Postprint: Research on the Construction of an Urban Emergency Management Intelligence Platform

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Abstract

[Purpose/Significance] Changes in emergency management organizational paradigms and urban risk environments have catalyzed corresponding transformations in the organizational relationships and technical implementations of intelligence systems, wherein intelligence platforms furnish the tools necessary to support the dynamic networked operation of urban emergency management. [Method/Process] Through literature review and case analysis, this study employs information resource planning methodologies to organize intelligence flows for emergency event management, and deductively constructs an urban emergency management intelligence platform oriented toward real-time, integrated intelligence operations. [Results/Conclusion] The urban emergency management intelligence platform provides channels for intelligence exchange and venues for intelligence production for heterogeneous management information systems and intelligence information systems, and furnishes emergency management with a continuously updated knowledge base and real-time dynamic information data through persistent sensing of urban systems.

Full Text

Preamble

Research on the Construction of Urban Emergency Management Intelligence Platforms

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Abstract

[**Purpose/Significance**] Changes in emergency management organizational models and urban risk environments necessitate corresponding reforms in the organizational relationships and technical implementation of intelligence systems. Intelligence platforms provide tools that support the dynamic network operations of urban emergency management. [**Method/Process**] Through literature review and case analysis, this study employs information resource planning methods to organize emergency management intelligence flows for emergency incidents. Focusing on real-time, integrated intelligence work, it deduces and constructs an urban emergency management intelligence platform. [**Result/Conclusion**] The urban emergency management intelligence platform provides channels for intelligence exchange and venues for intelligence production for heterogeneous management information systems and intelligence information systems. Through continuous perception of urban systems, it offers an ever-updated knowledge base and real-time dynamic information data for emergency management.

Keywords: intelligence platform; urban emergency management; emergency incidents; intelligence engineering
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2. Research Review of Urban Emergency Management Intelligence Platforms

As counter-terrorism situations become increasingly severe and sudden social security incidents continue to rise, Western countries have placed greater emphasis on intelligence work. The United States has elevated intelligence sharing to a national strategy. The 2012 *National Strategy for Information Sharing and Safeguarding* focuses on five major objectives: driving collective action through collaboration and accountability; improving information discovery and access through common standards; optimizing mission effectiveness through shared services and interoperability; strengthening information protection through structural reforms, policy, and technical solutions; and safeguarding privacy, civil rights, and liberties [1-2]. Since 2003, the federal government, states, and local governments have established information fusion centers to centralize and integrate information systems of different ownership and heterogeneous structures, promoting information integration among intelligence agencies and facilitating law enforcement operations [3-4]. The EU has implemented security interoperability projects for crisis management, establishing the Secure European Common Information Space core platform as a central hub for information exchange and business coordination among all relevant agencies. This common information space can be managed as an independent storage and computing entity, allowing all crisis management-related information systems to connect to the core platform for operations regardless of differences in data and application models used by heterogeneous computer systems [5]. Australian scientists attach great importance to the role of computer systems in disaster management, believing that the application of information and communication technology in emergency management enhances the resilience of entire social systems [6]. Canadian and Chilean scholars, drawing from disaster relief experiences such as the Haiti earthquake, recognized the potential of voluntarily provided geographic information from the public for emergency management and designed a Volunteered Geographic Information System based on open-source software and open standards [7]. Korean scientists believe that integrated emergency management should include both disaster information computing and on-site support response, with three-dimensional geographic information service-based visualization platforms providing comprehensive support for emergency management [8]. The Czech Republic' s Crisis Map project adopts a "See-Think-Do" framework, making location-based emergency information production and exchange a social application supported by crowdsourcing platforms [9]. Evidently, recent Western research and practice in intelligence work have concentrated on three priorities: promoting cross-departmental information and intelligence sharing and fusion; emphasizing public-generated and disseminated intelligence; and applying geographic information systems in emergency management.

In China, emergency management faces enormous challenges, and corresponding intelligence work still has many limitations and deficiencies. Yao Leye et al. [10-12] analyzed the current status of intelligence work in China' s emergency incident management, identifying problems such as weak intelligence awareness, lack of necessary training, uneven intelligence utilization capabilities, imperfect intelligence resource systems, and unsmooth intelligence networks. They advocate for top-level overall planning and dynamic aggregation of emergency intelligence systems through integrated approaches, making the connection of intelligence flows and intelligence activity elements the core task of intelligence resource management in emergency response. Guo Hua et al. [13-14] argue that urban information resources exist in a combined state of centralization and decentralization, sharing and independence, attached to different business activity entities, forming an interconnected and interwoven network structure. Urban emergency management intelligence is a temporary, integrated product that occurs based on specific business entities and management decisions through intelligence activities, rather than a pre-structured predictable outcome.

