


# Theory and Practice of Accident Risk Management for Large-scale Events

# 大型活动事故风险管理

## ——理论与实践

佟瑞鹏 著

 中国劳动社会保障出版社

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## 内容简介

大型活动事故风险管理是保障大型活动安全举办的重要技术支撑,可以帮助不同类型的活动辨识主要风险因素,增强针对性,协助制定防范措施及安全保卫方案,是系统评价大型活动安全水平,进行大型活动安全管理的重要依据。本书内容针对的目标是减少活动中的安全隐患进而降低事故发生的可能性,保障主办人员、参与人员及场馆周边人员的人身安全,降低事故造成的各类损失,也为政府主管部门进行监管和审批提供必要的理论和方法。本书内容有重要的应用价值,有关的理论已经应用于实践,得到安全监管部门的认可并获得优秀科技成果的奖项。

本书内容共分8章,包括:绪论、大型活动事故风险管理研究进展、大型活动典型事故案例与风险因素分析、大型活动事故风险综合评价方法、拥挤踩踏事故风险定量评价技术、大型活动事故风险管理控制对策、大型活动事故风险评价方法应用、结论与展望。本书可作为高等院校安全科学与工程、公共管理、行政管理等专业本科生、研究生的参考书,也可供从事大型活动风险管理及相关行业的人员阅读使用。

# 前言

大型活动已经成为社会生活表现形式之一。然而,安全是大型活动举办的基础和生命线,事故是扼杀大型活动成功的最直接和最不期望的制约因素,无数憾人事故的发生和惨痛的人员伤亡后果警示我们,加强大型活动风险管理工作刻不容缓。因此,有必要分析大型活动事故发生的过程和机理,研究大型活动事故风险评价的理论和方法,以有助于提高大型活动事故风险管控能力。

本书运用安全系统工程学、事故致因理论和风险评价等基础理论知识,深入研究了大型活动事故风险评价的程序、内容、方法体系和控制对策等问题。本书在事故案例统计分析的基础上确定大型活动主要事故风险因子和风险构成要素,以此来构建大型活动事故风险评价方法体系,包括定性、半定量和定量评价,对应风险构成要素分别提出大型活动事故风险管理控制对策,并应用于具体大型活动事故风险评价的实践中。

本书共 8 章。

第 1 章为绪论,确定本研究的选题背景、研究技术路线和主要研究内容等。

第 2 章是文献综述。综合相关研究文献,本书研究确定大型活动的内涵为临时组建管理机构,面向社会公众,具有特定目的,暂时占用活动场所,参与人数达到一定规模的非日常性活动。大型活动规模一般要求人数达到 1 000 人以上,是对公众开放,不包括群众自发的活动,举办频率低、一次性或不经常举办的活动,一般是临时占用活动场所。大型活动事故风险特征主要集中在人群的密集性、突发性、不确定性、社会影响性和非程序化决策上。人群聚集易导致事故的进一步扩大,造成更严重的损失,而且一件极小的事情就可能导致非常严重的社会影响后果,且事故发生无章可循,使得无法提供程序化的事故应对决策方案。大型活动自身的特性也是决定其事故风险的重要因素。

第 3 章进行事故案例统计分析,确定和分析大型活动主要事故风险因素。大型活动典型事故案例统计分析表明:火灾、爆炸、结构风险、中毒、人群拥挤 5

个主要风险因子所带来的伤亡占大型活动事故总伤亡的比例大于90%。大型活动的一般原发性事故是可能发生的火灾、爆炸、中毒、建筑物类事故,而次生事故最主要的表现形式为人群拥挤踩踏事故。人群聚集特性是大型活动事故风险产生、演变和扩大的根源,根据原发事故和次生灾害的关系确定人群拥挤踩踏事故为大型活动主要事故风险控制对象。人群类别因素、场所风险因素、环境风险因素、管理风险因素和活动内在特性是大型活动事故5个风险构成要素。人群类别因素包括人群密集程度、人群行为和心理状态、人群构成和比例、组织者安全水平等;场所风险因素有场所类型、场所布局、建筑安全、危险物品、应急装备和资源等;环境风险因素是指影响大型活动运行过程中安全运行的社会环境、自然环境、人工环境等;管理风险因素包括安全机构建设、风险管控措施、应急能力建设以及相关方管理;大型活动的内在特性需要考虑活动内容、活动规模和活动的影响。大型活动事故发生机理在于各风险要素之间的平衡关系遭到破坏。安全管理失误的后果与突变的环境因素相互作用,致使活动场所内人群混乱,进而导致了大型事故的发生。大型活动事故风险构成要素间的作用方式与作用过程以及相互之间的关系,常常决定大型事故的发生时间、强度及破坏程度。

