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Review of fundamental theories and research prospects of emergency management science from the disciplinary perspective

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Abstract

Emergency management is currently a hot topic in the field of safety and security, yet the foundational theory of the emergency management discipline is still relatively weak. The main goal of this article is to supplement and improve the theoretical foundation of emergency management. Methods such as literature review, theoretical analysis, deduction, and induction were adopted in the investigation. Accordingly, the basic definitions and conceptual system of emergency management are summarized; the research methods and scope of emergency management, the basic rules and general principles of emergency management are suggested; the classification of emergency management and its sub-disciplines are put forward; also, some of China's emergency management systems and experiences are introduced, and some important research topics in current emergency management are prospected. The research results have solidified the theoretical foundation of emergency management and can play an important leading role in the development of the emergency management discipline in the future.

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Introduction

Any discipline needs to have its disciplinary definitions, attributes, basic principles, research methods, and application scope etc. These fundamental theories are also the basis of a discipline for independent existence, and have extremely important significance for developing the discipline to a mature one[1].

Emergency management is an applied discipline, which belongs to the category of both safety and security management and public management. Emergency management has both differences and complementarity with public safety and security management. In theory, emergency management is an important branch of both safety and security science and public management. Therefore, emergency management also requires both safety and security science and public management as its theoretical basis[2].

The development process of emergency management disciplines in Western countries has gone through the stages of germination, formation, mid-term institutional construction and legal improvement, and then rapid development for a long time. At present, the discipline has formed a relatively complete disciplinary system and knowledge, providing a strong talent guarantee and intellectual support for Western countries to respond to various emergencies[3–6].

The discipline of emergency management in China has gone through a process from technology priority, individual exploration and then to coordinated development of government leading, and is currently in a rapid development stage[7–9]. In the past decade, emergency management has become a hot topic in China's safety and security fields. On November 1, 2007, the 'Emergency Response Law of the People's Republic of China' came into effect; In March 2018, China established the Ministry of Emergency Management; In 2020, the Academic Degrees Committee of the State Council of China officially approved the establishment of 'Emergency Management' as a second level discipline under the first level discipline of public management; On June 28, 2024, the newly revised 'Emergency Response Law of the People's Republic of China' was passed and came into effect on November 1, 2024[10].

Emergency management has a long history of development. Although emergency management has rich practical content and a wide range of practical fields and scenarios, the fundamental theory of emergency management at the disciplinary level is still relatively weak. So far, there have been few research papers published on scientific theories, methods, and principles related to emergency management. Therefore, the fundamental theory of emergency management needs to be consolidated and further studied in depth[2] and this is also the goal of the present article.

In the future, with the continuous advancement of the modernization of the national governance system and governance capacity, the discipline of emergency management will continue to play a more important role in providing strong support for responding to various emergencies.

Disciplinary theoretical basis of emergency management

Definitions of emergency management and emergency management science

If interpreted according to the Chinese dictionary, 'emergency' means to deal with urgent needs and is to respond to

sudden and urgent events that require urgent handling. Emergency is a term that can be understood as having both positive and negative meanings. It contains two meanings: objectively, events occur suddenly, and subjectively, it is necessary to urgently handle such incidents. The Chambers Dictionary defines an emergency as an event that suddenly occurs and requires immediate handling.

Sudden events that require urgent handling may not be accurate. 'Urgent' is a subjective feeling of people. For an urgent event, if you think it is urgent, I may think it is not an urgent one. 'Sudden' is an objective description of the process of an event, but 'sudden events' may not necessarily be bad and therefore do not necessarily require emergency response. Therefore, the term 'emergency' in national documents usually refers to serious incidents.

Management refers to the process in which managers in a certain organization coordinate the activities of others by implementing functions such as planning, organizing, leading, coordinating, and controlling, to achieve established goals together with others. It is the most common and important activity among various human organizational activities.

The 'incidents' referred to in emergency management are different from the events in people's daily lives or production activities. Emergency management is usually proposed to deal with larger public security incidents. Incidents in the 'Emergency Response Law of the People's Republic of China' (2024) refers to natural disasters, serious accidents, public health incidents, and social security incidents that suddenly occur, cause or may cause serious social harm, and require emergency response measures to be taken[10]. The scope of emergency management is very broad. In addition to the four major types of emergencies mentioned above, it can also include more emergencies, such as local wars, world economic crises, and global ecological crisis, etc.

The definitions of emergency management have been extensively researched and defined for a long time[3–9]. Based on summarizing those definitions, the author provides the following definition of emergency management: emergency management refers to the activities of the government and other public institutions in the process of incident prevention, incident response, in-process disposal, and post-incident recovery, especially for the incident in the initial stage, by establishing necessary response plans, mechanisms, systems, and legal systems, adopting a series of necessary measures, applying management, planning, technology, education, and other means to ensure the safety and security of public life, health, and properties, and promoting social harmony and healthy development.

Emergency management science is a science that studies the scientific laws and their applications in emergency management. For example, emergency management combines management methods and engineering technology to study management issues such as emergency planning, organization, decision-making, and disposal, to reveal the mechanisms of the incubation, occurrence, and evolution of disaster events, to understand the essential characteristics of emergencies, and to lay the foundation for scientific prevention of serious incidents and ensure the safety and security of people, finance, and properties. Emergency management assesses safety and security risks and takes effective measures to monitor, control, and warn of incidents. Emergency management develops emergency plans and contingency plans for incidents, scientifically carries out emergency rescue and accident disposal, coordinates emergency resource allocation, correctly guides public emergency shelters, evaluates post-disaster recovery capabilities, and scientifically and efficiently carries out post disaster reconstruction. Emergency management reveals the psychological and behavioral characteristics and patterns of people in safety production, corrects unsafe behaviors and develops psychological assistance plans for personnel after disasters and accidents. Emergency management establishes and improves the legal and regulatory protection system for disaster prevention, reduction, relief etc.

Core definition group of emergency management science

Emergency management science involves multiple concepts and definitions, which together form the theoretical foundation and practical framework of emergency management science. Emergency management science is an interdisciplinary field that involves knowledge and methods from multiple disciplines. It is a complex task to comprehensively list all the concepts and definitions of emergency management, and it is also difficult to reach a consensus of all people.

