Chapter 14
Paradigm for Urban Safety and Risk Management with Big Data

Nan Jia, Tengfei Zhang, and Siquan Wang

Abstract Risk management of urban public safety, as an important part of urban management, is crucial to the healthy development of cities. In recent years, with the rapid development of big data technologies, urban safety and risk management have also entered the era of big data. Obviously, in this context, it is urgent to reform the traditional risk management model and establish a new paradigm for urban public safety risk management based on big data technology. Firstly, we summarized basic theories related to urban safety and risk management from the aspects of disaster-bearing carrier and risk characteristics. On this basis, it puts forward the connotation of urban safety and risk management and expounds its current situation. Secondly, we analyze and summarize the opportunities and challenges of urban safety and risk management in the era of big data. Finally, the big data-driven paradigm for urban safety and risk management is proposed, and the policy recommendations for urban public security management construction based on this paradigm are given. Obviously, this study will provide theoretical and methodological guidance for the development and implementation of urban safety and risk management of China in the era of big data.

14.1 Introduction

With the continuous advancement of China's industrialization and urbanization, the city's scale and population have expanded rapidly, leading to increased vulnerability of urban buildings and structures, road traffic, lifeline management networks, and personnel gathering places, and the situation of urban safety is grim. How to effectively manage, operate and maintain a complex giant system with huge population size and economic volume is an important issue faced by the urban management in the new era, and achieving a fine urban management has become an important task for municipal governments across the country. The risk management of urban safety, as an important part of fine urban management, is the foundation for ensuring urban

N. Jia · T. Zhang · S. Wang (✉)
School of Informatics and Cyber Security, People's Public Security University of China, Beijing, China

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2022

L. C. Jain et al. (eds.), *Wireless Technology, Intelligent Network Technologies, Smart Services and Applications*, Smart Innovation, Systems and Technologies 258,
https://doi.org/10.1007/978-981-16-5168-7_14

residents' personal and property safety. Therefore, it is essential to improve the risk management capability of urban safety.

With the rapid development of big data technology, the risk management driven by big data is a relatively new research field that has emerged with the big data method and has set off a research boom at home and abroad. In 2008, "Nature" launched the "Big Data" research topic to explore the application and challenges of big data in the subjects and fields of the Internet and computer technology. In 2011, "Science" launched the topic of "Dealing with Data," mainly discussed the processing technology and application of big data. In 2018, the United Nations e-government survey report pointed out that building a resilient society needs to have resources and capabilities to predict, reduce, and respond to various risks based on big data and through ICT. At the same time, the arrival of the era of urban management big data has made more and more scholars and research institutions aware of the importance of big data in risk management and conducted related researches. However, the current researches with the application of big data technology to carry out the urban safety and risk management are still very rare. The existing big data-based urban risk management researches are scattered in specific areas or links such as urban risk prevention, urban safety management, and urban safety construction, which haven't been specifically developed for the entire city safety construction and process, and haven't yet formed the universal guiding theory and practice system, which can't meet the theoretical and practical needs of China's urban fine construction which is under a rapid development. It is urgent to conduct an exploration on the systematic model of urban safety and risk management in the era of big data, so as to provide a theoretical basis and practical guidance for the researches on urban safety and risk management of China in the era of big data [1].

14.2 Summary of Risk Management of Urban Safety

14.2.1 Characteristics of Urban Risks

The city has the complexity and intensity of the spatial and temporal overlap of human, buildings, and systems. In a limited area, the accumulation of large population, resources and social and economic activities have formed a dense network, resulting in the urban risks have the characteristics of mobility, diffusivity, emergence, and dynamic uncertainty.

(1) The high mobility of risks, the city as an open and complex system, the interaction of people flow, objects flow and information flow, the frequent flow of various people, and the advanced and convenient urban public transportation, road traffic, rail transit and other public transportation modes have facilitated the transportation of personnel and materials. This can easily lead to high mobility of various types of risks in various areas of the city, such as key personnel of security monitoring, suspicious people, and hazardous chemicals.

