Research Paper

Construction of urban security risk intelligent attack and defense system based on TIM platform under climate change

——A case study of Lanxi City, Zhejiang Province, China

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Abstract

Currently, the world is experiencing unprecedented extreme weather, with some regions suffering from severe flooding. Against the backdrop of the rapid development of digital infrastructure such as big data, mobile internet, and cloud computing, how to apply the latest achievements in information technology to urban flood control and drainage is an urgent problem to be addressed. This study takes full advantage of new technologies and methods such as big data and AI, based on the TIM (Threat Intelligence Management) platform, to construct an intelligent offense-defense system for urban safety risks. Compared with the existing systems that are characterized by single functions, slow data loading, complex core algorithm steps, and a lack of defense systems, this system boasts significant advantages such as wide monitoring scope, scientific and efficient algorithms, rapid real-time response, and intelligent offense-defense. The study takes the flood risk attack and defense simulation of Lanxi City, a key flood control city in Zhejiang Province, China, as an example, focusing on the key technologies of urban intelligent "real-time perception, data analysis, monitoring and evaluation early warning, command and decision-making, and intelligent offensive and defensive simulation " in five aspects. It achieves real-time dynamic monitoring and simulation of all elements in the urban area, including "precipitation, runoff, pipe network, river network, surface, sluices, and pumps," By using the risk and disaster factors to simulate the attack to different degrees, calculate the attack scope and influence scope, take defensive measures, propose solutions and damage analysis. The application of the intelligent offense-defense system for urban safety has improved the scientificity and effectiveness of urban risk management, ensuring the safety and sustainable development of the city.

Keywords

climate change, urban flood risk, intelligent offense-defense, risk warning

1. Introduction

As global climate change intensifies, the frequency and intensity of extreme weather events are rapidly increasing. According to the United Nations Office for Disaster Risk Reduction's "Cost of Disasters 2000-2019" statistics, the number of disasters worldwide has risen "alarmingly" since the beginning of the 21st century, with the number of reported disasters rising from 4,212 to 7,348 compared with 1980-1999 and 2000-2019, including a 134% increase in floods. The risk of urban rainstorms and floods has greatly increased, posing a great threat to people's lives and property safety and social and economic development. In March 2022, the World Meteorological Organization (WMO) also asked relevant organizations and scholars around the world to take action to promote the construction of disaster early warning systems from the aspects of science and technology, policy and funding in the "Action Plan for All Early Warning".

At present, typical studies on intelligent urban flood management systems at home and abroad are quite abundant. Huang Jing et al. (Huang et al., 2019) proposed a simulation method of urban rainstorm and flood disaster early warning strategy based on agent modeling, and set three early warning strategies based on rainfall forecast, flood inundate and population exposure. The change of urban flood disaster risk under different early warning strategies was analyzed. Based on digital twin technology, Zhao Mengqi et al. (Zhao et al., 2024) established a digital-intelligent water control system in Binjiang district, including twin data mapping, mathematical model deduction, virtual and real interactive prevention, intelligent service linkage and other modules, for intelligent flood control in Binjiang district. Nardo et al. [3] (Nardo et al., 2013) put forward the application of the new water network in the Intelligent Water network (SWAN), which can do the early warning and monitoring of pipe network, and can also do the flood management of water resource basin, forecast water supply demand analysis and other functions through big data analysis. However, these studies often have different focuses and are not comprehensive enough. Some studies lack real-time monitoring and early warning function, and some lack the ability of attack and defense simulation of virtual and real game.

In view of these deficiencies, this study further optimized, through the combination of big data and artificial intelligence technology, fully filled the current five gaps in urban risk management - "no awareness of risk", "no technology with awareness", and then "no platform with technology", "no data with platform", "no learning and deduction with data". It has realized the four-step leap from instant perception, data fusion analysis, intelligent learning to offensive and defensive reasoning, and built a comprehensive monitoring and early warning platform for urban safety risks with an international perspective of "monitoring, warning, and quick disposal", effectively improving the city's response ability in the face of flood disasters.

