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Research on the Integrated Urban Fire Protection Solution of Monitoring, Management, Prevention, and Control

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Abstract. Based on smart city concept, empowering urban smart firefighting construction with digital technology is a key focus of China's fire safety industry. Guided by the integrated concept of "monitoring, control, prevention, and management," the construction of a smart fire safety system emphasizes 3 main aspects: fire hazard monitoring, operational rescue support, and the establishment of a comprehensive system. By leveraging intelligent sensing, intelligent decision-making, and comprehensive interconnectivity, a unified smart firefighting solution is developed, encompassing monitoring, management, prevention, and control. This solution provides a new approach for the research and development of an integrated and intelligent safeguard system, facilitating comprehensive fire prevention and control through inspection monitoring, response decision-making, and multi-platform collaboration in fire safety work.

Keywords:smart city; smart firefighting; hazard monitoring; operational rescue; public collective construction.

1. Introduction

1.1 Policy Background: Strengthening the Leading and Supporting Role of Science and Technology

In the latest "14th Five-Year Plan for National Firefighting Work," issued by the State Council's Work Safety Committee in 2022, five specific sub-objectives were proposed, including the "Basic Construction of China's Special Fire and Rescue Force System," "Enhanced Role of Technological Leadership," and "Establishment of a Basic Pattern of Joint Construction, Joint Governance, and Shared Benefits." It explicitly emphasizes the need to enhance the intelligent fire prevention and control capabilities by actively integrating firefighting system development into the "Smart City" and "Smart Community" initiatives, as well as the information systems for emergency management, housing, and urban-rural development. It also advocates for the establishment of an interconnected and shared mechanism and the utilization of a comprehensive fire safety big data system, with a focus on strengthening fire risk analysis, early identification, monitoring, and warning. Furthermore, it highlights the importance of leveraging information technology tools such as remote monitoring, Internet of Things (IoT) surveillance, and electrical monitoring to enhance the effectiveness of fire prevention and control efforts.

1.2 Current Challenge: The Fire Safety Situation Growing More Severe

According to official data, in 2021, China reported a total of 748,000 fire incidents, resulting in 1,987 deaths, 2,225 injuries, and direct property losses of 6.75 billion yuan. Compared to 2020, there was an increase of 9.7% in the number of fire incidents, a 24.1% increase in injuries, and a 28.4% increase in losses, while the number of deaths decreased by 4.8%. Among these incidents, there were 84 large-scale fires, which increased by 9 compared to 2020, and 2 major fires, an increase of 1 compared to 2020. It is worth noting that significant fires have been occurring continuously for the past 6 years. Please refer to Figure 1 for details. As shown in fig 1.

Furthermore, new technologies, materials, and emerging industries have introduced new risks. Fire and explosion incidents related to electric bicycles, new energy vehicles, energy storage facilities such as hydrogen, photovoltaic, and lithium-ion batteries, as well as natural gas leaks and large-scale warehousing and logistics facilities, have shown an increasing trend. The development of new energy industries such as energy storage power stations, photovoltaics, hydrogen energy, as well as emerging business models like live streaming with product sales, indoor ice and snow venues, and novel entertainment formats such as "bathing + KTV + murder mystery" and "movie + foot massage," have gradually accumulated fire safety risks. The development of new fields and emerging industries, combined with the unresolved historical issues in firefighting construction, has resulted in a persistently severe fire safety situation in China.

1.3 Development Orientation: Broad Prospects for the Smart Firefighting Industry

With the advancements in technologies such as the Internet of Things (IoT), artificial intelligence (AI), virtual reality (VR), and communication, the traditional firefighting approach of "post-rescue" is gradually being replaced by smart firefighting. The construction of a fire safety system with Chinese characteristics is transitioning from response-oriented to prevention and control-oriented. The overall market size of China's smart firefighting industry is continuously growing. In 2020, the market size was approximately 275.7 billion yuan, with an average compound annual growth rate of 18.3% between 2015 and 2020. According to estimates by the Foresight Industry Research Institute, the market size of China's smart firefighting industry is expected to reach 422.2 billion yuan by 2026. The future prospects of smart firefighting are vast, aligning with the development trend of IoT and the current demand for intelligence. Please refer to Figure 2 for illustration.

