. The Hazard element is characterized with strong uncertainty and determined by particular evolving rules. Bearing element is the entity under direct influence of the disaster, including the people and buildings during the earthquake, the crops in the out-of-season snowstorms and the roads after the debris flow. Condition element describes the background factors that accompany the disaster, for example the area and date of the stampede accidents and the region and altitude of the storms. Each condition element of different emergencies may lead to different contingency plans and implementation measures. Resource element are people and resources that can be used during the emergency intervention, including vehicles, communication and medical equipment. The occurrence and evolution of emergency and its dealing plans consist of the four kinds of scenario element.

Based on above analysis, we can also divide and abstract the time-and-space feature, basic authority, functions and rules of the scenario element. The mathematical definition of scenario element is shown below:

Definition 1:

$$SE = \{H, S, C, R\},\ SE = F\ (a, t, \varphi, W, v) \quad (1)$$

SE represents scenario element, and every scenario element can be expressed as an F function related to a, t, φ, W, v, in which refers to space, t refers to time, φ refers to authority, W refers to property, and v refers to the evolving rules of scenario element. The rules can be originated from either the object law of development of things or the regulation of the contingency plans. In a flood disaster, when $SE = H$, the hazard element will be flood, and its specific state property W fits the model that flood overflows the dike. It meets the requirement of particular evolving rules of time t and space a, and thus causes corresponding harm and effect φ.

CLASSIFICATION OF EMERGENCY SCENARIO AND MODEL ESTABLISHMENT

According to the analysis above, an emergency scenario, which is the primary carrier for the space-time evolution of an emergency, can be represented by the combination of the four types of elements, including Hazard Element, Bearing Element, Condition Element and Resource Element. Only under a specific scenario can the evolution of an emergency follow the actual route; detached from the scenario where the emergency happens, the evolution will only go into a deviated direction. In addition, there exist underlining relations among different emergency scenarios, and the deduction of the scenario determines the evolution direction of the emergencies. In order to lower the difficulty for scenario deduction, as well as to correctly project the corresponding evolution route, which would enable decision makers to develop timely and appropriate emergency plans, it is necessary to simplify the projection process but meanwhile stay exclusive in scenario development and analysis. The explanation of the classification steps for

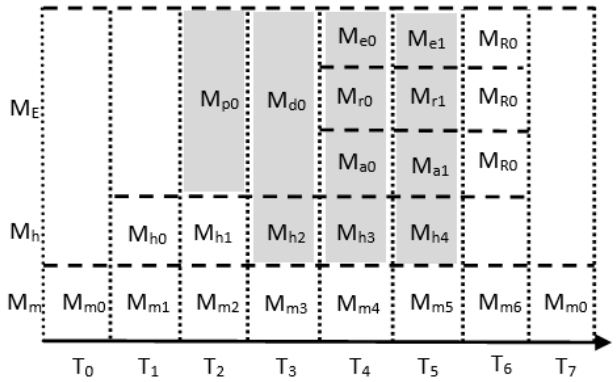
emergency scenarios is as follows. First, conduct an analysis of the emergency plans and cases, and extract the basic elements in each case, so that three types of basic scenarios– Monitoring Scenario, Hazard Scenario and Emergency Scenario are formed. Second, based on the space-time relationship between the Hazard Scenario and Emergency Scenario, successively establish Preparing Scenario, Disposal Scenario and Recovery Scenario. Third, according to the correlation between the Preparing Scenario and the Hazard Element in the Disposal Scenario, systematically establish Evacuation Scenario, Rescue Scenario and Assist Scenario. The classification of emergencies and their corresponding plans are undertaken through the three steps above. Also it is worth mentioning that various scenarios evolve based on certain natural and human behavioral rules. However, since the elements consisting of those scenarios stay unchanged, for simplicity, they are defined as sub-scenarios of its corresponding scenario.

Upon this basis, the components, basic types and logical principles of emergency scenarios are then categorized and abstracted. The mathematical expression of scenarios is as follows.