2. Materials and key technologies

2.1. Overview of the study area

Lanxi City, located in the middle reaches of Qiantang River, China and the north edge of Jinqu Basin, is known as "the convergence of three rivers", "the waist of six rivers" and "the thoroughfares of seven provinces" since ancient times (Figure 1). Lanxi is an area with high incidence of Meiyu heavy rainfall. Affected by the backwater of Fuchunjiang Reservoir downstream, floods have always occurred frequently. The flood peak water level rises year by year and the flood control pressure increases sharply. In the 68 years from 1950 to 2017, there were 144 times of over-warning water level floods in 54 years, of which 48 times of over-critical water level floods occurred in 30 years. Frequent flood disasters cause great losses in Lanxi City, which seriously restricts the sustainable development of urban economy and ecological environment.

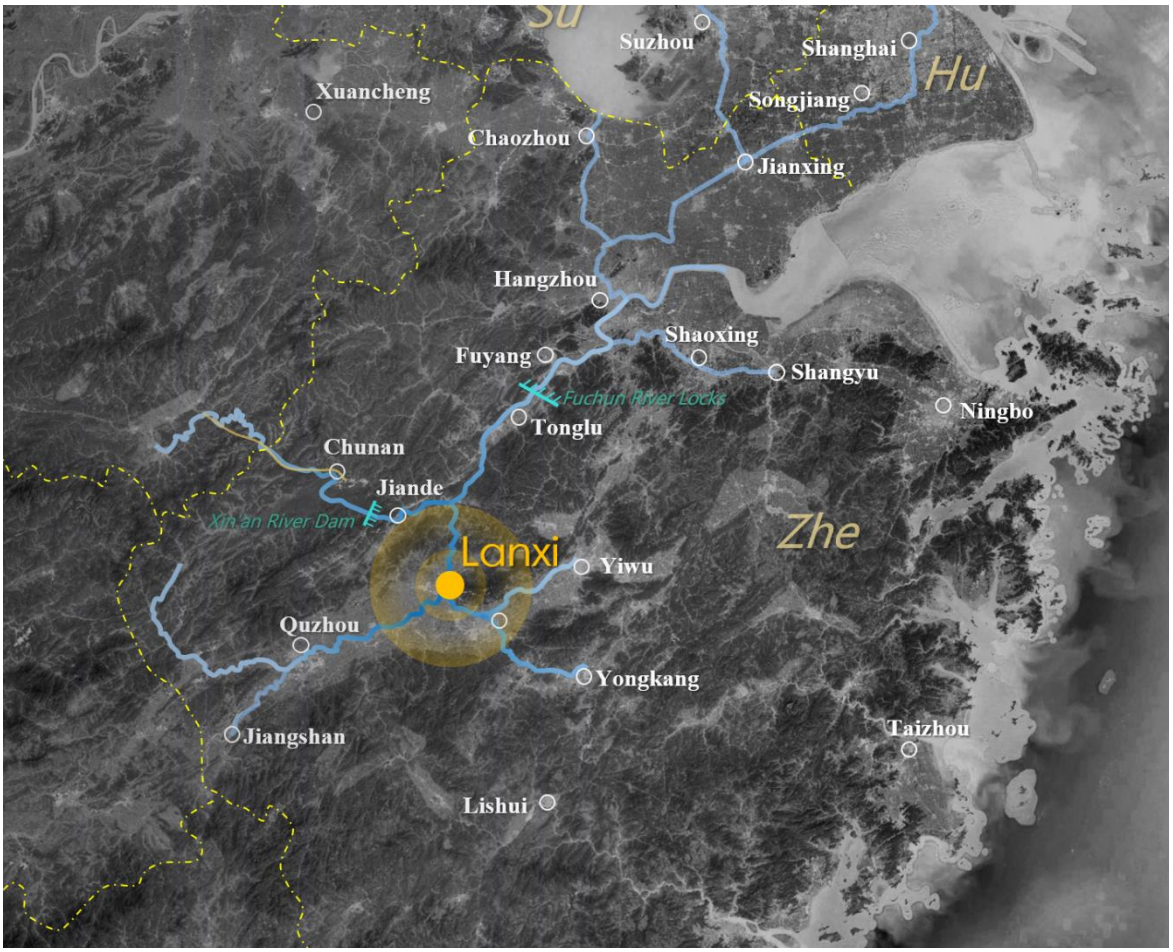

Figure 1. Overview of the study area. Source: ISOCARP.

2.2. The key technical problem of urban security risk intelligent attack and defense system construction

2.2.1. Integration and processing of multi-source data

This process involves collecting and standardising information from sensors, satellite imagery, weather data, GIS and historical flood data, and using advanced algorithms and machine learning to analyze the data to quickly and accurately predict flood risk. In addition, it is necessary to address the challenges of real-time data transmission and storage to ensure that the system can respond to emergencies in a timely manner. The system must have high scalability and reliable security measures to protect data integrity and privacy. This is the core technical problem of realizing efficient and accurate urban intelligent flood warning system.

2.2.2. Multi-party collaboration and resource scheduling

Urban security incidents often require multi-party collaboration between the government, relief agencies, and public service departments. How to consider the coordination and resource allocation among different roles in the simulation and simulation, and how to quickly and effectively organize the forces of all parties to linkage before, during and after the flood disaster is the key to achieve efficient distribution and use, and ensure the efficient, accurate and timely flow of emergency materials, rescue forces and information.

2.2.3. Population factor analysis and decision response