第4章和第5章研究大型活动事故风险评价的方法体系。第4章从风险管理的角度提出大型活动事故风险评价的程序和内容,包括活动方案评估、静态风险评估、动态风险评估、管控能力分析、应急能力分析、现实风险综合评估等6个方面,每一环节评估分析的内容共同构建起大型活动事故风险评价的内容体系。针对大型活动动态风险评估环节提出了人群聚集场所事故风险定性评价方法,通过风险识别的关键词、危险有害因素列举、风险因素分析示例等方法,将评价方法归结成7步简易评价流程。在此基础上由大型活动的内在特性系数、原发事故风险和风险抵消因子建立了大型活动事故风险评价指标体系,提出用事故风险指数评价模型来评估大型活动的相对现实风险。该模型采用火灾指数、聚集指数和场所指数表示大型活动原发事故较多的火灾、拥挤踩踏事故和建筑物类事故,风险抵消因子包括疏散抵消因子、管理抵消因子和应急抵消因子3种,各指标取值是通过与其制约因素建立的数值关系来评判。根据各因素取值范围,确定大型活动事故风险指数取值范围在0~170之间,并划分成六级风险等级。

第5章从波动、恐慌、信息和环境4个方面分析了拥挤踩踏事故发生的原因,研究了人群恐慌特征、心理反应模式、过程描述、群集特殊现象等拥挤踩踏



事故呈现的风险特征。构建由触发因子、区域滞留人数和表征事故严重程度的死亡人数组成的人群拥挤踩踏事故风险定量模型,其中触发因子用弱势群体比例、出口的吸引力和拥挤人群信息通畅程度来表征,根据拥挤踩踏事故中力的作用形式、大小和持续时间确定特定区域滞留人群的死亡人数,而区域滞留人数通过表示为人群密度和人群移动速度的函数的人群流动系数来计算。目前对于人群疏散过程中特定区域内滞留人数大小的计算可通过滞留人数模型进行求解。死亡人数是一个难以确定的因素,其不能通过实验或方程推导得到,因此需要借助计算机模拟来进行求解。进一步讨论了通道堵塞对人群疏散的影响程度,可以证实人流流量随人群密度的变化发生复杂变化。在密度较低时人群密度与人流流量成正比关系;人群密度大于互不影响的临界密度时,人流流量与人群密度之间成非线性关系;当人群密度达到最大密度时,可以认为人流流量为0。而在人群初始密度在4人/ $\text{m}^2$ 左右时,人流一旦发生阻塞将很难恢复初始流量。

第6章研究大型活动的事故风险控制对策。采用预防管理、风险转移、风险规避、自我管理策略控制大型活动事故风险,风险控制层次和范围需要根据事故风险情况从大型活动场所内部延展到场所外部。

第7章涉及案例应用与分析,是本书研究内容的实测和验证部分。将大型活动事故风险评价程序、内容、方法体系和控制对策应用于沈阳世界园艺博览会,对其事故风险进行辨识和分析,定量化计算模拟了事故风险的关键场所和区域,在综合评价基础上,制订事故风险预防和控制的对策。验证基于风险分析的大型活动事故风险评价方法体系是全面、科学、合理的,具有良好的操作性,可为活动组织者和风险管理人员提供技术支持。

第8章总结本书研究的内容,明确研究的结论和创新点,并提出进一步深入研究的建议和展望。



## Preface

At present, large-scale events have being an integral part of social life forms. However safety is the basis and lifeline for large-scale activities organizing, accidents strangle the success of large-scale events through the most directly and unexpected constraints. It makes the risk management of large-scale events to the top because of the accidents occurred with countless awesome severe casualties. Therefore, this dissertation gives the accident analysis and its mechanism of large-scale activities, the study of theories and methods about accident risk assessment, the improvement of control ability to accident risk in large-scale activities, which can provide a scientific decision-making basis for the safety and sustainable development of large-scale events.

The procedures, contents, methods systems and control measures of large-scale events are studied in-depth, making full use of the theory of safety systems engineering, accident causes, and risk assessment so on. Based on statistics and analysis of the accident cases of large-scale events, the major risk factors, component elements and its formation mechanism are identified, the risk assessment methodologies are built including qualitative, semi-quantitative and quantitative evaluation. Corresponding to the component elements, it brings out the incident risk management and control measures for large-scale activities, and their application to the practise of incident risk assessment for large-scale events.

This dissertation comprises eight sections.

Chapter 1 is for the introduction to identify topics background of this study, the study about the technical line and main content and so on.

The literature review is in Chapter 2. Through colligating related literatures, the conception of large-scale events is demarcated to establishment of interim



management organization, facing the public, having a specific purpose, temporary occupation for ground, a certain number level of participants and non-routine activities. The large-scale activities which their general requirements of number is more than 1, 000 people, not including the spontaneous activities, low frequency, one-time or regular events, is generally a temporary occupation activity. The accident risk characteristics of large-scale activities mainly concentrated in the crowded, sudden, uncertainty, the social impact and the non-procedural decision-making. The assembled crowd can easily enlarge a further severely accident, resulting in the loss even more serious, and a very small thing can lead to very terrible consequences of the social impact, then the accident occurred unsystematically, it makes impossible to provide the procedures of decision-making to deal with the accident. No doubt the inherent characteristics of large-scale activities are also an important factor, which determine their accident risk.