Based on relevant existing information and knowledge[2–9,11], some core definitions of emergency management science can be summarized as follows:

(1) Emergency management: As mentioned above, refers to the general term for the prevention, response, disposal, and recovery activities carried out by the government, enterprises, and other public organizations before, during, and after sudden incidents to protect public life and properties, maintain public security and safety, environmental safety, and social order, etc. It runs through the entire process of incidents, integrating pre - and post- incident management with emergency response during and after the incident.

(2) Sudden incident: As mentioned above, it refers to an emergency event that suddenly occurs and can cause or may cause significant casualties, property damage, ecological environment destruction, and serious social harm, endangering public safety and security.

(3) Risk assessment: It conducts probability analysis and consequence assessment of the risks of possible incidents to determine their potential impact and likelihood of occurrence, providing a basis for developing emergency plans and allocating emergency resources, etc.

(4) Emergency plan: It is a pre-formulated action plan for the rapid and orderly implementation of emergency actions in response to possible incidents.

(5) Emergency resources: These refer to various human, materials, finance, and other resources used to respond to incidents, including rescue teams, material reserves, transportation, medical aid, etc.

(6) Emergency response: The process of quickly initiating emergency plans, organizing rescue operations, controlling the development of the situation, and reducing losses in the sudden incident. It includes emergency command, resource allocation, on-site disposal, and other links, etc.

(7) Emergency command: It refers to the process of unified command and coordination of emergencies, with the aim of ensuring that all emergency work is carried out in an orderly manner and maximizing emergency efficiency.

(8) Emergency drill: It refers to various activities that simulates actual situations and organizes relevant personnel to conduct emergency response to possible emergencies, aiming to test the feasibility and effectiveness of emergency plans and improve the collaborative combat capabilities of emergency teams.

(9) Recovery and reconstruction: These refer to the process of taking measures to restore production and life to normal or further improve after the handling of emergencies, including clearing ruins, disinfection, decontamination, assessing losses, insurance compensation, restoring production and life, post disaster reconstruction, etc.

(10) Psychological intervention and counseling: Psychological support and services provided to victims of emergencies, their families, rescue personnel, and other groups to reduce psychological trauma, and promote psychological recovery, etc.

Strong correlative definition group for emergency management science

Based on relevant existing information and knowledge[2–9,11], some strongly relevant definitions in emergency management science can be summarized:

(1) Risk management: It refers to the process of identifying, assessing, controlling, and handling risks associated with unexpected bad events, to reduce the probability and the impact of such events.

(2) Emergency warning system: It is a system that utilizes modern science and technology to monitor and predict potential disasters in real-time, and issues warning information in advance, to raise public and relevant departments awareness of disasters and take timely preventive measures.

(3) Emergency communication guarantee: These are measures and mechanisms to ensure smooth communication among emergency command, rescue teams, and relevant departments are crucial for rapid response and effective handling of emergencies.

(4) Emergency monitoring and surveillance: These are the real-time monitoring and surveillance of the scene of emergencies through technological means, obtaining accurate information to support decision-making and action, etc.

(5) Emergency coordination mechanism: It is a working mechanism and process for different departments and institutions to collaborate and cooperate in the process of responding to emergencies, ensuring efficient allocation of resources and orderly implementation of actions.

(6) Social mobilization and participation: In the process of responding to emergencies, it is necessary to mobilize various sectors of society to actively participate in rescue and recovery work, to enhance social cohesion and improve emergency response efficiency.

(7) Emergency legal and regulatory system: These are the collections of laws, regulations, policy documents, and standard specifications related to emergency management, providing legal protection and policy guidance for emergency management.

(8) Emergency material reserve and management: These include various materials (such as food, medicine, rescue equipment, etc.) that are reserved in advance to respond to emergencies and their management processes, to ensure that the necessary materials can be quickly allocated and used in the emergencies.

(9) Emergency education and training: These include the emergency knowledge popularization and skill training targeted at the public, emergency management personnel, rescue teams, and other groups to enhance the emergency awareness and self-rescue and mutual rescue capabilities of the whole society.

(10) Public safety and security management: It can be summarized as the management activities adopted by the government or relevant organizational departments within the scope of relevant laws and regulations, involving personnel, materials and events related to the overall national and social safety and security, to achieve the desired level of safety and security.

The above definitions together constitute the connotation and extension of emergency management science. In practical applications, these definitions are interrelated and interact with each other, jointly supporting the effective implementation of emergency management work.

Research methods and scope of emergency management science

Research methods for emergency management

Emergency management research usually needs to apply many relevant theories and methods from multiple disciplines such as systems science, management science, safety and security science, engineering science, behavioral science, information science, psychological science, disaster science, health science, public security science, and social science, etc. Common research methods include[12]:

(1) Observation and analysis method: It is a method for researchers to examine natural phenomena under natural conditions, and it is also a method for contemporary people to initially perceive safety and security risks and understand scientific laws of safety and security.

(2) Experimental method: It is an effective method for people to consciously control or simulate natural phenomena and reproduce natural laws under artificial conditions. This special experimental process provides a sufficient basis for refining various knowledge systems of emergency management. In fact, accidents happened in various industry processes and engineering fields are also more extensive and authoritative experiments than these in laboratories except the conditions that cannot be controlled.

(3) Simulation method: It is a supplement to experimental method, which is an indirect experiment on the natural phenomena or processes, especially for the situation that is not allowed to make real experiments.

(4) Comparative method: The complex world of motion has extremely diverse forms and their connections are very extensive. By using logical comparison methods to determine the differences and similarities among research objects, people can understand the identities and differences of the objects, learn the relationship of the objects, and predict the varying potential of the objects.

(5) Analogy method: In nature, some different affairs have different contents, but may also have some common forms and relationships. Based on the similarities between the two types of research objects in certain aspects, it can be inferred that they may also be similar or identical in other aspects.

(6) Logical analysis method: By starting from the possible or already occurring accidents in the system, people can analyze the causes of the accidents until they cannot be further decomposed, and list the causal events that led to the accidents layer by layer according to the logical relationship of causality, then simplify and calculate this model to conduct qualitative or quantitative risk analysis, identify various possible paths and probabilities of the events, and propose targeted plans and measures to avoid accidents.

(7) Qualitative and quantitative analysis methods: These are the methods by transitioning from initial qualitative description to quantitative analysis and precise measurement. The mathematical methods involved include Bayesian estimation, artificial neural network, Monte Carlo simulation, cluster analysis, analytic hierarchy process, and fuzzy comprehensive evaluation, etc.