(2) The diffusivity of risk emergencies. When the risk evolves into an emergency, due to the spatial and temporal overlap of urban people, buildings and systems, the dense multi-type carriers catalyze and aggravate the spread and diffusion of emergencies. For example, the accidental fire in the residential housing, which is easy to develop into a big fire accident, because the fire can spread quickly with the help of dense urban carriers, which can cause a heavy loss.
(3) Emergence (coupling) of risk accident system. The city is a typically complex system. This kind of urban system is prone to produce a comprehensive disaster that evolves from a single risk to an integrated risk coupled with multiple disasters due to the three-dimensional density of the urban spatial structure and spatial interaction of human, buildings, and systems. Once an accident occurs, it will present an emergent and disastrous effect. Specifically, it will be the occurrence of disaster chain successively in time, spatially dependent on each other. And these catastrophes have cause and effect correlations, interact as both cause and effect, have a chain reaction and occur in turn.
(4) Dynamics and uncertainty in the process of risk evolution. As a typical and composite system, the city collects complicated risk factors and spatial overlaps. And with highly convergent and intricate coupling relationship of the risk factors, it lead to a highly dynamic uncertainty of urban disaster evolution. Or even worse, disaster evolution has an involute and multivariate disaster structure that may cause huge potential risk for disaster state space and disaster variation space.

14.2.2 Present Situation of Urban Safety and Risk Management in China

The urban safety and risk management refer to the monitoring of the whole system and the whole period of human, buildings and systems in the urban scope based on the vulnerability of disaster carriers for urban emergencies. The occurrence time, space, and intensity of possible disasters should be comprehensively calculated analyzed, forecasting and alarm to make positive risk prevention and control response, actively reduce and prevent the disasters, lower the possibility of urban emergencies or mitigate the casualties and losses caused by disaster events. The process of urban safety and risk management is the process of identifying urban risk factors, analyzing risk and giving human intervention to prevent or reduce urban risks and their consequences [2]. At the present stage, the risk management of urban safety in China has the following drawbacks:

(1) Risk perception has the drawbacks of locality and one-sidedness. Urban risks are complex, human, buildings, systems overlap in time and space, and multi-agent risk mobility, and concealment are strong. In the stage of risk discovery and identification of urban safety, most risk response processes are based on risk control and management after the appearance and outbreak, and it is difficult

to truly realize the active perception of the risk of the whole system and whole period within the urban scope.

(2) Risk analysis is mainly appearing in its empirical and subjective characteristics. Urban risks mostly are multi-body convergence and coupling. At the same time, due to the complex and intensive urban spatial structure, the city shifted from the space with low uncertainty to the space with high uncertainty, which increased the difficulty of risk analysis and prediction. At the present stage, risk analysis and prediction are mainly based on expert experience, qualitative and semi-quantitative analysis, and use static data such as case and survey data for calculation and verification. The ability to portray real-time evolution risks is clearly lacking, and the ability of objectivity and generalization is extremely limited.

(3) The risk response has the drawbacks of passiveness and lag. The evolution process of urban risks presents a highly dynamic uncertainty. In the risk response, there is still a state of passive risk management of "no overall plan for a fundamental transformation," and rarely involves early detection and active control of risk factors, and the accurate response after the risk has emerged.

(4) The drawbacks of the existence of coexistence of multiple institutions and lack of synergy in risk management. At present, urban safety risk management belongs to various departmental channels such as public security, health, transportation, water conservancy, electric power, and propaganda. In the actual risk management work, the lack of communication and sharing of risk information is a common problem. Due to the complexity, relevance and comprehensiveness of the risk issues of urban safety, the status quo of "lack of coordination" of various departments and agencies lead to a lack of overall control over comprehensive risk management, making it difficult to comprehensively utilize decentralized data information for intelligent analysis and effective prevention.

14.3 Opportunities and Challenges in Urban Safety and Risk Management in the Era of Big Data

In the wake of the rapid development of mobile Internet, e-commerce, Internet of things, cloud computing and social media, network information flow are inseparably linked with the human behavior in real life. The integration between the real world and the digital world is getting deeper gradually [3]. Simultaneously, data information is more capable of fully reflecting the actual state of urban operation, along with the wide spread and extensive application of new information equipment in urban management such as the construction of digital city and intelligent city, sensors, intelligent terminals, personnel positioning system, identity identification, wireless sensor network and so on [4]. Big data technology makes it attainable to manage the risk of urban safety throughout the whole system and cycle. Informatization, networking and delicacy have gradually become an inevitable direction of risk management of urban safety. The incessant development of Internet of things, radio

frequency, sensor, wireless network and other information technologies provide data sources and bases for risk information of urban safety. Meanwhile various computer systems and big data computing platforms have a winged progress in the aspects of computing power, storage capacity, data mining and computing speed and so on. The development of high-performance computing technology has considerably improved the analytical capability for complex problems. Rapid collection of risk data in every corner of the city and deep sharing and extensive analysis of multi-source and massive risk data provides technical support for the risk management and decision-making of normalization, digital, all-weather, seamless urban safety. Big data impel the transformation of the traditional model of risk management from a qualitative analysis to the quantitative management. New scientific research methods and management decision methods can be derived by means of the intersection of data, methods, knowledge and domains, which can provide more accurate means and capabilities of prediction, inference, and deduction and so on for urban public safety and risk management.