In urban security incidents, human behavior and decision-making often play a key role. The system should integrate multi-level and multi-dimensional data such as population density, socio-economic status, traffic flow, and historical flood disaster data in the simulation and calculation, fully consider factors such as crowd response, evacuation path selection, and emergency response decision-making, and incorporate them into the overall risk assessment to ensure personal safety and social stability in flood disasters.

2.2.4. Emergency decision support mechanism for emergencies

In the face of such a complex and fast-changing natural event as flood disaster, it is very important for the system to make efficient and scientific decisions at all stages of the event by combining the results of attack and defense calculation with actual operation and maintenance, so as to realize the sustainable guarantee of urban safe operation.

2.2.5. Verification and optimization of simulation results

In order to ensure the accuracy and reliability of the simulation results, the system should compare the game results with the dynamic monitoring data, and timely feedback and update. In the process of multiple inferences, machine learning and feedback mechanism are used to continuously optimize the algorithm, adjust and improve the model parameters and emergency strategies, so as to achieve the system to provide high-precision and high-reliability prediction and decision support under various complex situations.

2.3. Urban security risk intelligent attack and defense system to build the overall framework

The overall framework of the system is shown in Figure 2.

2.3.1. Integration and processing of multi-source data

Through the satellite communication network - satellite remote sensing, UAV detection, monitoring feedback, etc.; Internet - social forums, online public opinion, etc.; The mobile communication network - mass reporting, enterprise response, etc., and the electronic financial external network - surface sensing, statistical data, planning reports, etc., provide basic data support.

2.3.2. Integration and processing of multi-source data

The data layer is the foundation of the system and is responsible for storing and managing all kinds of raw data. The Internet monitoring database and government department database have been built. Through real-time perception, the system can obtain a variety of key data, including hydrology, meteorology, satellite remote sensing, geographic information, water-prone point information, flood rainfall, water level data and other Internet monitoring data, as well as population information, historical disaster records, urban roads, pipe networks, base stations and sluice layout and other government data.