Xiang Liwen and Ouyang Hua [15] focused on the information silo problem in government emergency management, emphasizing that information silos pose significant obstacles to the integration and sharing of emergency management information resources and the construction of emergency management information systems. This problem results from a combination of institutional, human, and technical factors, with the technical solution being the construction of a unified emergency information platform. Zeng Yuhang and Xu Xiaodong [16] addressed the difficulty of information coordination in emergency information management, proposing an emergency information coordination mechanism framework model that envisions integrating and coordinating emergency information at the provincial administrative level, including service integration, process integration, data mining, and security management, enabling management decisions to be based on deep analysis and scientific understanding of massive emergency incident information. Yang Yue [17] studied the use of multi-source information fusion technology to enhance government emergency management intelligence collection capabilities, improve intelligence processing and analysis capabilities through intelligence officer networks, and construct a mass incident emergency management intelligence fusion platform to address weaknesses in intelligence analysis capabilities and poor sharing in traditional emergency management. Cheng Ran [18] examined the U.S. National Incident Management System, concluding that its operational practices demonstrate the need to strengthen communication and coordination among organizations within the emergency response network. Domestic and international research and practice have proven that the path for intelligence work to support integrated emergency management cannot be separated from the construction and operation of intelligence platforms.

In specific industries and business domains, emergency management intelligence platforms have been studied in depth and gradually applied, primarily in social security, community policing, geological disasters, and public security firefighting. Peng Zhihui [19] systematically studied the construction of public security intelligence systems, arguing that such systems are comprehensive systems dominated by human intelligence, supported by public security informatization, with information processing as the main content and serving public security decision-making as the goal. The overall framework consists of three components: a public security information comprehensive platform, a public security intelligence business process system, and a public security intelligence organization management system. Chen Liang [20] proposed an "information-model-knowledge" integrated early warning mechanism for major social security incidents, providing an overall framework design for an emergency decision-making platform for major incidents, with the research focus being action-oriented early warning guided by intelligence. Jin Jianhui [21] designed a prevention and early warning system for sudden social security incidents, including intelligence resource databases, intelligence information collection modules, and intelligence information processing modules, making intelligence work an important foundation for social security incident early warning [22]. Yang Zhu [23] and Niu Xueyun and Zhang Ran [24] respectively studied and designed community emergency management information platforms and community policing intelligence platforms, with system functions focusing on emergency management and policing intelligence within communities, targeting sub-district offices and the communities under their jurisdiction. Gao Fanghong et al. [25] designed and implemented a public participatory geographic information system-based mass earthquake disaster information service platform prototype system to improve the capability of earthquake information systems serving the public, enabling the public to actively obtain multi-source earthquake disaster information and knowledge, submit and feedback disaster information and rescue needs. Huang Bo [26], in public security firefighting practice, identified deficiencies in fire supervision and management systems for fire investigation work and proposed preliminary ideas for establishing a fire scene data information intelligence service platform to achieve functions such as fire scene information collection, editing, secure storage, transmission, management, and retrieval for fire accident investigation business.

These intelligence platforms serve specific industries or fields, attach to fixed business procedures, and achieve specific management goals, but they also have certain limitations, including one-way intelligence transmission, poor information circulation, and lack of overall planning. There is an urgent need to achieve multi-source data complementarity and deeper information mining on a larger scale. The diverse, complex, and dynamic characteristics of emergencies in cities make cross-industry, cross-regional, cross-departmental, and cross-business-boundary emergency management activities increasingly common. Unprecedented emergencies disguise themselves with similar known scenarios to confuse managers and managed objects. People believe they can handle emergencies according to pre-set contingency plans, only to find results vastly different from expectations. Changes in emergency management organizational models and urban risk environments necessitate corresponding reforms in intelligence system organizational relationships and technical implementation. Urban emergency management intelligence platforms provide tools that support network-based emergency management and will become the core technology platform supporting emergency management business in the future.

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3. Intelligence Platform Functions and Technical Implementation

3.1 Practical Significance of Intelligence Platforms

Modern cities contain numerous risks that have not yet been perceived or are imperceptible. The crisis events triggered by these risks are complex in origin, broad in scope, and difficult to handle. Traditional emergency decision-making relies on past experience, but when facing new crisis events, especially when extreme, unprecedented crises erupt suddenly, their scale and danger far exceed the scope that managers can understand and handle [28]. The challenge cities face is no longer managing known, linearly developing emergencies, and emergency management is no longer a task that a single administrative department or organization can handle [29].

