Research on Comprehensive Risk Analysis and Prevention and Control of Large-Scale Stampede Accidents

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Abstract. In recent years, with the rapid development of China's social economic and cultural undertakings and the continuous improvement of people's living standards, various large-scale activities have also been flourishing. Due to its characteristics of large scale, large number of participants, high risk factors and so on, security issues become serious, and security control is the focused and difficult point in large-scale activity management. According to the data collected, the risk of accident is different for different activities, and accident probability is different for the same activity held in different places or times. For the risk management of large-scale activities, it is not only related to the activity characteristics, but is also concerned with many other factors such as safety management. The Scientific risk management needs to take consideration of the types of accidents, venues, components of participants and so on. For this reason, the large-scale activities held in enclosed space will be analyzed in this paper, and the basic theory of risk management of large-scale activities will be put forward based on the risk assessment of various events and the accident type and formation mechanism.

Keywords: Stampede Accidents · Risk · Prevention and Control

1 Introduction

In recent years, with the rapid development of Chinese social, economic and cultural undertakings, the nation's pursuit of economic and cultural life has become higher and higher. There are more large-scale events held in China. Large-scale events can not only invigorate people's cultural life, but also promote economic development. And it has become vital for economic development. According to statistics, in the past five years, China has held an average of more than 14, 000 large-scale events with more than 1, 000 people each year, and nearly 300 million people participated. Moreover, with the development of the social economy, the number, specifications and grades of various activities will continue to rise in the next few years.

Large-scale events have outstanding safety issues due to their large scale, large number of participants, and high-risk factors. Safety control has always been the focus and difficulty of event management. However, according to the safety inspection statistics

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of the Public Security Organs, about 62% of activities in China have serious safety hazards. Every year, due to inadequate event safety organization and management, the accidents and losses caused are extremely huge. The safety situation of large-scale events in China is severe.

1.1 Imperfect Construction of the Risk Management System for Large-Scale Events

Because large-scale events have the characteristics of high crowd density, strong mobility and special environments, the implementation and supervision of their risk management have always been an important task for all level governments and competent public security organs. Local governments have also issued regulations for large-scale events. For example, Beijing, Xiamen and other cities have established safety management regulations for large-scale events. It is required that any activity requires risk management supervision and implementation before it starts. However, due to the complex relationship between large-scale event undertakers, the imperfect construction of the actual risk management system, and the lack of detailed evaluation plans and management order, the actual work has unclear responsibilities, unclear tasks, and chaotic risk management and control.

1.2 The Risk Management of Large-Scale Events is not Supported by Scientific Methods, and the Management Level is Uneven

The risk management of large-scale events is not only related to the characteristics of the event itself, but also related to safety management. Different types of activities have different risks. Faced with the ever-increasing number of activities and activity demands, it is urgent to carry out further in-depth scientific research.

2 Literature Review

The Chinese national standard defines large-scale events as non-daily theatrical performances, sports competitions, exhibitions, job fairs, temple fairs, lantern fairs, garden fairs and other group activities held by legal persons or other social organizations for the public, as well as group activities organized by government organizations with specific needs.

Some Chinese cities, such as Beijing and Liaoning, also have different terms, or they are called large-scale social events. According to the definitions in the "Regulations on the Safety Management of Large-scale Social Activities in Beijing", [6] "Measures for the Safety and Security of Large-scale Social Activities in Liaoning", "Regulations on the Safety and Security Management of Large-scale Mass Activities in Taiyuan" and other regulations, large-scale social activities refer to the sponsor's renting, borrowing or temporary occupation of places and venues in other forms, theatrical performances, [7] sports competitions, exhibitions, trade fairs, job fairs, temple fairs, lantern fairs, garden fairs and other group activities held for the public.