In conclusion, as the upgrading of the firefighting system and the trend of industrial integration become evident, it is necessary to create an integrated solution that combines "technical defense" and "human defense" through monitoring, feedback, and support. It is crucial to continuously upgrade, explore, develop, and construct application platforms and fire safety ecosystems that integrate diverse technologies, data, and resources. The urgent task is to achieve the integrated system upgrade from "response" to "prevention" to enhance China's emergency management capabilities.

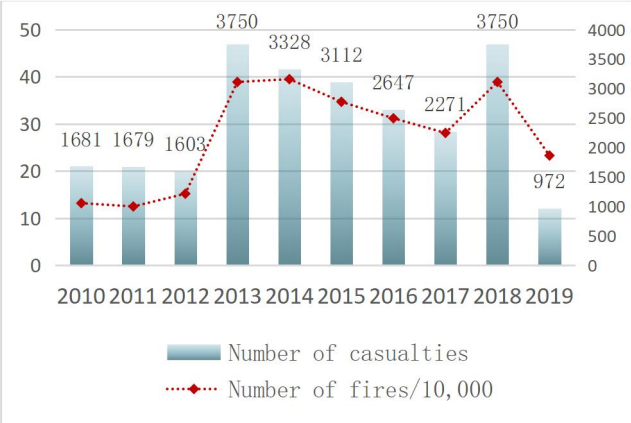

Figure 1. Statistics on fire occurrence in china from 2010 to 2019.
Data source: United Nations World Fire Statistics Center

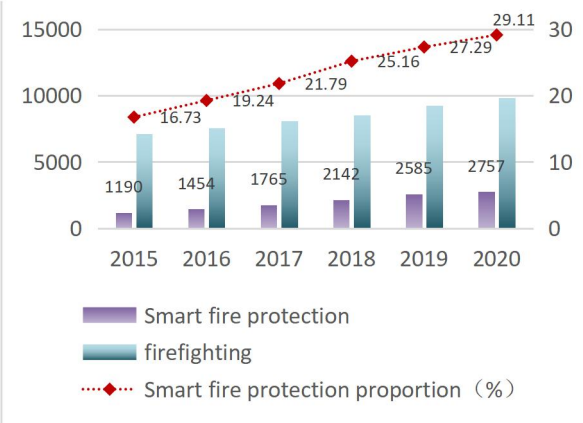

Figure 2. The development scale of china's smart firefighting industry.
Data source: Foresight Industry Research Institute

2. Literature Review

2.1 Research Overview in the Field of Urban Firefighting

Combined with the policy background, practical problems and industry development trends, it is crucial to complete the real-time analysis and calculation of urban fire risks with the help of technical means such as Internet of Things, cloud computing and big data to achieve accurate deployment and control, and effectively improve prevention and control efforts to avoid the emergence of crises. At the same time, the use of data sharing and coordination linkage and other forms, to solve the post-crisis fire control and security problems is of great practical significance and necessity.

In the field of social fire safety, there have been many studies focusing on monitoring of fire hazards and fire rescue. The researcher of Drcreport, Tianlong Pu, and senior engineer of Anhui Provincial Fire and Rescue Corps, Lu Guangbin, Discussion on the Construction of Intelligent Firefighting in Modern Cities makes it clear: fire prevention and control automation, law enforcement standardization, firefighting command intelligent, team management refinement of modern urban fire safety needs, proposed from data collection and analysis, early warning command, and then feedback optimization of the dynamic process of intelligent firefighting [1,2]; Tian Maoliang, the professor of Beijing University of Architecture proposed to leverage 5G technology to improve the deployment of intelligent firefighting, focusing on solving fire safety disadvantages such as poor device versatility, while strengthening the issue of regulatory working mechanisms for products and systems [3,4]. Rui Gao of Pinghu Brigade of Jiaxing City Detachment of Zhejiang Provincial Fire and Rescue Corps, Fire Prevention and Control Application Based on Smart City IOT Platform emphasizes the need to efficiently integrating modern form information technology, improving fire monitoring and controlling information base, promoting the establishment of firefighting big data platform, to establish a smart city which is safety and reliable operation and smart control of firefighting work [5,6].