Taking the "8 · 12 Tianjin Binhai New Area Explosion Accident" as an example, at around 23:30 on August 12, 2015, a fire and explosion accident occurred at the dangerous goods warehouse of Ruihai Company in Tianjin Port, Tianjin Binhai New Area, resulting in 165 deaths, 8 missing persons, 798 injuries, and damage to 304 buildings, 12,428 commercial vehicles, and 7,533 containers. The accident was caused by multiple factors. Ruihai Company was a dangerous goods loading supervision station designated by Tianjin Maritime Bureau and a port dangerous goods operation permit unit approved by the Tianjin Transportation Commission, and had conducted emergency response drills for highly toxic chemical leaks multiple times. However, for a considerable period after the accident occurred, whether Ruihai Company, Tianjin Port, or relevant management departments of the Tianjin municipal government all lacked the ability to obtain on-site information and correct, effective handling methods. It was not until nine hours after the incident that an AC311 helicopter conducted aerial survey and mapping of the explosion site and potential fire points, obtaining partial real-time information. The State Council accident investigation team proposed at 10:00 on August 13 to suspend firefighting efforts, with the important reason being that the quantity and content of hazardous chemicals, storage methods, and environmental monitoring data were unclear.

This accident not only directly affected residents and enterprises in the surrounding area but also significantly impacted various aspects of urban system operations including transportation and environment: the Jinbin Light Rail Line 9 was temporarily suspended, multiple highway entrances and exits in Tianjin were traffic-controlled, and on-site traffic was chaotic; the port and Tianjin Customs building were destroyed, rendering Tianjin Port unable to operate normally; the atmospheric, water, and soil environments in areas near the accident site suffered varying degrees of pollution. Emergency rescue and disposal operations continued from the night of August 12 to September 13. Units participating in emergency response before the explosion included the involved enterprise, Tianjin Public Security Bureau, Tianjin Port Public Security Bureau, Tianjin Municipal Public Security Fire Brigade, and others. After the explosion, the People' s Liberation Army, Armed Police, safety supervision, health, environmental protection, meteorology, and other departments were further organized and coordinated for emergency management, with professional teams for chemical accident rescue and nuclear-biological-chemical detection from public security fire brigades in Hebei, Beijing, Liaoning, Shandong, Shanxi, Jiangsu, Hubei, and Shanghai mobilized to participate in rescue operations. Enterprises including Tianjin Power Company, China Mobile, China Unicom, China Telecom, Tower Company, and China Feilong General Aviation also participated in technical support to varying degrees. Administrative management departments participating in accident emergency management also included the State Oceanic Administration, Tianjin Oceanic Administration, China Meteorological Administration, Tianjin Meteorological Administration, and even the World Meteorological Organization and International Atomic Energy Agency activated meteorological support and environmental emergency response modes [30-31].

Due to the lack of effective intelligence work and intelligence information system support, the emergency response work for the "8 • 12 Tianjin Binhai New Area Explosion Accident" was in a state of blind decision-making under incomplete information conditions for a period of time after the incident occurred. From the lessons of this accident, the extreme importance of real-time intelligence, integrated intelligence, and specific professional domain knowledge for emergency response to sudden incidents is evident. Especially when urban management faces extreme, unprecedented major crises, an urban emergency management intelligence system with the intelligence platform as the core hub and overall planning becomes the decision-making foundation and core asset for urban emergency management.

3.2 Functional Requirements of Intelligence Platforms

The urban emergency management intelligence system is a holistic intelligence system supporting urban emergency management—a complex system with comprehensive relationships. The intelligence information system is its functional, technical, and structural implementation. Observing existing or planned intelligence information systems in different business units reveals that dispersed and isolated information systems struggle to support cross-scale, cross-spatial, and cross-boundary risks [32] and their crisis consequences within and between cities in urban management. The urban emergency management intelligence platform connects urban intelligence resources and service objects, becoming the most important technical implementation form of intelligence information systems in the urban emergency management field.

Functionally, the urban emergency management intelligence platform is an intelligence platform that serves urban managers, is oriented toward management decision-making business, and concentrates common functions. The platform integrates various intelligence resources required for urban emergency management while providing comprehensive intelligence services for different types of emergency management entities. First, unlike traditional emergency management intelligence information systems or functional modules that only serve specific emergency management entities and support limited emergency management intelligence business, the urban emergency management intelligence platform is a platform with concentrated business functions and comprehensive services. Second, the urban emergency management intelligence platform provides common capability services for other organizations and departments' emergency management intelligence information systems within the city, including urban basic information, monitoring and detection information, decision support information, and intelligent management information at the intelligence resource level, as well as model construction, simulation services, reporting services, identity authentication, and other services at the intelligence service level, avoiding repetitive construction of intelligence functions in information systems oriented toward different emergency management entities, as shown in Figure 1 [Figure 1: see original paper].