Urban public safety and risk management have got a new historical opportunity following the high-speed development of modern information technology, computing system, comprehensive data base and fast data calculation. In the aspect of risk awareness of urban safety, it is achievable to realize the stereoscopic and omnidirectional status detection [5] and the coverage of big data in the whole system and cycle of the city by the fusion of real-time data collected from different forms and channels. Monitoring and analysis of abnormal risk data can help managers to perceive risk changes and identify risk locations in a timely and comprehensive manner, which is favorable to overcome the situation of high-risk concealment caused by the complex interaction of multi-agent such as human, buildings and systems in the city [6]. In terms of risk calculation and analysis of urban safety, real-time information mining and analysis based on physical space and cyberspace can provide the basis for timely and correct research and judgment of risk development and event situation [7]. The event deduction on account of the full-dimension data association can supply the reliable assurance for the risk control strategy of urban safety [8]. The sharing and interaction of real-time GIS data information, personnel trajectory information [8, 9], urban lifeline system, and emergency rescue information can provide identifiable ground for scientific, timely and effective rescue route planning, relief material allocation and personnel evacuation strategy [10]. In view of risk prevention of urban safety, the problems of multi-sector segmentation and complicated data types are overcome to promote multi-sectorial coordination and integrated management in post-disaster reconstruction through the sharing of risk big data and multi-department cooperation [11].

But at the same time, the explosive surge of risk data information due to the widespread coverage of cameras, sensors, intelligent terminals, etc., will increase the difficulty of the risk information analysis of urban safety. The traditional and simple method based on data and experience has been unable to satisfy the need for accurate and rapid risk management of urban safety. Therefore, it is urgent to establish the real-time analysis method of wide-area big data with the guidance of full-system risk analysis. Big data from different sources has great differences in form,

structure, attribute, granularity, etc. The convergence, fusion, analysis and calculation of structured, semi-structured, and unstructured multi-source heterogeneous data are the key to risk analysis with the help of big data [12, 13]. The massive increase in risk data of urban safety and multi-agent interweaving of risk factors of a complex convergence also put forward new requirements for the innovation of traditional urban methods of risk prevention. Risk prevention should accumulate thoroughly on the basis of massive data and model analysis to provide more accurate and quantitative support for the exact and active risk prevention scheme and realize the intelligent and active prevention of urban risks.

Under the influence of the technology driven by big data and method changes, the risk management mode of urban safety has a completely new look from the bottom support mode to the upper method application. Obviously, in the context of the construction of urban delicacy management, it is imperative to take full advantage of the new historical opportunity of the urban public safety and risk management brought by the present big data era, convert the traditional experience-oriented mode of risk management and establish the urban public safety and risk management with the support of big data technology.

14.4 The Proposal of Paradigm for Urban Safety and Risk Management with Big Data

Based on the analysis of the basic theories and status quo of urban public safety risks, combined with the core ideas of public safety management, and integrating the new opportunities of urban safety and risk management in the era of big data, the urban safety and risk management paradigm are constructed.

14.4.1 Characteristics of Urban Risks

Various kinds of urban components may make the hidden risk factors obvious. Traditional urban risk management built on experience is partial and one-sided. Simultaneously, risk factors in the city have perfect mobility and urban public emergencies possess the characteristic of significant emergence. As a consequence, the most important task of urban safety and risk management is to carry out the full-cycle and whole system risk monitoring and control from the source in order to avoid changing from unremarkable urban risk to tragic disaster. Timely perception of risk, control of potential urban risk factors, the suppression of occurrence and evolution of risk as early as possible are critical factors to the urban safety and risk management in the stage of risk inoculation.

The state and changes of the monitoring objects are obtained by the full-cycle and whole system monitoring and control on human, buildings, and systems in the

city (The status quo of the research objects is obtained through the state monitoring. While the possible change in future is predicted by the object's change or track monitoring). The premise is to obtain the big data of the human, buildings, systems, and environment within the urban coverage by means of monitoring and control. The purpose is to mine the abnormal information in the urban real-time monitoring data with the assistance of big data analysis methods such as data fusion, semantic association analysis, data mining and so on, through the aggregation and fusion of multi-source and heterogeneous data. Meanwhile risk factors and space–time information in the data are extracted, which will break through the bottleneck of the locality and one-sidedness of risk perception of urban safety and actualize the overall perception of urban risks.