Chapter 3 is for the statistical analysis of accident cases, which identifies and analyzes the accident risk factors of large-scale events. The statistical analysis of typical accident cases for large-scale activities shows that the casualty proportion brought by fire, explosion, construction risk, poisoning and crowded is more than 90 percent in all the accidents of large-scale activities. The general primary accidents of large-scale activities may be that fire, explosion, poisoning, structure accidents, and the most important expression form of induced hazards is the crowd trample accident. The characteristic of assembled crowds of large-scale activities is the root causes of come into being, evolution and expansion. The crowd trample accident is considered as the major control object of accident risk in large-scale activities according to the relation of the primary accident and induced disaster. Five risk construction elements of large-scale activities are comprised of crowd category, places risk factors, environmental risk factors, managing risk factors and inherent characteristic of activities. The crowded category elements include the crowd density, behaviour, mental state, proportion, safety standards of organizers and so on; The places risk factors contain place type, place layout, construction safety, hazardous materials, emergency equipment and re-

sources and so on; Environmental risk factors are the social environment, natural environment, artificial environment which affect the safety function in the operation process of large-scale activities; Managing risk factors include safety institution-building, risk management and control measures, emergency capacity-building as well as related side management; The intrinsic characteristics of large-scale activities need to consider the contents, scope and affection of the activities. The accident mechanism of large-scale activities is due to the balance destruction with risk factors relations. The failure of safety management and the consequences of environmental factors interacts mutation, caused crowds chaos in the building, which led to a large-scale activities accident occurring. The role models, processes and relationship among the risk inscape of large-scale activities often decide to the incidents time, intensity and the extent of damage.

The study about accident risk assessment methodologies of large-scale activities is in Chapter 4 and Chapter 5 this paper. The author put forward the major accident risk assessment procedures and contents for large-scale events based on risk management, including programme assessment, static risk assessment, dynamic risk assessment, management and control analysis, emergency analysis, comprehensive reality risk assessment and so on, The contents about assessment and analysis of every aspect construct the contents system about the accident risk assessment of large-scale activities. For the dynamic risk assessment, the paper presents the accident risk qualitative assessment methods about the crowd gathering places, according to the key words of risk identification, harmful risk factors listed, example analysis methods and so on, which can make assessment methods summed up into seven steps evaluation process with easy. On this basis, the risk index system is established by the characteristic factors, the inherent risk elements and the counteraction factors, and the accident risk assessment model are brought forward to evaluate the relative risk to reality for large-scale events. At the same time, the model uses fire factor, crowd factor and site factor to denotate the fire accident, the crowd trample accident and the construction accident of large-scale activities; three kind of counteraction factors

are consist of evacuation counteraction factor, management counteraction factor and emergency counteraction factor. The indicator values are calculated through their constraints about the relations established. According to the value ranges of the factors, it determines the accident risk of large-scale activities in the range from 0 to 170, and it can be divided into six risk level.

The thesis of chapter 5 analyzes the occurrence reason of hustle trample according to four areas like the motion, dismay, information and environment, and the characteristic of crowd dismay, mental state to respond mode, process description, special swarm phenomenon etc are also studied. The quantitative risk model of crowd trample accident is constructed from the trigger factor, the regional stranded crowd number and the calculating process of death number for the severity of accident. The trigger factor is expressed by the vulnerable population proportion, the attraction of exports and the communication of crowded information; The deaths number in regional stranded crowd is associated with the form, size and duration of the power of crowd trample accident, which the regional stranded crowd number is calculated by the crowd flow coefficient function for the crowd density and the speed of mobile crowd. At present the process of crowd dispersal stranded in a particular region can be calculated by the model stranded number to solve. The deaths number is difficult to determine, which can not be done with experiment or equations, hence it need to rely on computer simulation to solve the problem. The influence of plugged channels to crowd dispersal is further discussed, and it can be confirmed that the traffic flow make complex changes with the crowd density. In lower crowd density, the crowd density is in a positive relationship with the traffic flow; when the crowd density is greater than the critical density, the crowd density is in non-linear relationship with the traffic flow; when the crowd density reaches to the maximum density, the traffic flow was considered as 0. Once the initial crowd density is in  $4/\text{m}^2$  around, it will be difficult to restore the initial flow in case of flow obstruction.

The major control measures of accident risk in large-scale events are put forward in Chapter 6. Such strategies as precautionary management, risk transfer,

risk aversion, self-management and so on are adopted to control accident risk of large-scale activities. The level and scope of risk control should extend the inside of place to the external in large-scale activities. The physical preventive measures and safety management measures of risk control are constituted from the human factor, material factors, environmental factors and management factors.

The case in chapter 8 is the part to verify and prove the research in this dissertation. The procedures, contents, methods system and control measures of accident risk assessment for large-scale events are applied in Shenyang World Horticulture Exposition, identifying and analyzing the accident risk, simulating the key places and regions quantitatively, formulating the prevention and control measures on the basis of the comprehensive evaluation of accident risk. The conclusion validates that it is comprehensive, scientific, rational and good workability of the accident risk assessment method for large-scale events, which can provide technical support for the organizers and risk management staff.

In the last chapter, the contents of this dissertation are summarized, at the same time the conclusions and innovations are put forward including of the suggestions and expectations for further scientific research.

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