As the technical core component of the urban emergency management intelligence system, the emergency management intelligence platform supports information accumulation and knowledge updating for intelligence through big data technology and machine learning capabilities. By enabling rapid, real-time perception and measurement of the natural, social, economic, and built environments in cities, the intelligence platform allows emergency management entities to obtain realistic data that approximates the objective operation of urban systems. The platform supports rapid response and high-frequency decision-making, and through tracking and feedback on the consequences of management behaviors resulting from management decisions, it enables coordination and correction of emergency decisions and decision objectives. Facing challenges of risk globalization and institutionalization, and supported by new-generation information and communication technologies represented by big data and the Internet of Things, emergency management intelligence platforms characterized by dynamic knowledge updating have become practical applications in emergency management adapted to modern urban characteristics.

3.3 Technical Implementation of Intelligence Platforms

3.3.1 Key Technical Requirements Technically, the urban emergency management intelligence platform is an information system combining Internet of Things and big data technologies, supporting multi-source heterogeneous data fusion. First, unlike traditional emergency management intelligence systems or functional modules that operate in relatively closed network environments, the urban emergency management intelligence platform has an open and operable architecture to connect with various types of intelligence information systems and, when necessary, dynamically form a whole through networks to provide intelligence services for urban managers. Second, the urban emergency management intelligence platform no longer only supports relatively simple information processing functions such as document retrieval or emergency material information collection, but simultaneously supports collection, transmission, and processing of different types of data, including structured data and non/semi-structured data. Furthermore, the technical architecture of the urban emergency management intelligence platform supports real-time data collection and processing, enabling high-speed operation and high-frequency decision-making required when intelligent machines or intelligent machine systems serve as specific management entities, as well as real-time requirements for feedback loops in the emergency management intelligence system.

The urban emergency management intelligence platform integrates information and communication technologies such as the Internet of Things, big data, SOA architecture, cloud computing, and communication networks. It is a complex comprehensive information system, among which the integrated application of SOA architecture, big data, and Internet of Things technologies gives the emergency management intelligence platform technical capability differences from other intelligence information systems. As a technical platform providing intelligence services to management entities, the urban emergency management intelligence platform should adopt a service-oriented [33] coarse-grained, loosely coupled architecture in its technical implementation, enabling its service components to be mutually recognized and uniformly called with the help of standard universal interfaces without being constrained by the diversity of hardware systems and basic software. Further, multiple intelligence platforms built on the same technical system also possess the basic capability for mutual recognition and uniform calling. When new intelligence business requirements arise, the urban emergency management intelligence platform can add, combine, or update intelligence services in a modular manner and provide them as system services to third parties. In technical implementation details, a layered model can be adopted, with ESB as the core to split business functions into system-level services and application-level services, separating business, logic, and presentation according to different application purposes and scenarios to reduce the coupling degree of the entire platform system and facilitate development and maintenance.

Against the background of smart city construction and operation, the urban emergency management intelligence platform has sufficient information resource conditions. Emergency management and emergency disposal revolve around cross-domain, cross-departmental, and cross-industry data and information of various types, sources, and characteristics, including both structured data and unstructured data such as images, video surveillance, and XML files. This information usually also has characteristics of spatiotemporal multi-dimensionality, multi-scale, and multi-granularity. The intelligence platform needs to consider the data evolution characteristics and data correlation relationships across time and space dimensions, and even needs to consider the impact of data scales and data granularity in different fields on data characteristics. The emergency management intelligence platform needs to collect, process, and analyze massive amounts of multi-source heterogeneous data and information, organically fuse, reorganize, and mine them for utilization. This intelligence production process has typical big data characteristics, requiring the use of big data technologies such as non-relational databases [34], parallel databases [35], stream computing [36], and distributed data mining in system construction. Different big data technologies are suitable for different business scenarios. For example, non-relational database technology NoSQL (Not Only SQL) is often used for urban basic information queries to accommodate coexisting structured and non/semi-structured data with flexible and extensible data schemas [37]. Memory computing technology [38] has become key to technical implementation in applications such as real-time decision-making and feedback for IoT perception network monitoring data, real-time population density statistics and flow analysis based on mobile phone signaling data, and other real-time location-based emergency decision support. Data mining technology helps urban managers better establish model spaces for the subjective world and operator spaces for the information world, with various intelligent emergency decisions widely using data mining technology for prediction, classification, and correlation analysis applications.

Internet of Things technology, especially IoT platform technology applications, enables the urban emergency management intelligence platform to obtain real-time capabilities to master various environmental data of urban systems. The intelligence platform shields various complex device interfaces and private protocols, supports interconnection of IoT sensing devices with different protocols, and achieves decoupling of IoT applications and terminals. It conducts full life-cycle management of massive IoT sensing devices in cities, enabling the system to have sufficient security and scalability. To adapt to the heterogeneous deployment environment of modern urban sensor networks, the intelligence platform needs to both parse and adapt commonly used CoAP and MQTT protocols for embedded devices and possess the capability to parse relatively complex XMPP and HTTP protocols. Perception of industrial IoT devices is essential in emergency management activities, requiring adaptation to connectivity protocols such as ModBus and OPC.