Definition 2:

$$M_S = f(H, S, C, R) \quad (2)$$

M_S refers to the emergency scenario which is composed of various types of emergency elements. According to the difference in function and objective, M_S differs in its element composition, which mainly includes Monitoring Scenario, Hazard Scenario and Emergency Scenario. Moreover, the Emergency Scenario can be categorized into Preparing Scenario, Disposal Scenario and Recovery Scenario. Also based on the correlation between the Preparing Scenario and the Hazard Element in the Disposal Scenario, Evacuation Scenario, Rescue Scenario and Assist Scenario can then be systematically established. The logical expression of the temporal evolution of emergency scenarios is presented below as figure 2 shown. M_s represents the monitoring scenario and along with whole emergency, the M_h level above the M_s level reflect the disaster scenario which start on the T1 time, in a similar way, other scenarios are fused by kinds of scenario element.

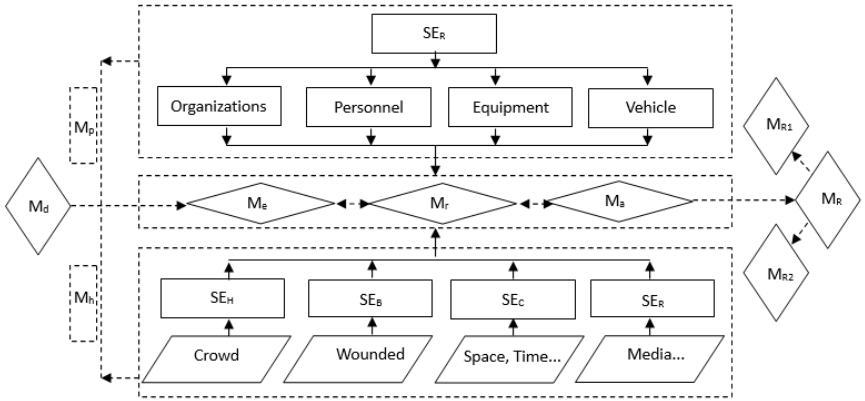


Note: combinations of scenario, M_m=monitoring scenario,M_h=hazard scenario, M_E=emergency Scenario, M_p=preparing scenario, M_d=disposal scenario, M_e=evacuation scenario, M_r=rescue scenario, M_a= assist scenario, M_R=recovery scenario, T= time series

Figure 2 Evolutions of Scenario

CASE ANALYSIS

In this section, the above conceptual framework is applied to a typical emergency of stampede accident. The accident typically occurs on situation of huge fluidity and large-scale of crowdedness gathering on large public spaces like square, cinema, stadium, bus station, dock, Central Business District(CBD), and super market. Such kind of emergency accident would usually lead to serious loss of life and property. A recent stampede accident happened in Shanghai Chenyi Square, China on Jan 1st, 2015 took 35 lives and injured hundreds of people whom were ready to welcome the new year. It aroused the concern and reflection of the whole nation. Hence, we will demonstrate the effectiveness of the above conceptual framework to elucidate the scenario elements constitution and logical relationship between them.



Note: M_h=hazard scenario, M_p=preparing scenario, M_d=disposal scenario, M_e=evacuation scenario, M_r=rescue scenario, M_a= assist scenario, M_R=recovery scenario, M_{R1}, M_{R2}=sub-scenario of recovery, SE_H= Hazard element, SE_B=Bearing Element, SE_c=Condition Element, SE_R=Resource Element

Figure 3 Analytical framework for stampede by scenario element model

According to section 2, a stampede accident is firstly divided into hazard scenario and emergency scenario; the emergency scenario is further separated into three categories: preparing scenario, disposal scenario and recovery scenario, where the disposal scenario is combined by emergency scenario and disaster scenario. In figure 3, we can see that the evacuation scenario M_e, rescue scenario M_r and assist scenario M_a combined to impress the characteristic of hazard element and bearing element from the definition 2. The evolutionary analysis of the stampede scenario can be traced to crowd congestion deduction rules which is the prerequisite and foundation on how to form the dispose scenario and its sub-scenarios M_e and M_r. As a result, we could adopt crowded stampede quantitative risk evaluation model to deduce the hazard element and bearing element of the hazard scenario, which is shown as formula (3~5). Therefore, we obtain the quantitative attribute of the hazard element SEH and bearing element SE_B, namely the number of crowd and wounded respectively. The numerical value can be used to assess the risk of crowded stampede event, which also serves the emergency resources arrangement and start-up emergency plans as a scientific support, such as the number and type of SE_R, including organizations, personnel, equipment as well as vehicle. Next, consider to establish the evacuation scenario M_e following the characteristic of hazard scenario in order to hold-up the stampede event by evacuating the hazard element SE_H. Similarly, the assess of scenario M_r is based on the bearing element SE_B, condition element and other resource elements together, M_r reflects the rule and characteristic of SE_B and synchronize with M_e. This scenario is aimed at curing and medicining the injured people through emergency plans and START methods(Nocera and Garner 1999)，conforming to the spatio-temporal variation rules especially related to the time strongly. Besides, assist scenario M_a serves for the rescue scenario and dispose scenario passively and proceed under the emergency plan's guide, including assist the evacuation, blocking the road, canceling the activity, preventing the secondary the disaster, removing the negative information, and alleviating panic. The recovery scenario is divided into two parts to correspond the proper scenarios, including the field order recovery and the wounded's physical and psychological health recovery.