14.4.2 Accurate Prediction of Urban Risk Based on Forecasting and Alarm

The urban risks are highly converged and complexly coupled and interrelated. The evolution of urban public emergencies is dynamic and uncertain, with complex and diverse disaster structures, huge potential risk disaster state space and disaster variation space. Therefore, when the risk factors are perceived, make timely and accurate forecasting and alarm about the types of disasters, the consequences of disasters, the locations and the scope of impacts that may be triggered, as well as the prediction of the evolution of disasters and the effects of different rescue measures when disasters occur, so as to realize active response to emergency rescue and targeted.

With the diversity and complexity of the risk issues of urban safety, the demand for risk forecasting and alarm has also developed from qualitative to quantitative. Forecasting and alarm refer to conduct the effective forecast, risk quantitative forecast and risk evolution deduction of urban risks based on the monitoring and control big data of the risk, and through the quantitative analysis of disasters, large-scale and rapid numerical calculation and situational deduction and simulation, which is the key to the prevention and control of urban public emergencies. The goal of forecasting and alarm is to accurately predict the probability and evolution of risk by means of the analysis and calculation of the monitoring and control data, including what disasters may occur, the possibility of disasters, the damage that disasters may bring, the evolution of disasters and the impact of different measures on the evolution of disasters. The purpose is to break through the current risk analysis of urban safety, which is mainly based on the qualitative or semi-quantitative methods in the present situation, reduce the uncertainty of the risks, and the risk of high uncertainty will become low uncertainty risk, in order to provide the basis and guidance for risk prevention and control.

14.4.3 Collaborative Response to Urban Risks Based on Intelligent Prevention

The traditional risk management mode of urban safety has the disadvantages such as single method and organization, isolated resources and departments, and lack of multi-agent collaborative response mechanism. Insufficient communication and sharing of risk information lead to the lack of overall and global control of comprehensive urban risk management, making it difficult to use distributed data information for intelligent analysis and effective prevention. Therefore, on the basis of comprehensive risk perception and accurate prediction, overcome the disadvantages of the current risk response passiveness and lag in urban safety management, comprehensively consider the risk factor correlation, business attribute intersection, and realize the information sharing and rational allocation of resources under different actions, fields and permissions, and adapt to multi-agent online collaboration and dynamic coordination of different events, at different stages and different scenarios, as well as the intelligent prevention of the urban risks.

Based on monitoring and control and forecasting and alarm, intelligent prevention integrates urban historical information data, monitoring and control real-time data and the calculation analysis of forecast and early warning, by means of symptom identification and early warning of different types of urban risk emergencies to achieve target-driven and task-driven accurate response plan for urban risks, and to achieve the gateway forward, early warning and intelligent prevention of urban risk management. At the same time, on the basis of data integration analysis, through the construction of integrated urban risk intelligent prevention platform combining police, government affairs and property management, the data-business-service entire process integrated management and interdisciplinary collaborative operation are realized, in order to achieve unified, standardized and multi-level linked integrated information sharing and multi-sector multi-agent collaborative management, so as to conduct comprehensive prevention of urban disasters in advance, make effective rescue in the event and perfect recovery afterward.

14.5 Discussion and Conclusion

China is in a period of economic and social transformation, the foundation of urban public guarantees is relatively weak, the accidents are frequent, and urban safety is facing severe challenges. With the rapid development of big data technology, each city should actively grasp the new opportunities of risk management brought by big data and carry out the construction of safety and risk management in the era of big data.

In terms of risk perception, establishing a sound monitoring network, developing monitoring and control capabilities, and consolidating the city's big data base. The comprehensive coverage of monitoring and control equipment is the basis for

obtaining big data on urban risks. In response to the demand for the fine management of urban safety, increasing the investment in monitoring equipment and system, establishing and improving urban safety monitoring networks for public emergencies in different cities, including urban pipe network monitoring systems, rail transit monitoring systems, and meteorological monitoring systems, to eliminate blind spots in monitoring of the perception facilities and sensor networks, realize full period and system coverage of urban data information and the real world, and fully grasp the risk big data of disaster carriers (human, buildings, and systems) in urban. Developing safety monitoring and controlling capabilities, increasing the research and development and investment of monitoring technology, risk spatial and temporal distribution methods to achieve timely and comprehensive awareness and accurate positioning after the risk is revealed.