3.3.2 Intelligence Resource Model Construction The urban emergency management intelligence platform processes collected information and data to form new knowledge and intelligence. Based on different application scenarios of urban emergency management and topics of concern to different emergency management entities, it establishes intelligent urban emergency management intelligence resource models. It analyzes and calculates data and information from smart city systems after clue-based processing to discover business-valuable intelligence and support emergency management decision-making and various management businesses.

The execution process of urban emergency management intelligence resource model construction includes:

- **Raw Data Collection:** Extract urban basic data and management business data from relevant data sources according to emergency management business objectives.
- **Data Processing:** Clean and transform the acquired data content and organize it according to preset data models.
- **Data Analysis and Utilization:** Conduct automatic or manual analysis through analysis models preset in the platform or obtained through exchange with other intelligence information systems. When valuable intelligence is discovered, it is published through distribution channels.
- **Intelligence Model Correction:** Through real-time monitoring and detection, track the impact of emergency management activities on emergency incidents and related urban system environments, and correct existing professional knowledge, data models, and analysis methods to improve analysis effectiveness.

The urban emergency management intelligence resource model collection includes urban emergency management tool models, professional field emergency management models, and hybrid emergency management models, such as emergency traffic management models and emergency environmental management models, as shown in Figure 2 [Figure 2: see original paper]. Emergency management tool models enable the establishment of urban emergency management monitoring indicator systems. Using auxiliary analysis tools such as frequency statistics, hierarchical analysis, correlation analysis, cluster analysis, and regression analysis, and based on large amounts of actual urban operation data, they systematically and quantitatively analyze the correlations of important indicators to obtain various indicator correlation models and evaluation weights, forming comprehensive indicator systems applicable to specific cities' emergency management and supporting urban emergency management decision-making and evaluation.

For example, the emergency traffic management model consists of tools and models such as urban traffic efficiency analysis, public transport passenger flow OD matrix estimation, and meteorological traffic congestion prediction analysis. Urban traffic efficiency analysis establishes both overall indicator models and detailed evaluation models to analyze the overall traffic efficiency of the entire city and traffic efficiency between urban areas, guiding urban emergency traffic management and guidance. Using passenger flow OD matrix estimation tools to analyze urban public transport travel behavior, it establishes temporal and spatial distribution models of public transport travel. Based on passenger boarding and alighting patterns, through public transport IC card/citizen card swiping records at boarding stations and combined with traffic section passenger flow data, after data purification and cleaning, it infers public transport passenger flow OD matrix data, accumulating normal and abnormal state information to form early warning and forecasting models for urban public transport emergency management.

Another example is the emergency environmental management model, which mainly includes two components: air pollution diffusion analysis tools and water pollution diffusion analysis tools. The air pollution diffusion analysis tool uses point source prediction models and multi-puff prediction models to visually simulate the flow and diffusion processes of pollutants in the atmosphere, thereby analyzing pollution impact trends and ranges in regions. Combined with collected real-time monitoring data, it dynamically simulates air environmental quality to provide technical support for early warning and emergency decision-making. The water pollution diffusion analysis tool mainly targets emergency decision-making and emergency disposal during sudden water pollution accidents. It inputs real-time monitoring data for dynamic simulation of environmental quality, and according to algorithms such as the Fischer-Rouse model, river complete mixing model, Fischer-Rouse attenuation model, and S-P model, it simulates and generates pollutant diffusion paths and concentration changes within specified time periods, visually expressing the spatiotemporal distribution of pollutant diffusion, pollution development trends, and predicting the impact degree and range of accidents on environmentally sensitive factors to provide decision-making technical support for emergency handling.

The crowd gathering risk simulation tool utilizes real-time data from mobile communication networks to establish models. Combined with real-time card swiping information from public transport and subways, it simulates urban crowd gathering and flow. Based on discrete data such as population density information, public space information, and activity-related information, it calculates and establishes risk assessment models for crowd gathering in specific areas and crowd gathering risk warning level models for urban safety emergency management decision-making.

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4. Application Scenarios of Intelligence Platforms

4.1 Emergency Incident Scenarios

Numerous risks lurk in cities, interlinked and ready to erupt. Once they break out, they often trigger numerous types of emergencies that are difficult to prevent and interrelated, including sudden geological disasters, meteorological disasters, accidents, as well as sudden social security incidents and public health events. The identification, management, and response to these risks and emergencies require the support of intelligence systems. Urban emergency management intelligence platforms need to face these specific scenarios of risks and emergencies in emergency management business practice.