Mozaffari M. Hamed, Li Yuchuan and Ko Yoon's Real-time detection and forecast of flashovers by the visual room fire features using deep convolutional neural networks explored the use of adopting artificial intelligence (AI) technologies for pattern recognition and feature extraction in the study, they proposed to build an optimized convolutional neural network named "FlashoverNet", to detect and forecast flashover occurrence in enclosure fire incidents [7]. Their investigations demonstrate that FlashoverNet can successfully detect and forecast flashover onset in real-time with more than 94% accuracy in full-scale actual room fire tests. Zhang Yuxin, Zhang Xiaoning and Huang Xinyan's Design a safe firefighting time (SFT) for major fire disaster emergency response presents a new concept considering the dynamics of firefighting and evacuation dynamics - a new concept of performance-based safe firefighting time (SFT) for tunnel fire safety design, and a framework for the application of SFT in future tunnel fire safety design and smart firefighting [8]. Zhang Guowei, Yan Su, Zhu Guoqing, Feng Pengyue and Jia Boyan's Smart firefighting construction in China: Status, problems, and reflections argues that smart firefighting construction in China should establish data interconnectivity, industrial normalized management, 2D/3D geographic information interaction and extension, high-integration fire protection theory, and many other aspects in the near future and truly realize firefighting visualisation and efficient data applications for 4D time space [9].Intelligent Fire Information System Based on 3D GIS highlights the importance of establishing an IoT-based firefighting information system, which is of great value in ensuring fire safety and conducting emergency rescue, and is worth promoting its application [10].

By reviewing the relevant literature and the current state of research, the importance and necessity of fire prevention and control problems are highly emphasized, and strategies are proposed to address current urban firefighting problems in specific scenarios such as hidden danger monitoring, fire rescue and firefighting co-construction.

2.2 Development Trends in the Field of Urban Firefighting

2.2.1 Current status of fire hazard monitoring

The current fire hazard detection systems utilized in the market mainly rely on equipment and facilities such as temperature sensors, light sensors, smoke detectors, and combustible gas detectors. These devices are deployed within the building spaces to assist in monitoring and provide feedback. During a fire incident, on-site personnel can respond quickly upon receiving alerts from the devices. However, there is a lack of proactive prediction systems and continuous equipment operation monitoring systems. Additionally, the existing risk assessment system for hazard levels is weak, primarily relying on expert assessments, which tend to be subjective. This system cannot cope with the increasing trend of a large number of diverse and rapidly changing fire hazards in the context of rapid development. As a result, users face difficulties in taking precise measures, leading to significant resource waste. Furthermore, the detachment between building monitoring systems and regional communication networks significantly reduces the response speed during fire emergencies.

2.2.2 Current status of firefighting and rescue operations

The current firefighting and rescue operations primarily rely on the immediate response of the fire-affected units and external assistance from urban firefighting departments. On one hand, many units have limited capabilities in dealing with sudden fire incidents. They are unable to promptly understand the distribution of firefighting equipment and develop corresponding firefighting plans. In the case of high-rise fires, individuals inside the building face challenges in quickly comprehending the progression of the fire, identifying evacuation routes or plans, and their inappropriate or untimely self-rescue actions often increase the difficulty of rescue operations. On the other hand, external rescue forces have limited knowledge about the fire situation from the time they receive the alarm, dispatch, and reach the rescue scene. The time cost of transporting rescue forces is also influenced by urban traffic conditions, which hampers the ability of firefighting teams to quickly formulate rescue plans and take appropriate measures [11].

2.2.3 Current status of fire protection system

For a long time, the fire departments in China have played a "nanny-like" role in firefighting and rescue operations. Additionally, the low awareness of supervision and weak regulatory capacity among various social units have led to numerous unnecessary fire hazards and incidents. Moreover, the scale of firefighting and rescue forces is small and lacks a systematic approach. The communication delays among different rescue forces in complex situations have resulted in rescue delays. Furthermore, the relevant management departments have been in a passive state when responding to fire incidents, and there has been a lack of progress in establishing relevant support mechanisms, management systems, and incentive measures for fire protection. This has created a gap in the construction of fire protection and support system in China [12].

In summary, the monitoring of fire hazards and practical rescue operations are the key and challenging aspects of current urban fire protection. In the digital era, empowering urban fire protection with digital technology for "monitoring, management, prevention, and control," optimizing the existing fire hazard monitoring models, improving monitoring efficiency, and enhancing practical rescue capabilities are of paramount importance for the smart construction of urban fire protection and the maintenance of people's lives and property safety. Furthermore, using digital technology to promote the "joint governance" of fire protection among all citizens is of significant importance for accelerating the establishment of a social governance pattern based on co-construction, co-governance, and sharing.