2.3.3. Integration and processing of multi-source data

The system integrates many cutting-edge technologies such as video analysis, big data analysis, AI recognition, 3D GIS, Unreal Engine and workflow engine to build a powerful and intelligent core architecture. Video analysis technology processes surveillance video in real time to quickly identify and warn of potential flood risks; Big data analytics dig deep into massive data to provide accurate trend prediction and risk assessment; AI recognition uses machine learning and deep learning algorithms to improve the intelligence level of detection and decision making; 3D GIS builds a fine geographic information

model to realize the overall control of urban space and the three-dimensional display of flood situation. Unreal Engine creates realistic virtual scenes for disaster attack and defense simulation and drills to enhance the actual emergency response capability; The workflow engine efficiently manages and schedules tasks and resources to ensure smooth collaboration between technical modules and efficient operation of the system.

2.3.4. Integration and processing of multi-source data

The system can be accessed through the large-screen system, PC or mobile terminal. Among them, the large screen is mainly used by the municipal emergency Management Bureau; The PC terminal is suitable for the district (city) county emergency management Bureau and relevant city departments; Mobile provides services for city safety managers, emergency responders and ordinary citizens.

2.3.5. Integration and processing of multi-source data

Based on the business needs, management mode and work flow of urban flood control and drainage, five functional modules are set up: flood disaster related data collection, intelligent monitoring and early warning, risk analysis and assessment, attack and defense drills and simulation, and emergency command and dispatch. The data collection module integrates baseboard data, site survey and real-time data to provide an overview and in-depth analysis of historical disasters. The intelligent monitoring and early warning module obtains real-time monitoring information through front-end equipment, issues accurate early warning and supports joint handling; The risk analysis and assessment module carries out structural assessment, disaster-induced environment analysis and post-disaster loss assessment; The attack and defense drill and simulation module builds realistic scenes, designs solutions, implements drills, and monitors and improves them in real time; The emergency command and dispatch module quickly starts the response mechanism, supports dynamic command decision-making, real-time communication coordination and resource optimization, and realizes efficient response to flood disasters.

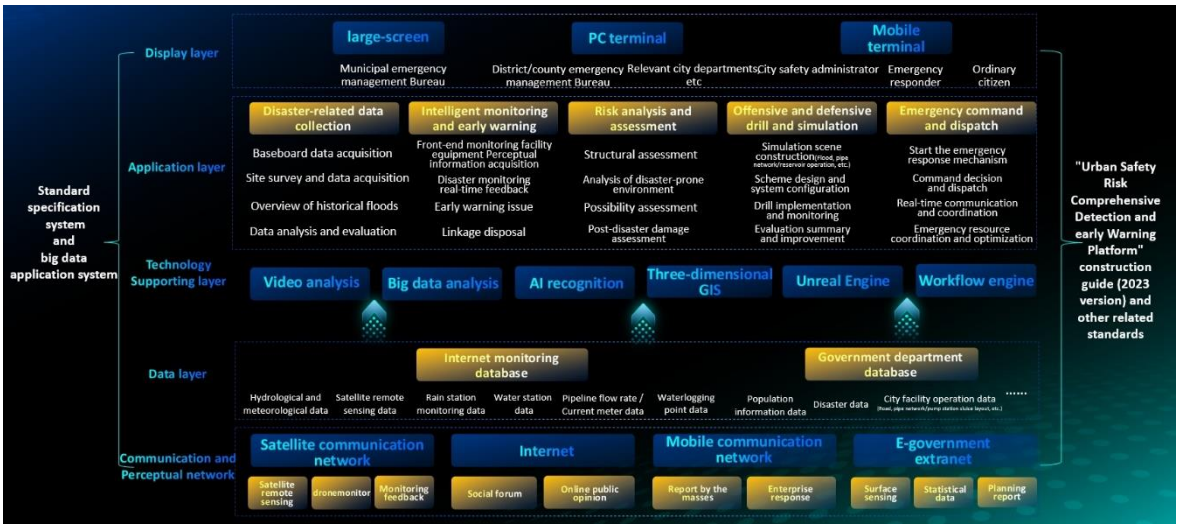

Figure 2. Overall platform architecture. Source: ISOCARP.