Chemical hazardous material production safety accidents are among the most hazardous emergencies in urban emergency management. They are often accompanied by disasters such as leakage, combustion, explosion, poisoning, radiation, and pollution. Improper or untimely handling can cause huge loss of life and property [39]. Different from general production safety accidents, the emergency disposal of chemical hazardous material production safety accidents is a complex systematic project involving multiple government agencies at the incident location, including public security, firefighting, environmental protection, health, transportation, and their higher-level departments. It has characteristics of being cross-departmental, cross-domain, cross-level, and requiring rapid response and accurate handling. The urban emergency management intelligence platform provides integrated intelligence support for urban managers' emergency response and decision-making. In this intelligence-supported decision-making activity, since the occurrence, development, and impact scope of chemical hazardous material production safety accidents will produce a series of complex effects and impacts on surrounding urban system environments, and these effects and impacts may generate new accidents or cause significant changes to the original accident, urban emergency management decision-makers cannot accurately predict the accident evolution process and anticipate disposal effects and impacts at various stages of accident handling. Managers are always in a process of continuous decision-making and continuous decision correction. Therefore, intelligence platforms also need to conduct dynamically organized real-time monitoring of changes in the accident itself and the urban system environment caused by emergency management activities to support intelligence service needs of different management entities at different management stages.

4.2 Intelligence Service Scenarios

During the occurrence, development, and emergency disposal of chemical hazardous material production safety accidents, different types of urban managers and different development stages of emergencies have different needs for emergency management intelligence, mainly reflected in the following aspects:

1. **Decision-makers** need to master monitoring and detection information and decision support information. They need to analyze monitoring and detection data based on relevant domain knowledge to judge the nature and development trends of incidents, predict and evaluate the consequences of various possible emergency disposal actions, and decide on and continuously correct emergency disposal behaviors.
2. **Organizational coordinators** need to provide functional management information. The organizational foundation for emergency management and disposal is based on pre-established institutional mechanisms, legal norms, and resource guarantees, including organizational structures, expert teams, legal regulations, resettlement sites, and material resources, to ensure that different participants in emergency management behaviors obtain necessary supporting intelligence.
3. **Different types of urban managers** need common basic information, especially location-based urban basic information, such as the geographical environment of the accident site, population distribution and flow trends, production facility layouts and underground pipeline routes of chemical plants, distribution of urban infrastructure components, indoor plans of surrounding buildings, and professional knowledge for emergency disposal such as simple self-rescue and mutual-rescue measures for ammonia leaks.
4. **With the development of emergencies**, urban managers need the intelligence platform to provide real-time information updates and feedback on disposal results caused by management behaviors, such as impact scopes at different time periods after accidents, changes in traffic evacuation routes, real-time carrying capacity of resettlement sites, dynamic positions of traffic and firefighting rescue forces, and treatment situations at medical institutions.
5. **The further evolution** of ammonia leak production safety accidents may be accompanied by new derivative accidents or related emergencies. There are still unknown factors regarding these events themselves and their correlations. Possible derivative accidents and emergencies include combustion, explosion, traffic congestion, crowd stampede, water and power outages, etc. The handling of these derivative accidents or emergencies

requires participation of new emergency management entities and needs new, larger-scale intelligence support.

The urban emergency management intelligence platform coordinates intelligence information systems at different levels and in different professional fields to provide comprehensive intelligence services for emergency management and emergency disposal. The urban emergency management intelligence platform is not a simple information system; it needs to be applied in actual urban emergency management business and actual emergency response scenarios for emergencies, and be connected with relevant information systems and information terminals to organically link with emergency management entities and objects and establish effective working mechanisms. Different types of emergency management entities and the urban emergency management intelligence platform coordinate intelligence work objectives, organizational structures, intelligence resources, and work procedures based on dynamically connected networks. As shown in Figure 4 [Figure 4: see original paper]:

The emergency management intelligence platform extracts relevant business information from urban management business systems, collects real-time urban system environmental perception data from IoT perception systems, exchanges and shares intelligence with other intelligence information systems, and ultimately provides intelligence content to various emergency management entities. Simultaneously, emergency management entities connect with different intelligence information systems as needed at different management stages and emergency development stages, forming dynamically changing organizational structures. In the emergency management process of a chemical plant ammonia leak production safety accident, the municipal emergency management office, as the leading unit for emergency response and disposal, organizes relevant administrative management departments such as the safety production supervision and administration bureau, park management committee, public security bureau, firefighting bureau, environmental protection bureau, and transportation bureau to carry out emergency management activities. Administrative management departments become the most important emergency management entities for this emergency. In addition, hospitals, schools, communities, commercial outlets, news media, and non-governmental organizations near the incident site also directly or indirectly participate in emergency management activities.