3. Strategy Design on the integrated urban smart firefighting solution of "monitoring, management, prevention, and control"

3.1 General Ideas and Principles

Focusing on the construction of urban smart firefighting, we aim to address the challenges faced during both "peacetime" and "wartime" scenarios. Considering the multitude of fire safety hazards in buildings during "peacetime" and the difficulty in assessing risk levels and consequences, as well as the complexity and ever-changing factors during rescue operations in "wartime," we propose a progressively developed module that encompasses hazard monitoring and operational rescue support. This approach aims to enhance fire prevention and assessment capabilities while improving the precision of rescue operations. Furthermore, we plan to establish a participatory fire safety system through means such as information platform development, harnessing the collective efforts of organizations and social entities. This will contribute to creating a favorable environment where fire safety becomes a collective responsibility. The overall project framework is illustrated in Figure 3.

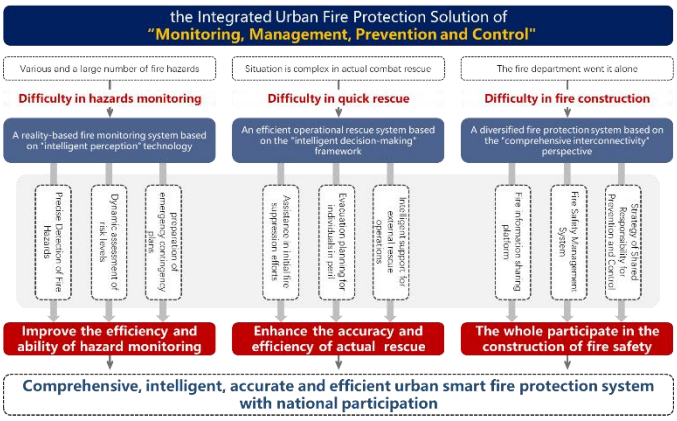

Figure 3. The overarching concept of the project

3.2 Feasibility Analysis

At the overall level, the construction of the project's technological system comprises three implementation plans: Plan 1 - Fire Monitoring System, Plan 2 - Firefighting and Rescue System, and Plan 3 - Fire Protection System. These plans demonstrate feasibility in terms of implementation, theory, and technology.

3.2.1 Implementation feasibility analysis

The Fire Monitoring System aims to establish a specialized, detailed, and immersive fire safety supervision system, enhancing the identification of fire hazards, assessment of risk levels, and preparation of emergency response plans. By addressing the root causes, it effectively reduces the likelihood of fire incidents while enhancing the precision of real-time firefighting and rescue operations. This system provides a foundational theoretical framework for the establishment of Plan 2 - Firefighting and Rescue System.

The Firefighting and Rescue System aims to facilitate rapid response to initial fire outbreaks, develop evacuation plans for individuals in peril, and provide intelligent support for external rescue operations. Its objective is to ensure swift fire response, expedite the evacuation of endangered individuals, and enable prompt external assistance. This system serves as a robust mid-term technological support for the construction of Plan 3 - Fire Protection System.

The Fire Protection System intends to leverage various channels, such as the establishment of a fire information sharing platform, the development of a safety management system, and the implementation of insurance mechanisms. It seeks to fully harness the societal aspects of fire

prevention capabilities, contributing to the realization of a "co-building, co-governance, and shared" approach to intelligent urban fire prevention.

3.2.2 Theoretical feasibility analysis

Plan 1 - Augmented Fire Monitoring System based on "Smart Sensing" Technology: From both peacetime and wartime perspectives, this plan focuses on fire hazard monitoring, risk level assessment, and emergency response plan preparation. By employing a combination of technical defense, human defense, and simulation-based preparations, it provides multiple layers of support for fire prevention and control. The system is characterized by a comprehensive, hierarchical, and logically sound framework, demonstrating its theoretical feasibility.

Plan 2 - Efficient Real-time Rescue System based on "Intelligent Decision-making" Framework: By utilizing an intelligent collaborative system, this plan showcases smart firefighting management for both networked units and supervisory authorities. It provides comprehensive data support through a "dual defense" approach, integrating technical defense and human defense. This combination enhances fire prevention efficiency and safety through regulatory measures, service provision, and technological advancements. The plan demonstrates theoretical feasibility.