(8) Quantitative analysis methods: These methods have some advantages in emergency management research and can provide important supplements for the analysis of emergency management mechanisms or comparative studies of cases, etc.

(9) Case study method: It is a commonly used method in emergency management research, which emphasizes the analysis of the structure of accident occurrence and response processes and reveals the inherent laws of emergency management through the construction of theoretical models.

(10) System analysis method: The method regards emergency management as a complex system, revealing the interaction relationships among various elements in the emergency management system, as well as the interaction between the system and the environment.

(11) Risk assessment methods: These methods intend to assess the likelihood of an emergency occurring and the severity of its consequences. Common risk assessment methods include expert consultation, the Delphi method, the risk matrix method, etc. These methods quantitatively assess the risk of emergencies by collecting and analyzing relevant information, providing a scientific basis for emergency decision-making.

(12) Predictive analysis methods: They are used to predict key indicators such as the probability of occurrence and degree of loss of unexpected events.

(13) Interdisciplinary research methods: Emergency management research involves multiple disciplinary fields and interdisciplinary research methods emphasize the comprehensive application of theories and methods from different disciplines to study emergency management issues.

Scope of emergency management research

The main research contents of emergency management are the management methods and disposal measures for prevention and response to natural disasters, serious accidents, sudden public health emergencies, and social security incidents, etc. Natural disasters include floods and droughts, meteorological disasters, earthquakes, geological disasters, marine disasters, biological disasters, etc; Serious accidents include major safety accidents in industrial and commercial enterprises, major transportation accidents, major failures in urban lifeline engineering, nuclear and radiation accidents, environmental pollution and ecological damage events, etc.; Public health incidents include pestis, cholera, SARS, COVID-19, mass diseases of unknown causes, food poisoning in large numbers of people, drug safety events, radioactive pollution events, etc.; Serious social harms include terrorist attacks, ethnic and religious conflicts, financial crises, market turbulence, international political and military conflicts and sudden incidents of online public opinion, etc.

By reviewing the relevant content in the literature[2–11], the basic contents of the research scope of emergency management are as follows:

(1) Basic theories and policies and regulations: These include studying the basic concepts, principles, frameworks, and models of emergency management to provide theoretical guidance for emergency management practice, exploring the policy and regulatory system of emergency management, including national laws and regulations, local regulations, as well as international conventions and treaties, and analyzing their impact and role on emergency management practices.

(2) Disaster risk assessment and management: These include using modern technological means (such as geographic information systems, remote sensing technology, etc.) to identify, assess, and analyze potential risks of various disasters, and predict the possible impacts of disasters, and developing effective risk control and mitigation strategies (management measures for various stages such as disaster prevention, emergency preparedness, emergency response, and post-disaster recovery) based on the results of risk assessment.

(3) Emergency response and rescue technology: These processes are intended to study how to develop scientific, reasonable, and feasible emergency plans, continuously optimize and improve them in practice, and explore the management mechanism and methods of emergency plans to ensure their effectiveness and operability, to develop and apply advanced rescue equipment and technical means to improve the practical ability and rescue efficiency of rescue teams, to utilize information technology (such as big data analysis, artificial intelligence, etc.) to enhance the real-time and accuracy of emergency response, providing strong support for rescue decision-making.

(4) Emergency resource allocation and optimization: These include accurately evaluating and classifying available emergency resources (personnel, materials, equipment, and funds), using optimization algorithms and decision models (such as artificial intelligence-based prediction models, genetic algorithms, etc.) for resource allocation, ensuring that resources can be quickly and effectively invested in the most needed areas in complex and changing disaster situations.

(5) Social psychology and disaster psychology intervention: These include enhancing the public's emergency awareness and self-rescue and mutual aid capabilities, and strengthening the public's emergency preparedness level through publicity, education, drills, and other activities. During the post-disaster recovery phase, psychological intervention, and counseling are provided to the affected population to help alleviate psychological stress and post-traumatic stress disorder.

(6) Emergency management in specific fields: These include emergency management and control of public health incidents such as infectious disease outbreaks and food safety, research of emergency management and restoration measures for ecological environment emergencies (such as environmental pollution, ecological damage, etc.), emergency management and disposal of accidents that may occur during the production, storage, transportation, and other processes of hazardous chemicals.

(7) Emergency management of natural disasters: These mainly include providing scientific management theories and methods for responding to major natural disasters such as droughts, floods, typhoons, storm surges, frost damage, hail disasters, tsunamis, earthquakes, volcanoes, landslides, mudslides, forest fires, etc.

(8) Emergency management of industrial accidents: These mainly include providing scientific management theories and methods for responding to various safety accidents, public facility and equipment accidents, transportation accidents, nuclear radiation accidents, ecological damage, and environmental pollution and other sudden major industrial accidents in chemical, mining, commercial, and other enterprises.

(9) Emergency management of social public events: These mainly include providing scientific management theories and methods for responding to economic security events, major group violations, terrorist attacks, infectious disease outbreaks, mass unexplained diseases, food safety, and occupational hazards, as well as other events that seriously affect public health and life safety.

General rules and principles of emergency management

General rules of emergency management

The general rules of emergency management refer to the basic guidelines that should be followed when responding to emergencies. These rules aim to ensure the scientific, standardized, effective, and sustainable nature of emergency management work. By reviewing the relevant content in the references[2–11], the following common general rules of emergency management are derived:

(1) Prioritizing people and valuing life above all else: This rule means that it should prioritize the protection of public life safety and physical health, minimize casualties caused by emergencies to the greatest extent possible, and prioritize the protection of human life safety in emergency decision-making and actions.

(2) Prioritize prevention, integrate preparedness for both peacetime and wartime: This rule emphasizes the importance of prevention, improves the ability to prevent and respond to emergencies through measures such as risk assessment, hidden danger investigation, and contingency plan formulation, and integrates emergency management into daily work to achieve an organic combination of prevention and emergency response.

(3) Unified leadership and hierarchical responsibility: This means that it should, under the unified leadership of the highest leadership body, governments at all levels, and their departments are responsible for emergency management work according to their respective responsibilities. It should establish a sound emergency management system with a hierarchical responsibility and local focus, ensuring effective allocation of emergency resources and unified coordination of emergency command.

(4) Quick response and collaborative response: This means that it should establish a rapid response mechanism to ensure that emergency plans can be quickly activated, and emergency responses can be carried out in the incidents, strengthen the coordination and cooperation among departments, regions, and military-civilian areas to form a joint force to respond to emergencies.