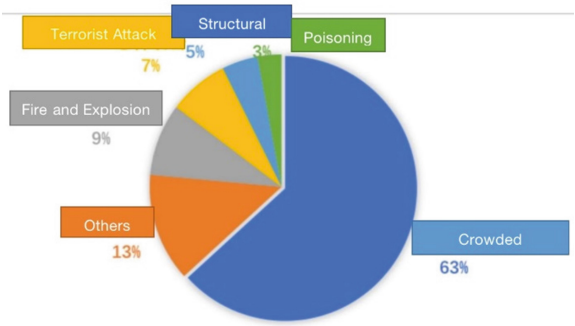

Fig. 1. Statistics of accident types in enclosed spaces

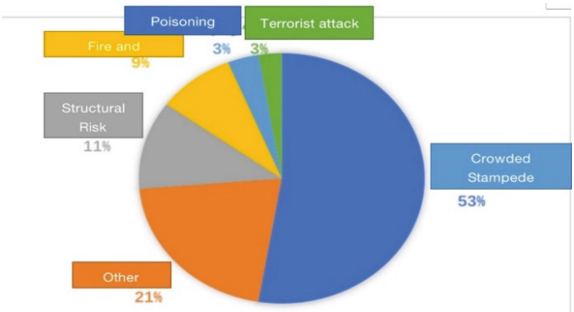

Fig. 2. Statistics of accident types in open spaces

No matter which way of definition, they all cover the characteristics of large-scale clusters. Of course, according to the gathering form and activity content, large-scale activities generally include literary and artistic, sports, exhibition, and political categories. According to the different nature, it can be divided into government behaviour activities and social commercial behaviour activities (including literary and artistic activities, sports activities, mass behaviour activities, etc.) [8].

Because of the different nature of large-scale mass activities, there are different accidental risk factors. Or the risks of holding the same event at different times and locations may be different. According to statistics, the occurrences in enclosed spaces are generally stampede, water and power outages, structural risks, poisoning, and fires. Generally, trampling and terrorist attacks occur in outdoor open spaces. The probability of accidents in different spaces and the problems that need to be prevented and controlled are also different (Figs. 1 and 2).

The risk management of large-scale mass events needs to be considered in combination with factors such as the nature of the event and the location of the event. For example, the risk prevention and control content of commercial activities and political activities held in the same venue is different. Also, the same event held in an open space or closed space, the risks of prevention and control still are different. Large-scale social activities must be managed, prevented and controlled in a targeted manner according to

actual needs. In previous research and practical work, due to the lack of theory of risk management for large-scale mass events, large-scale mass events of different types and venues were often studied together. This one-size-fits-all risk management model lacks pertinence in practical applications, and it is difficult to adapt to the needs of refined management. Therefore, this paper will dig deeper into the risk formation mechanism of large-scale activities, select large-scale activities in different spaces for research, in order to obtain a targeted risk management plan.

3 Analysis of Risk Factors of Large-Scale Events—Different Spatial Perspectives

Collected and sorted out accident cases since 1980, from the perspective of qualitative analysis. Although it is incomplete statistics, this set of data can provide a basis for a comprehensive analysis of the reasons and characteristics of the data, as a reference for the analysis.

3.1 Statistics on Accident Types of Large-Scale Events

This paper collected a total of 187 cases from 1961 to the present for analysis. In these cases, a total of 148 accidents occurred abroad, including 98 cases of crowding and trampling, 12 cases of structural risks, 11 cases of fires and accidental explosions, 4 cases of poisoning, 9 cases of terrorist attacks, and 24 other cases. In terms of the proportion of various types of accidents in the total number of accidents, congestion and trampling accounted for 62%, others accounted for 15%, structural risks accounted for 8%, fires accounted for 6%, and poisoning accounted for 3%.

A total of 29 cases were counted in China, of which 6 were crowded and trampled, 5 were structural risks, 5 were fires and accidental explosions, 2 were poisoned, and 11 were the others. Counting from the proportion of various accidents in the total number of accidents, congestion and trampling accounted for 21%, others accounted for 38%, structural risks accounted for 17%, explosions accounted for 17%, and poisoning accounted for 7%.

Comparing China with the rest of the world, it is found that more crowded stampede accidents occurred worldwide. Relatively speaking, China had all kinds of accidents, which were relatively average.