Plan 3 - Diversified Fire Protection System based on "Comprehensive Interconnection" Perspective: Embracing the opportunities brought by information technology in the new era, this plan adheres to fire safety regulations and implements fire safety management responsibilities. Throughout the implementation process, it efficiently mobilizes social resources such as insurance and finance to assist user units in fulfilling their fire safety management obligations. Simultaneously, it supports local governments in innovating fire safety management models, transitioning from a predominantly regulatory approach to a model that combines fire supervision with socialized fire services. The plan exhibits theoretical feasibility.

3.2.3 Technical feasibility analysis

Plan 1 - Augmented Fire Monitoring System based on "Smart Sensing" Technology: This plan utilizes indoor geographic information system (GIS) construction and video integration technology to achieve complete signal coverage and supervision of both indoor and outdoor monitoring areas. It enables immersive 3D modeling and virtual video surveillance. By leveraging technologies such as the Internet of Things (IoT), fire analysis models, and visualisation, it enables real-time monitoring and efficient information dissemination. The system also establishes a digitalized contingency plan system, continuously optimizing fire emergency response plan simulations.

Plan 2 - Efficient Real-time Rescue System based on "Intelligent Decision-making" Framework: This plan utilizes technologies such as the Internet of Things (IoT) and SAS algorithms to detect fire hazards, assess risk levels, and formulate proactive strategies. It employs ODA crowd positioning, UNITY 3D visualisation of buildings, and SMARTBI disaster propagation simulation technology to design optimal evacuation routes and guide endangered individuals to safety. With the support of GIS geographic information system data, RS remote sensing imagery data, ROS intelligent route planning systems, and PCMD communication networks, the system enables rapid deployment and efficient response of external rescue forces.

Plan 3 - Diversified Fire Protection System based on "Comprehensive Interconnection" Perspective: This plan relies on a visualized information display platform to comprehensively, real-time, and intuitively monitor the safety status of fire protection facilities in enterprises. Graphical formulation, execution, and tracking of inspection tasks streamline the management work of safety personnel, ensuring efficiency. User-friendly operations and intelligent assessment improve the quality of safety work. By establishing a standardized fire safety management system, efficient collection, access, and classified storage of data from community staff, grid members, and fire support officers in different regions are achieved, enabling real-time monitoring and control of service processes and quality. Leveraging digital technologies, the advantages of emerging technologies such as virtual reality (VR), artificial intelligence (AI), and holographic projection are utilized to create a multi-scenario system that broadens the dimensions of fire protection.

3.3 Features and Innovations

Plan 1 - Real-time Fire Monitoring System Based on "Intelligent Perception" Technology: Revolutionizing the traditional approach of primarily relying on manual inspections for fire hazard detection, the project adopts a "regulation and inspection integration" approach to achieve comprehensive and real-time control over the monitoring area. This innovative system significantly enhances the capability and efficiency of hazard detection, ensuring effective fire monitoring.

Plan 2 - Efficient Operational Rescue System Based on "Intelligent Decision-making" Framework: Enhancing the application of intelligent technologies in firefighting and rescue operations, this project integrates decision-making processes, crowd evacuation planning, urban communication networks, and regional firefighting arrangements. By leveraging these interconnected systems, the project aims to minimize casualties and achieve a rapid response time of within "5 minutes" for emergency dispatches.

Plan 3 - Diversified Fire Protection System Based on "Comprehensive Interconnection" Perspective: The project introduces an innovative social fire protection system that incorporates fire insurance mechanisms. By leveraging the collaboration of various stakeholders, including the public, market, and government, the system aims to foster a favorable environment for widespread public participation in urban smart firefighting. This approach encourages collective responsibility and promotes the active involvement of multiple sectors in the construction of intelligent firefighting measures.

4. Reality-Based Fire Monitoring System Based on "Intelligent Perception" Technology

4.1 Overview

The proposed plan aims to address the challenges of multiple fire safety hazards and difficult risk assessment in real-life situations. It involves the development of a reality-based fire prevention and control system using "intelligent perception" technology. By establishing a specialized, precise, and reality-based fire safety supervision system, the plan aims to achieve vertical and integrated control through accurate supervision, intelligent early warning, and swift rectification. The ultimate goal is to enhance the efficiency of hazard monitoring and reduce the likelihood of fire occurrences from the source.

4.2 Methods and Technological Pathway

The technical pathway of the reality-based fire prevention and control system based on "intelligent perception" technology is illustrated in Figure 4.