(5) Comply with laws and regulations, make scientific decisions: This means that it should carry out emergency management work in accordance with the law, ensuring that all emergency measures and actions comply with the requirements of laws and regulations; and utilize scientific methods and advanced technologies for risk assessment, monitoring and early warning, decision support, and emergency rescue, to enhance the scientific and effective nature of emergency management.

(6) Information disclosure and social participation: This means that it should be timely, accurately, and comprehensively release of emergency information to the public's right to know, encourage social organizations and the public to participate in emergency management work to form an emergency management pattern of government leading and society involving.

(7) Resources coordination and strong guarantee: This means that it should coordinate the utilization of various emergency resources, including manpower, material resources, financial resources, etc., to ensure the effective allocation and efficient use of emergency resources, and strengthen emergency material reserves and infrastructure construction to enhance emergency support capabilities.

(8) Continuous improvement and capability enhancement: This means that it should continuously summarize experiences and lessons learned, improve emergency management systems, mechanisms, and policy measures strengthen the construction, training, and drills of emergency teams, and improve the professional quality and response capabilities of emergency management and rescue personnel.

The general rules above provide a basic framework and guidance for emergency management work, helping to ensure the smooth implementation and effective execution of emergency management work. In practical work, these rules should be flexibly applied according to specific situations, and constantly improved and adjusted to adapt to new situations and task requirements.

Fundamental principles of emergency management

The fundamental principles of emergency management are the methodology of reducing natural disasters, serious accidents, transmit illness, and social security incidents, etc. Emergency management science requires the full absorption of the relevant theories and methods from other disciplines such as safety and security science, systematology, management science, law, and political science, etc. By reviewing the relevant content in the references[2–11], the following fundamental principles are derived, which together constitute the guiding ideology and action guidelines for emergency management.

(1) The principle of whole process management: Emergency management is the activity of managing the entire process of emergencies, including prevention and emergency preparedness, monitoring and early warning, emergency response and rescue, and post-recovery and reconstruction. These four processes are interrelated and mutually supportive, and together constitute a complete system of emergency management. Effective emergency planning is a continuous process.

(2) The principle of multi-agent participation: Emergency management involves not only the government and its public

institutions, but also multiple entities such as enterprises, social organizations, and the public etc. These entities play different roles and responsibilities in emergency management and work together to respond to emergencies.

(3) The principle of scientific response: Emergency management emphasizes scientific response, which means using scientific, technological, planning, and management methods to predict, warn, handle, and recover from emergencies. This requires emergency managers to have rich professional knowledge and practical experience, so that they can quickly make correct decisions and actions in the event of emergencies.

(4) The principle of prevention first: Emergency management should focus on prevention work, strengthen the prevention and control of risk sources and monitoring and early warning work through the establishment of a sound emergency management system and plan, and strive to eliminate emergencies in their infancy or reduce their probability and degree of harm. Even if emergencies occur, the principle of prevention first is still useful to avoid the expansion of emergencies.

(5) The principle of comprehensive coordination: Emergency management requires the comprehensive coordination of resources and forces from all aspects, including manpower, material resources, financial resources, etc. In the process of an emergency, emergency managers need to quickly mobilize relevant resources and forces for coordinated operations and effective response. Planning should address cross organizational coordination issues and integrate the single disaster plans managed by each community into a comprehensive management approach for dealing with multiple disasters.

(6) Principles of information disclosure and communication: Emergency management emphasizes the importance of information disclosure and communication quickly. In the process of an emergency, emergency managers need to promptly release relevant and correct information to the public, maintain communication and interaction with the public, to stabilize social emotions, and reduce panic and misunderstandings.

(7) Principle of legal protection: Emergency management activities need to be carried out in accordance with the laws to ensure that all emergency measures and actions comply with the requirements of laws and regulations. At the same time, emergency management also requires the establishment of a sound legal system to provide strong legal support and protection for emergency management work.

(8) Real-time dynamic adjustment principle: Emergencies often have complexity and unpredictability, and all elements are dynamic. Various dynamic elements are coupled together, making the entire system also have dynamic characteristics. This principle emphasizes dynamic adjustment and optimization of contingency plans based on real-time data and actual situations to improve their practicality and operability. It must be acknowledged that all disasters create a dynamically changing environment, and planning cannot cover all possible unexpected situations related to future disasters.

(9) The principle of adapting measures to local conditions: This principle emphasizes the full utilization of local resources and conditions in emergency management. In response to significant differences in human resources, material reserves, infrastructure, rescue capabilities, and other aspects that exist in different regions, reasonable allocation and utilization of these resources can improve the speed and efficiency of emergency response and reduce emergency costs. It should encourage the emergency management personnel to take appropriate actions in the process of emergencies.

(10) The principle of combining management, technology, equipment, and resources: The organic combination of management, technology, equipment, and resources can significantly enhance emergency response capabilities. Through scientific management and advanced technological means, rapid perception and accurate judgment of emergencies can be achieved. With professional equipment and sufficient resource support, efficient and orderly emergency actions can be ensured.

Classifications of sub-disciplines of emergency management science

Emergency management science is an interdisciplinary field that involves a wide range of aspects. If decomposed from two dimensions: theory–technology–equipment and disciplinary science – professional science – relative science (i.e. upper – middle – lower), the disciplinary classifications of emergency management science is shown in Fig. 1, which can also be referred to as the nine-grid model of emergency management disciplines[13].

Figure 1 represents the relationship among core science and technology disciplines, adjacent science and technology disciplines and extended science and technology disciplines in emergency management science. It should be pointed out that there is no clear boundary among all disciplines, and they all intersect and support each other, requiring collaborative development. Figure 1 can be used to classify the levels and types of emergency management practitioners and predict the number of market demand of those practitioners, as well as whether they are working in the core entities of emergency management or subsidiary one.

If starting from the time dimension of emergency management, it can also form another disciplinary classification of emergency management science[3–9] as follows:

(1) Emergency preparedness science: It is suitable for the pre-stage of emergency management, and the main contents involve the development of emergency plans, risk assessment, identification of potential hazards, a reserve of emergency resources and training of emergency teams, etc.

(2) Emergency response science: It is suitable for the stage in which emergency plans are quickly activated, emergency resources are mobilized, effective measures are taken to control the development of the situation and losses and impacts are reduced after an incident occurs. The contents include quickly activating emergency plans and establishing emergency command structures, organizing personnel evacuation and rescue operations, allocating emergency supplies and equipment, carrying out on-site disposal and rescue work, timely releasing emergency information, and guiding the public to take correct response measures, etc.