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5. Intelligence Support from Intelligence Platforms for Emergency Management

5.1 Business-Oriented Intelligence Support

Taking the example of an ammonia leak production safety accident at a chemical plant located in an urban area, the urban emergency management intelligence platform simultaneously provides intelligence support to multiple types and levels of management entities for emergency management. The intelligence obtained mainly includes urban basic information, monitoring and detection information, decision support information, and functional management information. The emergency management decisions and management behaviors supported by the intelligence platform are also diversified. Analyzing the management decisions and behaviors directly related to the emergency response for this emergency, the intelligence support mainly includes three categories: production safety accident description, pollution diffusion analysis, and risk zone and buffer zone analysis. The urban emergency management intelligence platform' s support for these management decisions and behaviors is reflected not only in monitoring emergencies and sorting out urban contexts but also in the application of specific professional domain knowledge and its emergency management-oriented applications, as well as in the evaluation, feedback, and iterative optimization of the consequences of management decision behaviors, as detailed in Figure 5 [Figure 5: see original paper].

Qualitatively understanding the incident situation and accident impact is far from sufficient for urban managers when handling ammonia leak production safety accidents. The urban emergency management intelligence platform obtains emergency state information on accident occurrence and development through various IoT sensing devices deployed at the incident site and surrounding environment, acquires urban normal state information combined with geographical location through urban management information systems, and obtains chemical accident impact calculation knowledge through professional domain intelligence information systems. When the intelligence platform integrates data, information, and knowledge from different information systems, it can dynamically calculate and simulate environmental quality changes affected by the accident. Based on existing knowledge foundations, the intelligence platform simulates and generates diffusion paths and concentration distributions of pollutants within different time periods, predicts pollution development trends, and assesses impact degrees and scopes on the environment to provide intelligence support for emergency management. In the intelligence production process, the urban emergency management intelligence platform exchanges collected urban emergency state information with industry domain intelligence information systems based on but not relying on existing knowledge foundations, enabling professional knowledge foundations to be updated and continuously enriching the knowledge system for emergency management facing emergencies.

5.2 Intelligence Support for Accident Description

The core of the urban emergency management intelligence platform's support for the management process of production safety accident description lies in monitoring and prediction, i.e., estimating the scale of hazardous chemical leaks and monitoring pollution conditions in surrounding environments. Once liquid ammonia from hazardous chemicals leaks, differences in container scale, pipeline routes, leak locations, crack sizes, and container pressure and temperature may cause different accident types. Typical leak accidents include instantaneous explosion leaks, continuous liquid leaks, and gas leaks. In applications, different leak quantity calculation models need to be selected from the leak quantity calculation model library according to actual accident conditions for leak quantity calculation. In this example, assuming outlet connection pipe leakage occurs mainly in the liquid phase space and the leakage path is short, liquid ammonia does not vaporize in the leakage pipe to form a flashing two-phase flow, and the Bernoulli equation is used to calculate liquid leakage velocity.

The urban emergency management intelligence platform supports description of accident generation and current status. Through the fusion application of relevant knowledge foundations on urban normal state information and abnormal state monitoring information, it establishes a chemical accident impact calculation analysis module, sets up chemical physical and physicochemical parameters and hazard tolerance threshold databases, provides real-time meteorological data to support environmental pressure calculations, and validates and corrects prediction data through targeted real-time monitoring of surrounding environments, possibly even continuously accumulating new accident development and change morphology cases to update relevant knowledge foundations.

5.3 Intelligence Support for Diffusion Analysis

The focus of the urban emergency management intelligence platform' s support for the management process of ammonia leak pollution diffusion analysis lies in using professional domain knowledge and real-time monitoring information to predict the scope and intensity of pollution diffusion. Pollutant diffusion calculations select diffusion models from the diffusion model library of the chemical accident impact calculation analysis module for computation. In this example, the multi-puff model [40] is selected, and considering the complex environment during actual safety accidents, engineering coefficients are used to correct results to reduce risks of accident mishandling caused by errors. The knowledge foundation for the urban emergency management intelligence platform' s support of gas pollutant diffusion analysis includes real-time measurement data of pollutant concentrations and collection of climate and meteorological data. In more complex models, gas pollutant diffusion analysis calculations also depend on the density and morphology of the urban system' s built environment. Due to unavoidable measurement deviations and calculation errors, the urban emergency management intelligence platform needs to assess the hazard degree of emergencies and the effectiveness of emergency decisions through repeated real-time measurements and calculations, and make rapid responses and correction optimizations. Figure 6 [Figure 6: see original paper] shows the dynamic intelligence support results of the intelligence platform, presenting the scope, morphology, and trends of gas pollutant diffusion from accident occurrence to different time nodes (15 minutes, 30 minutes, 45 minutes). In this dynamic process, different types and coverage ranges of sensors are triggered sequentially, with already-connected sensors continuously updating data to provide new information bases for intelligence analysis, forming a feedback loop supporting emergency management decision-making.