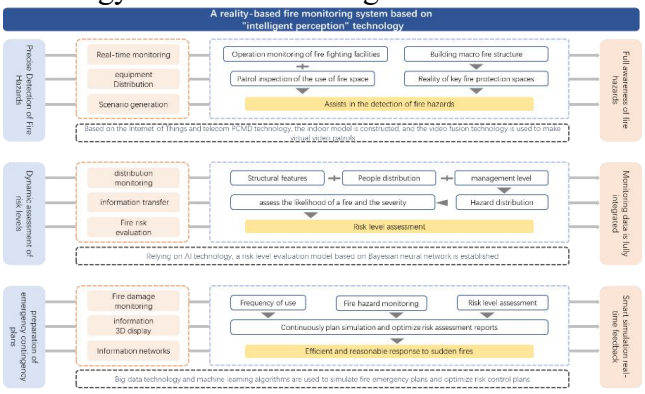

Figure 4. Methods and technological pathway

4.3 Implementation Plan

4.3.1 Precise detection of fire hazards

Leveraging the Internet of Things (IoT) and telecommunications PCMD technology, an indoor spatial three-dimensional model is constructed. The utilization of mobile interconnectivity technology establishes a rapid information channel, enabling real-time remote monitoring of the operational status of fire safety facilities. This effectively enhances the current situation of untimely fire response caused by malfunctioning fire equipment. Please refer to Figure 5 for illustration.

Furthermore, by employing video fusion technology, continuous 24-hour virtual video patrols are conducted in any designated area. Through analysis algorithms, real-time monitoring of flame and smoke conditions within the surveillance area is achieved, enhancing the intelligent identification of fire incidents by the monitoring equipment. In the event of a fire, corresponding video resources can be accessed in real time, allowing for an immediate understanding of the on-site situation. Please refer to Figure 6 for illustration.

Additionally, for key access units, a three-dimensional detailed modeling is conducted in conjunction with the Geographic Information System (GIS). This enables a multimedia augmented reality presentation of the macro fire structure of buildings, key fire sections, and specific fire safety facilities. By integrating fire hazard information, scientifically sound and timely fire inspection plans are formulated, establishing a spatial visualisation-based management model for specialized, precise, and immersive fire safety. Please refer to Figure 7 for illustration.

4.3.2 Dynamic assessment of risk levels

By leveraging AI technology and considering factors such as building structural characteristics, crowd gathering situations, fire management level, and distribution of hazards, a risk level assessment model based on Bayesian neural networks is established. This model enables the dynamic evaluation of fire risk status for individual buildings and regional structures, determining the likelihood of a fire occurrence and the severity of its consequences. It serves as a technological basis for fire prevention. Please refer to Figure 8 for illustration.

4.3.3 Comprehensive preparation of emergency contingency plans

By integrating data such as building occupancy rates, fire hazard monitoring, and risk assessment results, and leveraging big data technology and machine learning algorithms, continuous simulations of fire emergency plans are conducted. This process provides continuously optimized risk assessment reports and risk control plans, thereby enhancing the level of fire safety in buildings. Additionally, a three-dimensional simulation system is utilized to create realistic fire scenes, incorporating standardized scenarios based on height, size, complexity, and other factors. By simulating both domestic and international classic fire cases and leveraging algorithmic insights and learning, the response to unexpected fire incidents becomes more efficient, rapid, and effective. Please refer to Figure 9 for illustration.

4.4 Summary

The implementation of a reality-based fire prevention and control system, utilizing "smart sensing" technology, provides comprehensive and diverse mechanisms and preparations for fire prevention and control during normal circumstances. This system enhances the efficiency of fire hazard inspections, improves the intelligence and preparedness of fire prevention and control measures, and enhances the level of fire safety in buildings. By simulating numerous classic fire scenarios, the system helps refine response strategies in the event of a fire, effectively reducing the likelihood of fire occurrences, and ultimately elevating the overall fire safety standards in buildings.