(3) Emergency recovery science: It is suitable for the stage of post disaster reconstruction, restoration of production and living order, assessment of losses, and summary of experiences and lessons learned after the incident. The main contents include to repair damaged infrastructure and public facilities, provide temporary shelter and living safety, carry out post-disaster psychological assistance and rehabilitation work, assess losses and impacts, develop recovery and reconstruc-

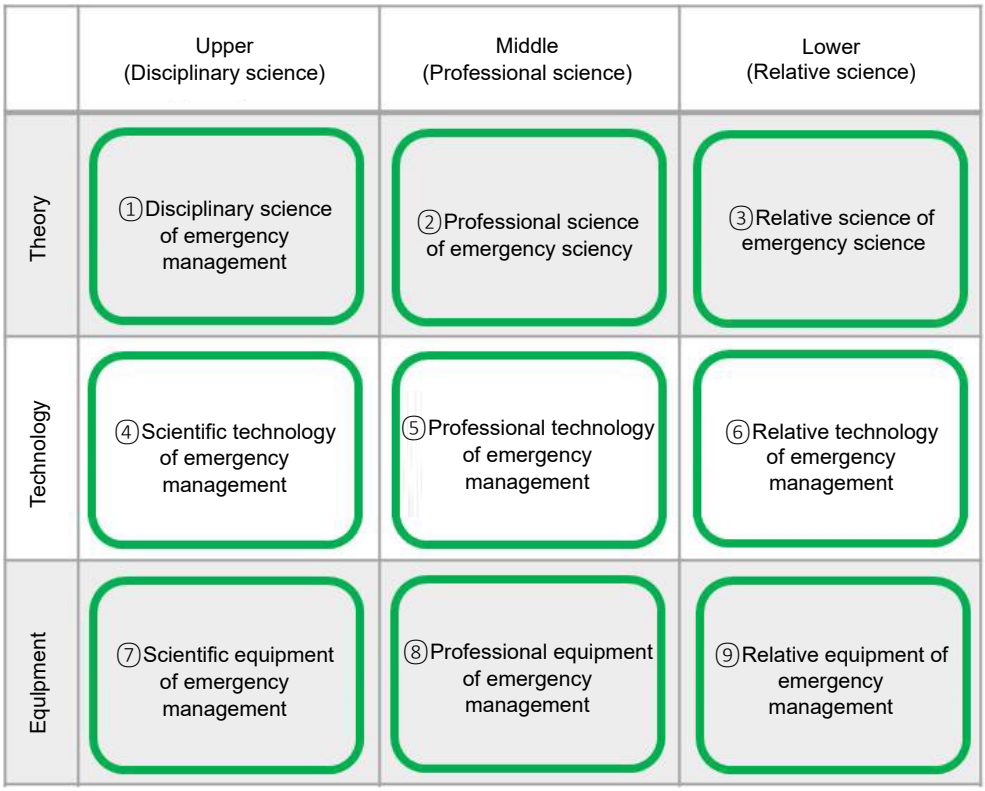

Fig. 1 Nine-grid model of classifications of emergency management disciplines.

tion plans, summarize experience and lessons learned, and improve emergency plans and emergency management systems, etc.

(4) Emergency systems science: Under the framework of emergency management, the emergency management should be regarded as a comprehensive system used to respond to incidents. This system includes multiple components, such as emergency command system, emergency plan system, emergency resource allocation system, emergency communication system, etc., which work together to ensure rapid and effective response in emergencies. In practical applications, the construction and operation of emergency systems require multidisciplinary knowledge and technical support to achieve efficient and orderly emergency management.

If starting from the dimensions of the key elements involved in emergency management, it can also form a disciplinary classifications of emergency management science[3–9] as follows:

(1) Emergency management basic theory: It refers to the knowledge framework and theoretical system of the emergency management discipline composed of concepts, definitions, characteristics, attributes, basic tasks, principles, methods, systems and mechanisms, system theory, risk management theory, crisis management theory, etc. in the field of emergency management.

(2) Emergency technology: It refers to the application of scientific and technological methods to improve the efficiency and effectiveness of emergency management and ensure the safety of public life and properties. The main contents include emergency communication technology, emergency monitoring technology, emergency rescue technology, and emergency decision support technology, etc.

(3) Emergency industry: It refers to the industrial field that provides products, technologies, and services to respond to emergencies, including the research and production of emergency equipment, the provision of emergency services, emergency training and drills, etc.

(4) Emergency resources: It refers to the sum of various resources such as manpower, materials, funds, facilities, information, and technology required by the emergency management system to effectively carry out emergency activities and ensure the normal operation of the system. It requires comprehensive consideration of various resources to respond to emergencies. At the same time, emergency resources also need to pay attention to issues such as resource integration, scheduling, and configuration to ensure rapid and effective response in case of emergencies.

(5) Emergency policies and management: It is a disciplinary field that studies the formulation, implementation, and evaluation of emergency management policies, including research on laws and regulations, policy systems, management systems, and operational mechanisms of emergency management.

(6) Emergency psychology and behavior studies: It is a discipline that studies change in human psychology and behavior during emergencies, including research on the emergency psychological responses, emergency behavior patterns, emergency psychological interventions, and other aspects.

(7) Emergency management informatics: It is a discipline that mainly focuses on the collection, processing, analysis, transmission, and utilization of information in the process of emergency management. It utilizes theories and technologies from information science, management science, computer science, and other related disciplines in the field of emergency

management to effectively manage relevant information before and after incidents, to improve emergency response speed, decision-making efficiency, and disposal capabilities.

The branches above are interrelated and interact with each other, together forming a complete system of emergency management science.

China's emergency management system and experiences

The research history of emergency management in China can be divided into several stages as follows:

From 1949 to 1978, China established some specialized institutions and high-level coordinating bodies to address natural disasters. However, the main response was still focused on specialized departments dealing with a single type of disaster. The research on emergency management mainly focused on the field of disaster management, and a systematic discipline system for emergency management has not yet been formed.

From 1978 to 2003, with the increase of social and economic activities, the uncertainty of risks also increased, requiring multiple departments to cooperate in responding to emergencies. China established multiple coordination institutions, and temporarily formed command centers when major emergencies occurred. However, it has not yet shaken off the single disaster response mode. Research on emergency management had begun to focus on multi-department collaborative response mechanisms, but the research contents were still relatively scattered and had not formed a unified research system.