Among these accidents, there were 60 accidents with more than 100 casualties. Among them, 5 were in China and 55 were abroad. Among the 60 accidents, 35 were crowded and trampled, 8 were structural risks, 6 were fires, 2 were explosions, 2 were terrorist attacks, 0 were poisoned, and 6 others. From the perspective of the proportion of various accidents in the total number of accidents, crowding and stamping accounted for 59%, others accounted for 10%, structural risks accounted for 13%, fires accounted for 10%, explosions accounted for 5%, and terrorist attacks accounted for 3%. It shows that China has sufficient experience in risk management of large-scale events and leads the world in preventing large-scale stampede accidents.

3.2 Comparative Analysis of Different Spatial Accidents

Among these accidents, classified and counted according to the types of places, there were 69 accidents in open places, including 43 congestion and trampling, 3 structural risks, 3 fires, 3 poisonings, 3 explosions, 5 terrorist attacks, and 9 others. From the perspective of the proportion of various accidents in the total number of accidents, congestion and trampling accounted for 63%, others accounted for 13%, terrorist attacks accounted for 7%, structural risks accounted for 5%, fires accounted for 5%, explosions accounted for 4%, and poisoning accounted for 3%.

A statistical analysis of the causes of the 187 cases reveals that the causes of the occurrence of enclosed spaces are as follows, mostly caused by emergencies such as unreasonable site set-up and inadequate management. The causes of open spaces are as

Table 1. Analysis of Causes of Confined Space Accidents

Closed Space				
Crowded Exit	Too Many Fans	Exceeds the limit of the number of people	Player falling injured	Crowd Conflict
Crowd Riot	Slip and Fall	Crowded Flow	Fan Riots	Emotions out of control
Fence Collapse	Stage Fire	Police Using Tear Gas	Exceeds the limit of the number of people	Food poisoning
Terrorist Attack	Lightning Strike Fire	Site Collapse	Accidentally Using Fire	Actor Falling From the Stage
Sudden Power Failure	Intentional Operation of Switch	Interactive Fall	Falling Wood	Channel Congestion
Cigarette Fire	Over-selling Ticket	Fans Pull Down	Fake Bomb	Terrorist Attacks
Grandstand Collapse	Water Heater Burning	Stage Fall	Falling Player	Management Negligence
Emotional Outburst	Match Cancellation	Terrorist Attack	Food Poisoning	Grandstand Collapsed
Sudden Hailstorm	Air Conditioning System	Sudden Rainstorm	Outbreak Disease	Device Falling
Sudden Death of a Player	Short Circuit	Outbreak of SARS	Short Circuit	Exceeds the limit of the number of people
Instruction Error	Firecracker Panic			

follows, mostly caused by environmental factors and inadequate management control of crowd hedging, etc. (Table 1).

4 Analysis on the Formation Mechanism of Risk Accidents in Large-Scale Activities

The statistical analysis of the cases reveals that although each trampling accident at a large event is unique, there are common factors that contribute to the trampling accident. However, by analysing and summarising the triggering factors of trampling accidents at large events, we found that there are common causal factors, as shown in Fig. 3.

It is usually caused by crowded people, unreasonable site design, improper command and control, and lack of reasonable management.

4.1 Crowded Flow

Crowd characteristic factors refer to the crowd-related factors that lead to the occurrence of stampede accidents. It is the most critical factor among various risk factors, and it can be greatly improved. Specifically, it includes crowd density, crowd composition characteristics, crowd psychological characteristics, crowd behaviour characteristics, and crowd safety. According to the research on crowd dynamics, crowd speed is determined by crowd density. The higher the crowd density, the lower the crowd speed. When the crowd density exceeds a certain standard, the crowd speed will drop to zero due to overcrowding. Figure 4 shows the relationship between crowd density and crowd speed.