3. Construction of urban security risk intelligent attack and defense system

3.1. Instant perception: Building a one-stop big data repository

3.1.1. Eight sources of data perception and three sources of micro perception

In the construction process of urban security risk intelligent attack and defense system, instant perception is the cornerstone of accurate prediction and scientific decision-making. The system integrates eight data perception sources and three micro-perception sources to build a multi-level and multi-dimensional data perception network. The eight major sources of data perception include high-resolution satellite image data (space imaging), ground-based sensor networks (surface sensing), aerial image data of drones and aviation equipment (aerial photos), historical flood data, population and economic data (statistical data), urban planning and design documents (planning reports), interview data, Internet crawl data (network data), and data All kinds of data collected by the independent research and development platform (acquired by the self-built platform). Three micro-perception sources cover the integration of the public security network and the government affairs network: the public reporting disaster information (data reported by the masses), the people-centered urban group perception: news media, social media and online forum data (online public opinion data), and the comprehensive and objective perception of social organizations: the response data of public service departments and enterprises (enterprise response data). These multi-source data together form a comprehensive and three-dimensional real-time perception network, which provides a solid data foundation for the early warning system.

3.1.2. Sensing device application

In order to ensure the comprehensiveness and real-time data perception, the system has deployed a variety of advanced sensing equipment. These devices include high-precision weather stations, rain gauges, water level gauges and soil moisture sensors, distributed in key areas of the city for dynamic monitoring; Using LiDAR, multispectral and thermal infrared imaging equipment to capture more detailed surface and atmospheric data; Unmanned aerial vehicles and satellite imaging technology are used to collect dynamic data at high altitudes and on the surface. At the same time, the system also integrates ground surveillance cameras, mobile sensors, sonar and radar systems to achieve all-round and three-dimensional monitoring of urban flooding. And intelligent traffic sensor real-time detection of road water; The intelligent manhole cover monitoring device monitors the underground drainage system in real time. All of these sensing devices can transmit data instantly to a one-stop platform data repository via wireless networks and iot technologies.

3.2. Data fusion: multi-source data fusion and analysis

3.2.1. Data fusion management

The system has made a remarkable breakthrough in data processing. First, through advanced data preprocessing technologies, including data cleaning algorithms, data conversion and formatting, and automated data type matching, data formats from different sources are converted to a unified standard and data fields and types are ensured to be consistent across different data sources. Next, the system aligns the data in time and space, ensuring that different data sources are compared and analyzed within the same point in time, coordinate system, or resolution. Data integration and standardization is an important part of data fusion. The system uses multivariate data standardization, complex feature extraction and transformation, and dimension normalization technology to standardize data from different sources into the same measurement unit and data range, and to extract key information points from data in common

format and specific industry. In the stage of data matching and fusion, the system combines rule-driven fusion, statistical fusion and machine learning algorithms to achieve efficient data fusion and intelligent processing. In order to ensure the orderly storage and efficient management of data, the system builds a unified data storage system, and implements detailed metadata management of the merged data. Finally, through real-time data analysis and iteration, feedback information is collected systematically, data fusion and analysis methods are continuously improved, data fusion strategies and models are continuously optimized, and the prediction and decision support capabilities of the platform are enhanced. Diversified data sources combined with sophisticated algorithms make risk identification more profound, risk assessment and diagnosis more accurate, and effectively solve the actual needs of urban planning personnel and data barriers.

3.2.2. Data analysis method

The system covers a variety of data analysis methods, including metadata analysis and verification, statistical analysis, machine learning and data mining, geospatial analysis, time series analysis, and text and semantic analysis. These methods work together to achieve high precision prediction and decision support.