Since 2003, the outbreak of SARS in 2003 had become a catalyst for the construction of emergency management systems; In 2005, the State Council issued the 'Overall Emergency Plan for National Public Emergencies', and some universities and research institutions began to standardize and systematize the construction of emergency management, built several emergency management disciplines or research centers, and the emergency management education and training system gradually improved. Research on emergency management gradually deepened, covering early warning, emergency response, recovery and reconstruction, etc; In 2014, China emphasized the importance of coordinating external and internal security, homeland security and national security, traditional and non-traditional security. The discipline of emergency management entered a period of high-quality coordinated development, and the establishment and enrollment scale of emergency management majors continued to expand, forming a relatively complete discipline system. Research on emergency management has diversified research directions and achievements, and the application of information technology and intelligent technology in emergency management research is becoming increasingly widespread, promoting the modernization and intelligent development of emergency management[14–17,20,23–28].

Generally, the development of emergency management in China has achieved great progress in recent decades. Some typical achievements and experiences are summarized in this section.

China's emergency management system is one of obviously effective examples, that is with the goal of 'all types of disasters and systematic emergencies', building an advanced pattern of 'one committee (one center), five features, and six guarantees' as below[14,15]:

(1) Establishing a national emergency management system under the unified leadership of the Central Emergency Management Commission (National Comprehensive Emergency Command Center), highlighting the authority, overall planning, coordination, and foresight of the Emergency Management Commission, and taking the construction and action of the Emergency Command Center as the starting point.

(2) Building an emergency management framework that covers all types of disasters, processes, directions, societies, and globalization (so-called the 'five features'), including responding to all types of emergencies (natural disasters, serious accidents, public health incidents, and social security incidents), complete process planning for four management stages (prevention and emergency preparedness, monitoring and early warning, emergency response and rescue, recovery and reconstruction), comprehensive design for all scenarios (land, sea, air, and space by virtual and real approaches),social forces and market mechanisms involved the entire society and coordinated construction from a global perspective.

(3) Comprehensively building six major guarantee capabilities including human, finance, material, technology, information, and laws[14].

The emergency plan (one plan), emergency management system, mechanism system, and legal system (three systems) are collectively referred to as the 'one plan, three systems', which together constitute the basic framework of China's emergency management system. The 'one plan, three systems' is a comprehensive system based on four dimensions in which the system is the foundation, the mechanism is the key, and the legal system is the guarantee, and the contingency plan is the premise. They have different connotations, characteristics, and functional positioning, and are inseparable core elements of the emergency management system. At present, the construction of China's emergency management system is carried out according to the basic idea of system priority to improve relevant work processes and institutional norms based on streamlining the emergency management system[15].

The establishment of China's emergency response plan for public incidents follow six principles: 1) Putting people first and reducing harm; 2) Being prepared for danger in times of peace and prioritize prevention; 3) Unified leadership, hierarchical responsibility; 4) Standardizing according to law and strengthening management; 5) Quick response and collaborative response; 6) Relying on technology to improve quality.

For specific accidents, disasters, incidents, etc., the principles followed are flexible and varied and need to be established based on specific emergency principles, practical experience, local situations, etc. Here are some examples:

(1) Eight principles for managing negative public opinion in comprehensive emergency rescue: 1) The principle of regularly enhancing 'risk immunity'; 2) The principle of avoiding 'endogenous risks' by internal risk control approach; 3) The principles of synthesis operations of new media; 4) The principle of maximizing communication effectiveness and service efficiency; 5) The principle of seizing the opportunity of 'information propagating ways'; 6) The principle of improving the quality and efficiency of emergency communication; 7) The principle of 'two links' between the practical scene and the public opinion field; 8) The principle of accurately grasping social mentality[16].

(2) Four rules for guarantee of emergency resources and distribution during major public incidents: 1) The guarantee of

emergency resources should adopt the principle of prioritizing regeneration and widening channels; 2) The procurement of emergency resources should adopt the principle of simplifying processes and strictly controlling prices; 3) The consumption of emergency resources should adopt the principles of pre-registration monitoring and strict post verification; 4) The allocation of emergency resources should adopt the principles of full trust of the main responsible person and avoidance of responsibility without intentional negligence[17].

(3) The four principles of emergency response for highway traffic in China are: 1) the principle of legal management; 2) The principle of putting people first; 3) The principle of prevention first; 4) The principle of prioritizing effectiveness.

(4) The two principles of storage management of relief resources for disaster reduction are: 1) to do a good job in the management of material procurement, warehousing, storage, outbound, and maintenance; 2) According to the principles of 'classified management, scientific management, and standardized entry and exit'.

In the aspects of emergency management education, China has been developing for decades. Before 2003, emergency management work mainly focused on the prevention and response to natural disasters, and the emergency management system was not yet perfect. As mentioned above, in 2003, the fight against the SARS epidemic exposed the shortcomings of China's emergency management. To strengthen the emergency management system and capacity building, China began emergency management education and training for leading cadres. The big earthquake in Wenchuan in 2008 further accelerated the development of emergency management education, and the construction of emergency management disciplines and majors was developed. Universities such as Jinan University and Henan Polytechnic University established emergency management colleges and launched emergency management majors. Relevant departments also held various emergency management thematic seminars, training courses, etc. The establishment of the Ministry of Emergency Management in 2018 has provided a broader space and more solid support for the development of emergency management education. The undergraduate and graduate majors in emergency management at universities have developed rapidly, making positive contributions to promoting the development of emergency management in China.

Some important current research areas of emergency management science

The main important fundamental research areas of emergency management at presented are as follows.

Basic theories and technical methods of emergency management

This mainly includes the mechanism of incubation, occurrence, development, and evolution of serious accidents and emergencies, as well as their new control methods; theoretical analysis of the causes of accidents and disasters, coupling mechanisms of related chains and simulation of their evolutionary pathways; simulation and optimization technology for emergency management process of incidents; coupling and optimization techniques for the components of emergency management systems; investigation of the vulnerability of emergency management systems; methodology of emergency management research; technical methods for ensuring safety throughout the entire lifecycle of urbanization process; corporation and social security governance policies and their long-term mechanisms; the intrinsic safety technologies of industrial and social systems, etc.[18–20].