4.2 Venue Design

There are many types of large-scale mass activities. Common types include religious activities, sports competitions, concerts and festival celebrations. Different types of large-scale mass activities require different venues and environments due to their different

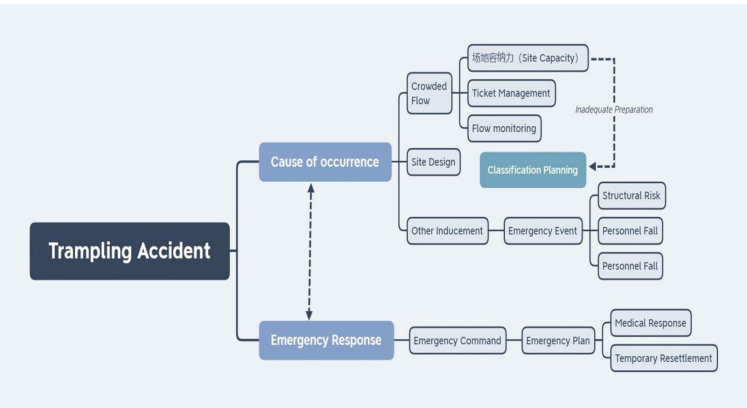

Fig. 3. The formation process of stampede accident risk

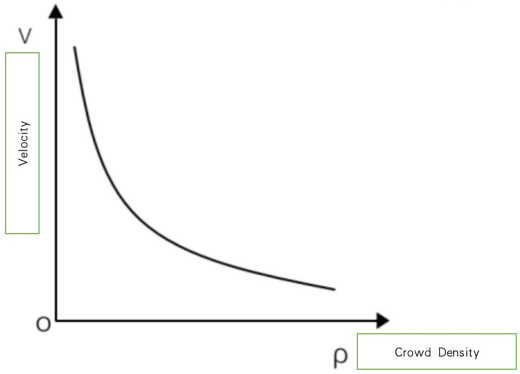

Fig. 4. The relationship between crowd density and crowd speed

nature and content. Including open places and closed places. Among them, the stadium type has a large space inside and a closed outer wall outside, which has the characteristics of both an open place and a closed place. For site safety, building safety is the primary consideration. The site is the physical carrier and basic element for large-scale mass events. Once the number of people exceeds the building's load-bearing limit or there are problems with building quality and safety, it will induce structural risks and cause crowd panic and trampling.

4.3 Management Factors

The success of any large-scale event is closely related to the management level of the manager. At the large-scale event site, when the risk factors of stampede accidents appear, efficient management is an important guarantee for reducing risks and preventing stampede accidents. The occurrence of stampede accidents of large-scale mass activities is closely related to management factors. Among the 109 stampede accidents in the statistics, 81 were directly caused by management factors, accounting for 34. 6%. And the total number of casualties was close to 20, 000. Therefore, strengthening management factors is an important part of preventing stampede accidents and reducing casualties. It is necessary to set up a full-time safety management agency to monitor the risks of the entire large-scale event to prevent the occurrence and expansion of stampede accidents.

5 Establishing Management and Control System for Risk Elements of Large-Scale Events

The Chinese national standard GB3001 and the literature studies in the last 20 years, summarised the influencing factors that cause safety accidents in large-scale events include Man, Machine, Medium and Management [1–5]. In accordance with the national requirements, while specifying the risk factors, this paper argued that for different spatial risks, their prevention and control needs to be considered in the following aspects.

5.1 Human Factor

People are the main part of large-scale activities. The safety level of a single individual has minimal impact on system security, but overall will then has a huge impact. Human safety is the main goal of large-scale activities.

Human assessment indicators mainly include crowd density, crowd status, and personnel composition.

5.2 Material Factors

For large-scale events in different spaces, venues and facilities are the most significant influencing factors and it is important to ensure the safety of the venue or site. Physical factors generally include venue architecture, evacuation routes and facilities and equipment.