In terms of risk prediction, improving the ability of big data integration and analysis, breaking through the core technology bottleneck of big data, and strengthening the training, introduction and guarantee system of professional and technical personnel. On the basis of the comprehensive collection of urban risk big data, through the integration and analysis of multi-source heterogeneous data, fully exploit the effective information in the data, so as to truly play the value of risk big data. Focusing on "collecting, communicating, and using" and its security support to break through the core technical bottlenecks such as data collection, aggregation, storage, cleaning, integration and analysis, and provide support for urban public emergency decision-making. At the same time, the smooth operation of urban safety and risk management is inseparable from the scientific research and innovative thinking of big data technology talents, who are the driving force and blood of urban innovation and development. Through the improvement of the training system for big data related professional and technical personnel, the establishment of big data disciplines and related majors, increase training, and reserve big data professional, and technical personnel. Implement practical talent introduction programs, including methods such as simple point system, high-level settlement subsidies, and low-cost housing. And a more targeted selection, use, education, and retention process, a comprehensive talent security system and policies, providing a good development space for professional and technical personnel, providing protection support from the perspectives of medical, pension, housing, and children's education.

In terms of risk response, build and improve the urban safety data resource information sharing mechanism and the deep collaborative and linkage mechanism of multi-department and agent to build a big data sharing service platform. In the event of urban emergencies, it is often necessary to coordinate with various government departments such as public security, transportation, communications, first aid, electric power, and urban management. Therefore, it is necessary to improve and perfect the deep synergistic linkage mechanism of multiple government departments to achieve cross-regional and cross-department, multi-agent unified command, rapid response, coordinated prevention, joint action. At the same time, the multi-departmental high-coordination linkage response must be based on the deep sharing of risk big data. Therefore, it is necessary to establish a resource database and a big data sharing service platform to form a resource complementing and information

sharing operation mechanism under the unified data management system. Confirm the boundaries, responsibilities, systems, and rules of data integration and sharing to ensure that urban safety data resources are exchanged and shared reasonably and efficiently, eliminating "data island," maximizing data collection, fully exploiting the added value of data, and comprehensively ensuring urban safety.

Acknowledgements This study is supported by National Key R&D Program of China (No. 2018YFC0809700), National Natural Science Foundation of China (No. 71904095), Beijing Natural Science Foundation (No. 9194027) and Basic Research Fund (2020JKF501).

References

1. Hall, S.W., Carolla, M.A., Deason, J.P.: The use of imagery in environmental disaster preparedness and response. Fedl. Fac. Environ. J. **16**(4), 65–72 (2010)
2. Kiekens, R.M., Maltha, J.C., van't Hof, M.A., et al.: Panel perception of change in facial aesthetics following orthodontic treatment in adolescents. Eur. J. Orthod. **30**(2), 141–146 (2008)
3. Wu, C., Jia, N.: Research on safety humanology connotation and basic principles. J. Saf. Environ. **6**, 153–158 (2016)
4. Comfort, L.K., Springer, C.G.: Emergency management research and practice in public administration: emergence, evolution, expansion, and future directions. Public Adm. Rev. **4**, 539–547 (2016)
5. Wang, Y.: The development of wireless personnel positioning in internet of things based on ZigBee and sensors. Int. J. Digit. Content Technol. Appl. **6**(12), 47–54 (2012)
6. Bouchrika, I., Carter, J.N., Nixon, M.S.: Towards automated visual surveillance using gait for identity recognition and tracking across multiple non-intersecting cameras. Multimed. Tools Appl. **75**(2), 1201–1221 (2016)
7. Mao, G., Fidan, B., Anderson, B.D.O.: Wireless sensor network localization techniques. Comput. Netw. **51**(1), 2529–2553 (2007)
8. Geng, H., Wu, Z., Ji, H., et al.: Risk zonation and assessment to flood disaster in Jiading District of Shanghai. J. Catastrophol. **30**(1), 96–101 (2015)
9. Deng, Q., Liu, Y., Zhang, H., et al.: A new crowdsourcing model to assess disaster using microblog data in typhoon Haiyan. Nat. Hazards J. **84**(2), 1–16 (2016)
10. Zhang, W.Y., Hai, Y.U., Zhang, F., et al.: Personnel positioning system of underground coal mines based on the ZigBee technology. J. Hefei Univ. Technol. **30**(9), 1087–1090 (2007)
11. Hashem, I.A.T., Chang, V., Anuar, N.B., et al.: The role of big data in smart city. Int. J. Inf. Manage. **36**(5), 748–758 (2016)
12. Troy, D.A., Carson, A., Vanderbeek, J., et al.: Enhancing community-based disaster preparedness with information technology. Disasters **32**(1), 149–165 (2010)
13. Zhang, F., Zhou, Z., Xu, W., et al.: Cloud manufacturing resource service platform based on intelligent perception network using fiber optic sensing. Adv. Inf. Sci. Serv. Sci. **4**(4), 366–372 (2012)