Basic theories and methods of emergency decision-making under complex conditions

Multi-objective, multi-stage, multi-factors, and multi-emergency decision-making theory and methods

This mainly includes: theory and methods of multi-objective emergency decision-making; theory and methods of multi-stage emergency decision-making evaluation; dynamic optimization theory and methods for multi-factor emergencies decision-making; emergency decision-making theory for unconventional emergencies; comprehensive decision support theory and methods for multi-event coupling and scenario construction; comprehensive emergency decision-making methods and technologies based on data integration processing, comprehensive prediction and warning, comprehensive risk analysis, psychological behavior analysis, and distributed model deduction, etc.[21].

Emergency decision-making assistance methods and their systems

This mainly includes the principles and processes of emergency decision-making, simulation models and methods; the composition principle and implementation method of the security decision expert support system; the principles and implementation methods of emergency decision support intelligent system; development and management strategies for a scenario simulation database of production accidents and emergencies; system modeling and analysis methods in emergency management based on artificial society theory[22].

Social science issues in emergency management

This mainly includes social ethical and moral elements and standards of emergency management; the disciplinary and social attributes of emergency management; research on the social driving forces and impact mechanisms of emergencies; the social impact and transmission mechanism and channels of the public incident; research on social risks and control of public incidents; construction of emergency management laws, regulations, and standard systems; research on the maintenance and response capability of the emergency management systems; construction of social dynamic mechanisms and models for emergency management; research on the mechanism and technology of social ideological and cultural communication in emergency management; audit systems and technical construction for emergency management behavior; emergency management economic models and benefit measurement techniques, etc.[23,24].

Basic theories and methods of emergency rescue information processing

Emergency response information processing and management for public incidents

This includes research on the formation mechanism, collection method, and transmission mechanism of information flow in emergencies; research on identification, detection, and analysis models of information feature parameters; methods for establishing and maintaining emergency system information

transmission channels; methods for obtaining emergency rescue information for public incidents; principles and methods of emergency response information processing for public events; research on the principles and approaches of emergency rescue information dissemination and diffusion based on different theories, the mechanism of information dissemination and evolution based on complex semantic chain networks, and the mechanism of multi-channel, fast, and accurate information transmission and release; mechanism and methods for sharing emergency rescue information; emergency rescue network information management and security, etc.[21].

Emergency rescue communication methods and command

This includes emergency communication and information collection, processing, and dissemination methods for incidents; new efficient sensors and their microelectronic integration; sensor data collection and spatial positioning in disaster environments; the theory and methods of multi-sensor collaboration and multi-sensor information fusion; full-frequency emergency communication methods and technical systems; emergency information visualization management systems; emergency positioning and search support application systems; development of emergency rescue information management systems and comprehensive command and dispatch systems, etc.[22].

Theory of collecting and analyzing emergency intelligence information based on big data technology

This includes the theory and methods of integration, mining, and fusion of massive data based on big data technology; development and system construction of emergency precursor warning technology based on big data technology; principles and methods of network data and information mining; fusion modeling and information processing methods for incomplete information; the relationship between abnormal data and disaster mechanisms, etc.[22].

Emergency rescue technology methods and systems

Basic theory and equipment for general emergency rescue

This includes key technologies for rescue equipment with features such as large-scale, lightweight, convenient, efficient dismantling and high-altitude; integrated emergency support systems and equipment for daily necessities; emergency transportation and logistics engineering; mechanisms and technology of intelligent mobile emergency rescue and resettlement complex; specialized emergency rescue technology and equipment, etc[24].

Specialized emergency rescue equipment and devices

This includes sensing theory and equipment based on real-time disaster monitoring and identification of mid- to low-altitude aircraft; the principle and equipment of mobile non-contact detection of toxic and harmful substances; research and development of equipment for detecting and monitoring characteristic physical parameters; microclimate and environmental monitoring technology and equipment for emergency sites; basic theory and equipment systems of emergency rescue and shelter; emergency behaviors and mechanisms for public health emergencies; the formation and spread mechanism of infectious diseases in emergency areas and their prevention and control methods; the mechanism by which disasters trigger public health and social security incidents; large-scale epidemics and their mechanisms for spreading social rumors etc.[24].

Basic theory and key equipment for emergency rescue of industrial accidents

This includes the formation mechanism of accidents and disasters in high-risk and special industries, as well as their emergency rescue system and response; basic theories, technologies, and equipment for major disaster prevention and control in industrial production; theory, technology, and equipment for emergency response to nuclear industry accidents, etc.[24].

Emergency evacuation of personnel during incidents

This includes the behavioral patterns and characteristics of groups during public incidents; dynamic mechanisms and simulation methods for crowd evacuation in emergency situations; the evacuation behavior patterns and disturbance mechanisms of personnel in complex environments and large-scale groups; theory and methods of public evacuation and rescue in different spatial scale zones; dynamic simulation technology and optimization theory for large-scale personnel evacuation routes; dynamic adjustment method for personnel evacuation strategy based on the evolution law of disasters; principle and design method of emergency evacuation dynamic visualization monitoring system; development of emergency evacuation support equipment and facilities under extremely harsh natural conditions, etc.[24–25].

Basic theories and key technologies for post disaster recovery and reconstruction in emergencies

This includes theories and methods of rapid restoration of post disaster for public health and social management systems, as well as key technologies for major epidemic disease prevention and control; emergency of post-disaster reconstruction and post-evaluation technology for public incidents; rapid assessment methods and technologies for disaster impacts and losses; evaluation and optimization methods for post-disaster recovery and reconstruction investment; theory and methods for rapid diagnosis and reconstruction of infrastructure security; technologies for ecological environment restoration and reconstruction, industrial and agricultural restoration, and reconstruction; mechanism and technology of lifeline and production line restoration; post-disaster environmental pollution assessment and control, dynamic monitoring, and effectiveness evaluation methods for restoration and reconstruction; comprehensive integration of post-disaster recovery theory and key technologies for urban agglomerations etc.[24,26,27].

Basic theory of personnel safety psychology and behavior

This includes cognitive mechanisms and psychological analysis of personnel operational behavior in industrial systems; the psychological and evolutionary mechanisms of safety management and emergency behavior; psychological causation mechanisms and prevention of safety accidents/incidents; the principle and mechanisms of human-machine matching in large-scale complex systems; psychological mechanisms and differences in individual and group safety management and emergency behavior; the mechanism of safety psychological

dynamics and its evaluation theory and methods; the psychological and behavioral characteristics and patterns of individuals and groups in human-machine interaction activities in complex industrial systems; the index system and methods for evaluating the occupational adaptability of industrial system operators, as well as the theory and methods for intervention and improvement; the psychological and behavioral characteristics and patterns of individuals and groups in human-computer interaction activities; theory and methods for assessing, adjusting, and improving the safety and occupational adaptability of homework personnel; methods of psychological assistance after major disasters and accidents, etc.[24,28,29].