5.3 Environmental Factors

Environment refers to the general term for the material, economic, information, and interpersonal factors that exist outside of the venue except for the human and physical system. For large-scale events in enclosed spaces, environmental factors are generally divided into the natural environment, social environment and surrounding environment. The natural environmental factors are mainly heavy rains and typhoons after the event. Social factors are the surrounding security situation, sources of danger, etc., the surrounding environment, and whether there are danger sources in the surrounding area.

5.4 Management Factors

Management factors mainly refer to the measures taken by event managers for large-scale events and whether the organizer have experience or not. The organizer's safety management confusion and management errors are the key factors that cause safety accidents in large-scale events. From a management perspective, the management factors of large-scale events mainly include the qualifications of the organizer, emergency command plans, and emergency capacity.

For large-scale events in different spaces, among all, human factors such as large crowds and uncontrolled flow of people are the direct cause of safety risks. Fragility of the venue is also a major cause of accidents. Management factors often act on the venue, causing more chaos. Environmental factors can also lead to incidents and even exacerbate the time process. For large-scale events, it is necessary to sort out the relationships between several elements in order to respond better. These factors interact and influence each other to form a catastrophe. For risk management, it is necessary to clarify the relationship between these four factors so as to make the analysis, prevention and control more pertinent (Fig. 5).

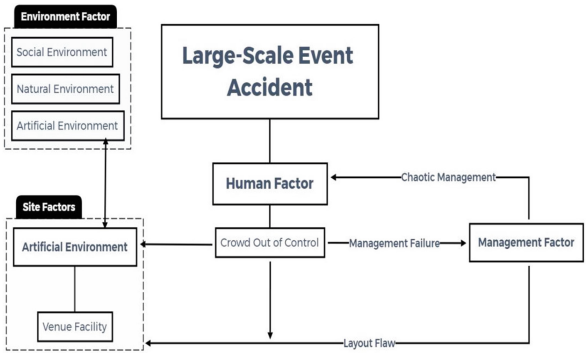

Fig. 5. The Risk Prevention and Control system

6 Conclusion

With the rapid development of China's social economic and cultural undertakings and the continuous improvement of people's living standards, various large-scale activities have also been flourishing. Due to its characteristics of large scale, large number of participants, high risk factors and so on, security issues become serious, and security control is the focused and difficult point in large-scale activity management. This paper focused on the risk management of large-scale events from different spatial perspectives. Summarized the development mechanisms of risky accidents in different spaces. As there wasn't much existing research on large-scale events, the research methodologies for the assessment of various types of accidents involved many disciplines such as management, behavioural science, engineering and informatics. Since there were few relevant studies to draw on, still many shortcomings in this research.

According to the data collected, the risk of accident is different for different activities, and accident probability is different for the same activity held in different places or times. For the risk management of large-scale activities, it is not only related to the activity characteristics, but is also concerned with many other factors such as safety management. The Scientific risk management needs to take consideration of the types of accidents, venues, components of participants and so on. For this reason, the large-scale activities held in enclosed space will be analyzed in this paper, and the basic theory of risk management of large-scale activities will be put forward based on the risk assessment of various events and the accident type and formation mechanism.

However, China's hosting of the Winter Olympics is imminent, it was hoped that this paper, done under great urgent, can provide a reference for the daily management of the 2022 Winter Olympics and others in the future.

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References

1. GB/T 33170.5-2016, safety requirements for large-scale events Part 5: security resource allocation
2. GB/T 33170.2-2016, safety requirements for large-scale activities, Part 2: personnel control
3. GB/T 33170.3-2016, safety requirements for large-scale events Part 3: site layout and safety oriented signs
4. GB/T 33170.4-2016, safety requirements for large-scale activities Part 4: Guide for temporary facilities
5. GB/T 33170.1-2016, safety requirements for large-scale activities Part 1: Safety Assessment
6. Li Z (1 March 2011) Research on risk assessment of large-scale sports events – Master's thesis of Suzhou University
7. Li S (31 March 2008) Research on safety risk index system of large-scale social activities. Capital University of Economics and Trade
8. Zhan Y (2008) Research on risk management and crowd gathering accident prevention system of large-scale social activities. Beijing University of Chemical Technology