Specifically, metadata analysis and verification ensures the relevance, consistency and reliability of data through correlation analysis, consistency verification and metadata comparison analysis; Statistical analysis uses regression analysis, Bayesian analysis and survival analysis to provide accurate estimation of the probability and impact range of flood events. Machine learning and data mining use cluster analysis, classification algorithms, anomaly detection and cluster analysis to identify potential risk patterns and anomalies; Geospatial analysis uses spatial hotspot analysis, spatial interpolation and buffer analysis to accurately locate and predict flood hotspots. The time series analysis provides the dynamic prediction of the future flood development through the autoregressive integrated moving average model (ARIMA), long short-term memory network (LSTM) and moving average analysis. Text and semantic analysis involves topic extraction and keyword extraction, natural language processing (NLP), topic modeling, and sentiment analysis to help extract valuable information and public sentiment from large amounts of text data. The synergy of these diverse data analysis methods enables the system to effectively respond to urban flood risks, providing comprehensive and accurate early warning and decision support.

3.3. Intelligent learning: Integrating AI methods and technologies

In terms of intelligent learning, the system integrates a large number of advanced artificial intelligence technologies to strengthen its application in the fields of natural language processing, computer vision, risk identification and offensive and defensive early warning. By integrating law learning, model structure optimization, inference acceleration and training strategies, the system has a strong feature depth mining and intelligent inference ability. Specifically, deep learning neural network technologies such as Figure Neural network (GNN), generative adversarial network (GAN) and spatio-temporal Convolutional neural network (ST-CNN) are used for the recognition and prediction of complex data patterns. Deep reinforcement learning and multi-agent reinforcement learning are used to optimize the decision-making process. Self-supervised learning is applied to disaster early warning and post-disaster UAV image analysis. Transfer learning and multimodal learning play an important role in social risk analysis. Time series analysis technology is used to monitor emergencies and detect network attacks; Automated machine learning realizes the efficient construction of disaster risk model. In addition, natural language processing technology is being used to analyze social media and news data to extract key information related to flood risk. The integration of these AI learning technologies improves the calculation power of risk rules, enabling the system to provide efficient and accurate flood warning and risk management support.

3.4. Attack and defense exercise: disaster attack and defense exercise and early warning

By carrying out disaster attack and defense early warning and deduction, the system provides a dynamic risk management means. It uses digital twin technology to simulate and deduce various operating mechanisms of real cities, and realizes all-directional, multi-level and real-time dynamic simulation of urban flood disasters by constructing highly realistic virtual security threat rings. By building an urban security simulation system based on multi-party attack behaviors and defense decisions, this function helps planners and city managers to explore the complex interaction between sudden floods and floods and formulate the best response strategy in time, which improves the emergency response ability and the spatio-temporal allocation of resources. In this process, game theory, artificial intelligence algorithm and multi-party collaborative model are used to simulate different reactions and decisions of government departments, emergency response teams and ordinary citizens, and analyze the game behaviors of all parties, so as to formulate the best defense countermeasures. This dynamic game and deduction ability makes the security protection of the city more three-dimensional and comprehensive, and allows citizens to get more sense of security.

3.4.1. Attack inference simulation

(1) Scene construction

Aiming at the problem of urban macro and micro data collaborative management, a multi-disaster simulation framework based on 3D GIS platform and driven by UnrealEngine is proposed by using digital twin technology. The framework can extract and integrate information from 3D GIS platform, and turn it into urban risk intelligent attack and defense analysis model. The system takes Lanxi City, Zhejiang Province as an example, and constructs the intelligent attack and defense analysis model of rain-flood safety risk in Lanxi City (Figure 3).



Figure 3. Analysis model of intelligent attack and defense of rain-flood safety risk in Lanxi City. Source: ISOCARP.

(2) Lanxi flood disaster attack simulation

1) Dynamic adjustment of attack degree

The system can simulate flood disaster events under different rainfall and water level conditions. In this study, the ten-year, 50-year and 100-year flood events were simulated in Lanxi City (Figure 4). The once-in-a-decade flood simulation shows that the moderate intensity flood mainly affects low-lying areas, which provides basic data for the design of flood control facilities. The one-in-50-year flood simulation shows that the impact of larger floods is wider, and it is necessary to strengthen key flood control nodes and emergency evacuation plans. The once-in-a-century flood simulation highlights the full threat of extreme flooding to cities and calls for more comprehensive flood prevention and public education.