Emergency psychology and behavior of personnel during emergencies

This includes the public crisis/disaster awareness and psychological change patterns; the impact mechanism of crisis/disaster environment on public behavioral ability, as well as the role mechanism of stress environment on individual psychology; public psychological behavior prediction and intervention mechanisms; psychological changes and interventions for emergency personnel; the psychological mechanisms of cognition, emotions, attitudes, and needs of key participants such as managers, rescue personnel, and the public in emergency situations; the behavioral patterns, structural characteristics, and intervention methods of groups during emergencies; mechanism and prevention of the impact of emergency conditions on the behavioral abilities of emergency personnel; personnel emergency psychology and behavior management for incidents, etc.[24,30–32].

Emergency science and technology of low-altitude economy

With the rapid development of new energy, new materials, internet of things, artificial intelligence, and especially unmanned aerial vehicle technology, new possibilities have been provided for the diversified development of the low altitude economy. The low-altitude economy has become a promising new economic growth point in the world. Unmanned drones have been constantly expanded for use in the field of low-altitude economic activities, including industry, logistics, transportation, tourism, meteorology, geography, medical care, sports, emergency response, and disaster reduction in addition to traditional military, national security, rescue, surveying, agriculture, etc.[33]. However, low altitude economic activities are also accompanied by a large number of safety and security issues in unmanned drones, traffic, entire industry chain, production activities, malicious use of aircraft, etc. Its emergency management and technology urgently need systematic and in-depth research.

Structural model of emergency management science

The disciplinary system structural model of emergency management science constructed based on the above contents of all sections is shown in Fig. 2.

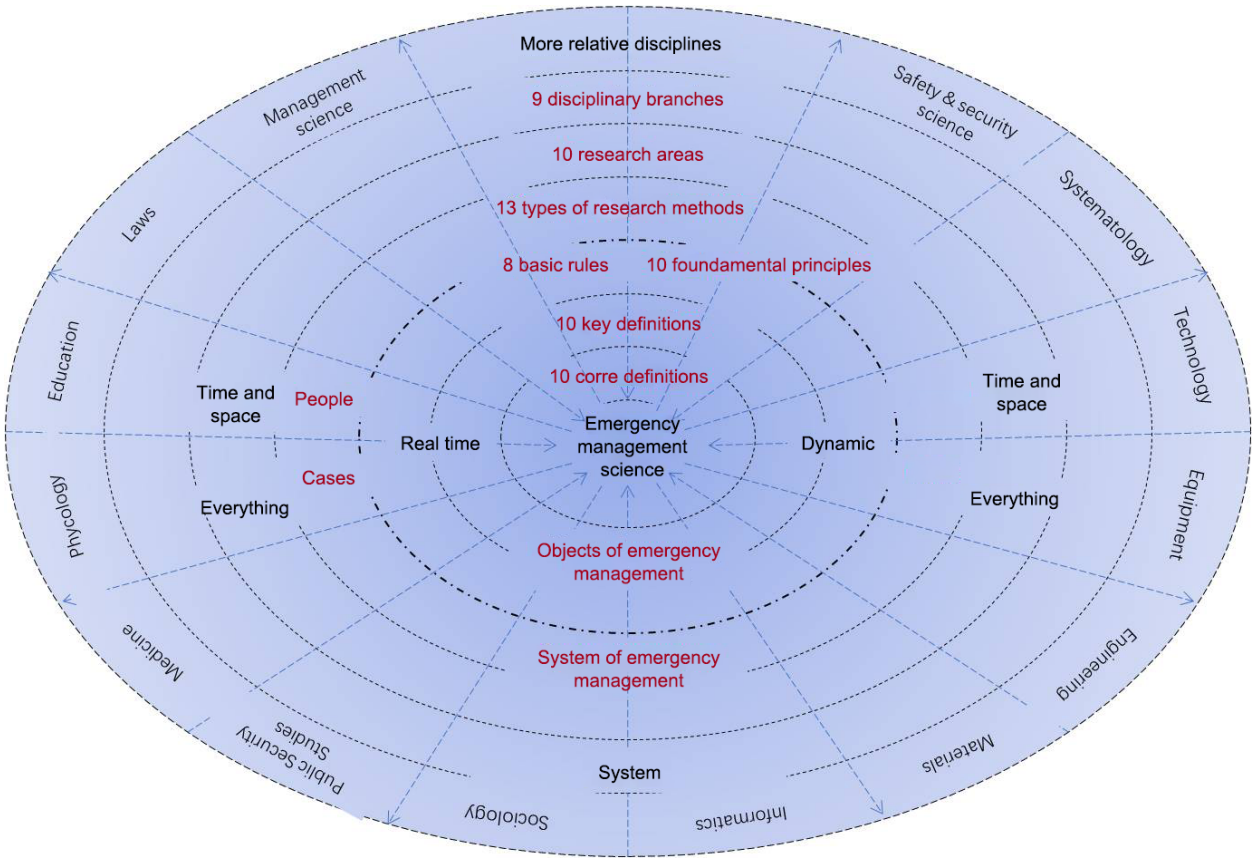

Fig. 2 Compositions of the fundamental theories of emergency management science in the present article.

Conclusions

The fundamental theories of emergency management science are very important. The article provides definitions of emergency management and emergency management science, 10 core definitions, and 10 strongly related definitions for emergency management science; summarizes 13 main research methods and main research objects and contents of emergency management science; summarizes eight general rules and 10 basic principles of emergency management science; classifies the sub-disciplines of emergency management science based on several approaches and visions; summarizes the typical experiences of emergency management in China; gives the outlook for 10 important research areas and topics in current emergency management. The above research results have solidified the theoretical foundation of emergency management science and have important guiding significance for the future development of emergency management disciplines.

Author contributions

The author confirms sole responsibility for the following: Literature investigation, review of basic theories of emergency management science, theoretical study, future research ideas, analysis and interpretation of results, and manuscript preparation.

Data availability

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Conflict of interest

The author declares that there is no conflict of interest.

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