According to definition 1 and crowded stampede quantitative risk evaluation model, the Crowded stampede value-at-risk A (LEE and Hughes 2005) is shown below:

$$A = \theta \times \frac{h_N}{c_N} \times s_N \tag{3}$$

Where h_N represents the value attributes of hazard element *H* at *t* time; c_N refers to the total number of public places where the accident occurred and C_N represents the value attributes of condition element *C*; s_N represents the value attributes of bearing element *S* at *t* time and refers to the death number of the stranded people. θ represents the trigger factor of stampede accident, and refers to the correlation coefficient between the stampede's susceptibility and consequence, the factor's value range is determined by the real data comprehensive analysis and expert grade.

h_N is shown below：

$$h_N = h_{N1} - h_{N2} = \sum_{i=1}^{n} \int_{T_0}^{T} f_i'(t) B_i'(t) \mathrm{d}t - \int_{T_0}^{T} f(t) B(t) \mathrm{d}t \quad (4)$$

h_{N1} expresses the total rescued number from the evacuation from when time *t*=0 to when time *T*, and *n* represents the number of inward entrance available; h_{N2} expresses the total number which is counted from the final passage from the evacuation from when time *t*=0 to when time *T*, and (4) represents the rescued number in $0 \sim T_0$ time; $f_i'(t)$ represents the crowd flow coefficient at the i entrance branch, and p/(m•s); $B_i'(t)$,(t) represents people flow width at the i entrance branch; $f(t)$ represents the crowd flow coefficient at the exit, and p/(m•s); *B(t)* represents people flow width of all the exit route(we usually use the width of exit route to express); T_0 represents the time when the crowd stranded;*T* represents the total evacuation time.

s_N is shown below：

$$s_N = \sum_{i=1}^{m} [f_i(t) \geq 4500, t \geq 3] \cdot e^{t/3} \quad (5)$$

$f_i(t)$ represents the acting force among the stranded crowd; *t* represents the congestion duration; *m* represents the number of people who suffer the stress force more than 4500 *N* on their chest (Tong., et al 2013). The time unit is second(*s*), width unit is meter (*m*), acting force unit is newton（N）.

When people gather in the public places, stampede accident may occur at a certain probability, and we can effectively acquire the crowded stampede value-at-risk by crowded stampede quantitative risk evaluation model. By deducting and analyzing the emergency scenarios, we achieve the evolution rules and specific state of the scenario elements, consequently , the results serve for the emergency resources, arrangement and start-up emergency plans as a scientific support.

CONCLUSION

Scenarios are the temporal and spatial carrier of emergencies, which also are the basic factor for revealing the actual evolution of emergencies. This paper presents a deduction model for emergency scenario based on scenario element theory, and builds a scientific framework of emergencies and emergency disposal for practical purposes. In addition, through the empirical analysis scenario element theory is proved to be an effective way to make a systematic division and unified expression for specific disasters, finally providing solid support for the formulation and evaluation of emergency plans and emergency drilling.

ACKNOWLEDGMENT

The authors would like to thank the support of the National Natural Science Foundation of China (Study on Pre-qualification Theory and Method for Influences of Disastrous Meteorological Events, Grant No.91224004), the youth talent plan program of Beijing City College (Study on Semantic Information Retrieval of Decision Analysis of Emergency Management for Typical Disastrous Meteorological Events, Grant No.YETP0117) and the National Natural Science Foundation of China (Key Scientific Problems and Integrated Research Platform for Scenario Response Based National Emergency Platform System, Grant No. 91024032) and Key Program of the National Natural Science Foundation of China, No.71433008 and Key Research Program of the Chinese Academy of Sciences, No. KZZD-EW-06-04.

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