5.4 Intelligence Support for Buffer Analysis

The focus of the urban emergency management intelligence platform' s support for the buffer analysis management process lies in predicting and quantitatively assessing areas with occurred dangers and potential risks. The intelligence platform compares the results calculated from pollutant diffusion analysis with the concentration thresholds for severe, moderate, and mild hazards caused by hazardous chemicals and short-term allowable exposure limits in the chemical physical and physicochemical parameters and hazard tolerance threshold database to determine the scope of risk areas that have been, are being, and will be caused by production safety accidents. By fusing the calculated risk areas with location-based urban basic information, emergency state monitoring information from IoT perception systems, and historical monitoring information from business databases, the risk areas and buffer areas for the production safety accident can be obtained, predicting the scope of risk areas and buffer area setting recommendations at different time points from emergency occurrence. These predictions and actual deployment results for risk areas and buffer areas will be dynamically adjusted with changes in real-time monitoring results of surrounding environments and pollution sources themselves. These possible monitoring result changes include: changes in meteorological environments, deformation of storage tank pressure and cracks, changes in traffic conditions, deviations between IoT perception system measured data and predicted data, and changes in pollution conditions caused by emergency disposal measures.

5.5 Intelligence Support for Comprehensive Disposal

The urban emergency management intelligence platform provides customized scenario analysis for urban managers to determine the number of enterprises and institutions and population that may be affected at time nodes such as 15 minutes, 30 minutes, 45 minutes, 1 hour, 2 hours, 12 hours, and 24 hours after emergency occurrence, the scope and location of possible secondary accidents, the scale of personnel and equipment requiring evacuation, planned evacuation traffic routes and target resettlement sites, and supporting staff, equipment, and tools for emergency disposal. In this example, based on certain emergency characteristics (ammonia leak) and meteorological conditions (northwest wind at level 6, wind speed 3 m/s) and specific urban system environments, the analysis obtains the size and scope of affected areas, population quantity and density distribution, scale and nature of built structures. On the basis of fully mastering disaster relief resource intelligence, it delineates traffic control areas, recommends resettlement sites for disaster victims, recommends green rescue channels, and conducts real-time tracking of on-site conditions (including video images, location information, and other real-time IoT perception information), as detailed in Figure 7 [Figure 7: see original paper].

The urban emergency management intelligence platform calls and pushes the above comprehensive intelligence to serve emergency management entities at different levels, of different types, and with different business scopes, enabling organizers and participants in these emergency management activities to coordinate and make effective decisions. The support of the urban emergency management intelligence system for emergency management decision-making is a dynamically changing complex process. On one hand, management entities' emergency disposal of emergencies produces new effects on urban systems, and business behaviors change the environment. The intelligence system perceives environmental information in real-time, making it new decision-making basis. On the other hand, decisions made by different management entities interact, and their actions and reactions produce mutual multiple impacts. In this example, organized rather than spontaneous evacuation behaviors based on intelligence will lead to changes in affected population density distribution and urban road traffic conditions in risk areas, as well as results caused by emergency disposal itself, all of which will cause adjustments in intelligence such as traffic control areas, rescue green channels, and hospital carrying capacity. Emergency evacuation plans cannot be considered unchangeable. In extreme disasters, ammonia leak-caused combustion and explosion production safety accidents lead to changes in the scale and morphology of surrounding built structures, even causing changes in meteorological conditions or triggering new derivative accidents, making intelligence support at various stages including accident description, diffusion analysis, and buffer analysis a closed-loop feedback and continuously developing process. The intelligence platform also provides continuously updated knowledge foundations and evolving new intelligence for emergency management decision-making through continuous perception of urban systems.

Intelligence is the cornerstone of all scientific management, and intelligence platforms are the most important supporting information systems for future urban emergency management activities and important supporting tools for intelligence engineering. Complex emergencies in cities often require participation of different managers in emergency disposal. Only intelligence exchange and application can maintain dynamically changing emergency management organizational structures at effective relationship levels [41]. Integrated and dynamic management activities make intelligence platforms the core assets of urban emergency management intelligence engineering. The urban emergency management intelligence platform is an intelligence platform oriented toward and supporting integrated, dynamic, and whole-process management. It should be designed and constructed with intelligence work as the guide and intelligence users as the center to achieve matching between its technical architecture and business requirements, ultimately supporting and promoting the development of urban emergency management business levels.

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Author Contributions

Guo Hua: Proposed research ideas and paper framework, wrote the paper and revised the final version.
Qu Fang: Collected research materials, designed application scenarios and technical implementation, participated in writing the paper.
Zhan Peizhi: Established intelligence analysis models for hazardous chemical production safety accident emergency management.

Note: Figure translations are in progress. See original paper for figures.