Figure 4. Lanxi City ten years, fifty years, one hundred years flood simulation. Source: ISOCARP.

2) Analysis of different attack paths

When the rainfall in each area of Lanxi City will reach more than 100mm within 3 hours, or has reached more than 100mm and the rainfall may continue, the water level exceeds 20m(Wusong meter), and the water points in each area (roads, Wells, tunnels, etc.) reach the warning line or preset threshold, that is, the flood disaster attack, the system will automatically trigger the alarm mechanism and enter the defense mode.

3.4.2. Defense simulation

(1) Urban equipment testing

The system can fully test and evaluate all types of urban infrastructure in flood simulation, accurately monitoring and analyzing the flood resistance and operation of critical infrastructure such as roads, Bridges, drainage systems, communications facilities and power supplies. At the same time, a large amount of real-time data is collected and processed to simulate urban response under various flood scenarios, identify

potential weak links and failure points, and carry out targeted reinforcement, so as to improve the overall flood resistance level of the city.

(2) Monitoring and early warning test

Combined with high-precision weather sensors, water level monitoring equipment, terrain monitoring technology and camera surveillance, the system will respond to disaster data in real time. Through open real-time information platforms and mobile applications, the latest disaster situation and evacuation information are released to the public (Figure 3), ensuring efficient organization and information transparency of emergency response, minimizing disaster losses and ensuring the safety of residents.

(3) Emergency response drill

1) Intelligent drainage management: the drainage pump station starts the pump in advance and adjusts the operation strategy in real time to remove the water in the optimal path; 2) Optimization of multi-party coordination ability and resource scheduling efficiency: rapid transmission and response of medical rescue resources, intelligent dispatch of rescue materials, and efficient linkage of different agencies; 3) Intelligent evacuation planning: Based on the traffic flow database of the professional map website, the data capture algorithm is designed to analyze the Volume-Dclay curve and traffic capacity requirements of the target area, and the safest and fastest evacuation route is developed for the personnel and materials in the disaster-stricken area; 4) Real-time data update: Collect and update the disaster situation and disaster risk level data of various regions in real time, and provide decision support through the visual interface. (Figure 5)



Figure 5. Intelligent emergency response measure module. Source: ISOCARP.

(4) Defense effect evaluation and plan optimization

After the disaster, the system will conduct emergency assessment and post-disaster resilience recovery. Using a large language model and social media data, the system proposes a rapid disaster assessment method and simulates urban restoration under a variety of complex constraints. In addition, the system

can automatically generate detailed diagnostic reports covering the current risk status, potential hazards and specific safety recommendations, helping urban planning managers to make scientific and reasonable decisions in a timely manner, thereby improving the city's emergency response capacity and resilience.

4. Results and discussion

Through the combination of big data and artificial intelligence technology, this study realized the following aspects: "instant perception, building a one-stop big data resource library, data fusion: realizing multi-source data fusion and analysis, intelligent learning: integrating artificial intelligence methods and technologies to offensive and defensive reasoning: The four-step leap of "carrying out disaster attack and defense early warning and prediction" has upgraded from static risk assessment to dynamic real-time monitoring, providing a new perspective and solution for urban flood risk management, effectively improving the accuracy and response speed of urban risk identification, and effectively guaranteeing the safe operation of the city.

In the future, the system will not only be limited to flood disasters, but also expand to other natural disasters, man-made disasters and man-made disasters and other fields, covering spatial planning, traffic management, disaster prevention and reduction and emergency response, etc., to build a national urban safety artificial intelligence diagnosis platform. In the context of "dual use", we continue to improve innovative service capabilities, optimize solutions, and actively explore new markets to better support urban safety management and development.

5. References

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