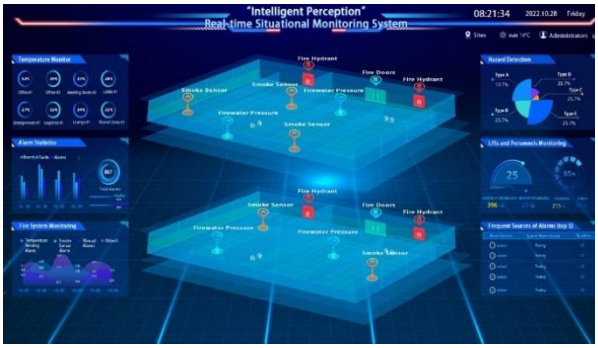

Figure 5. Monitoring the operational status of fire safety equipment

Figure 6. Rapid assessment of fire incident severity

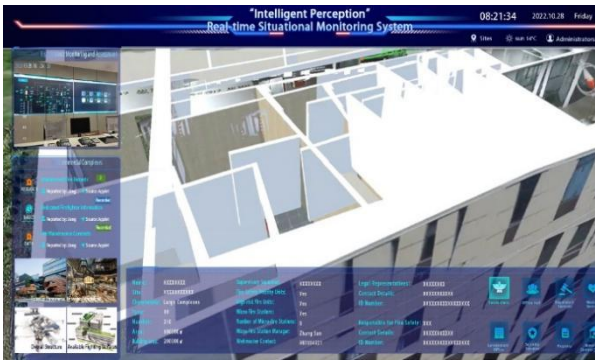

Figure 7. Real-time monitoring of key building spaces

Figure 8. Assessment of fire risk levels in buildings

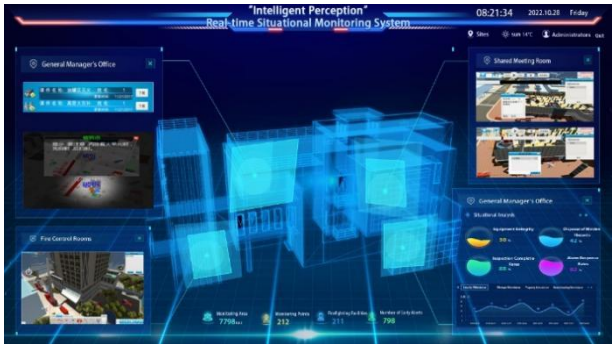

Figure 9. Stockpiling of fire emergency contingency plans

5. An Efficient Operational Rescue System Based on the "Intelligent Decision-Making" Framework

5.1 Overview

This solution focuses on addressing the challenges faced in firefighting and rescue operations due to complex situations and rapidly changing factors. It entails constructing an operational rescue system based on the "intelligent decision-making" framework. This system enables quick response to initial fire suppression, efficient planning for the evacuation of individuals in danger, and intelligent external support for rescue operations. It ensures rapid response to fires, swift evacuation of individuals in peril, and expedited external rescue efforts.

5.2 Methods and Technological Pathway

The technological roadmap of the operational rescue system based on the "intelligent decision-making" framework is illustrated in Figure 10.

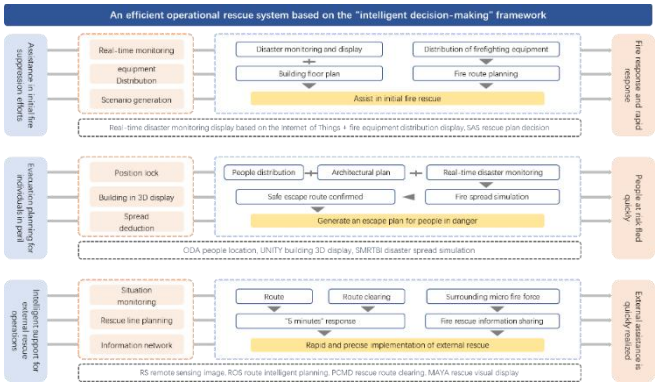

Figure 10. Methods and technological pathway

5.3 Implementation Plan

5.3.1 Assistance in initial fire suppression efforts

By leveraging fire equipment control terminals and integrating monitoring devices and fire safety facilities, rapid fire suppression assistance is provided during the early stages of a fire. Remote video viewing of the alarm scene is facilitated through monitoring devices, enabling visual representation of the fire situation. Additionally, based on the distribution of fire safety equipment, prompt fire suppression plans can be formulated, significantly enhancing the speed of fire response. Please refer to Figures 11 and 12 for illustration.

5.3.2 Evacuation planning for individuals in peril

By leveraging ODA (On-Demand Allocation) for crowd positioning, UNITY for three-dimensional visualisation of buildings, and SMARTBI for simulated disaster spread analysis, evacuation planning for individuals in peril can be effectively implemented. This process involves considering factors such as the location of individuals at risk, three-dimensional models of buildings, the likelihood of fire propagation, and emergency contingency plans stored in the database. The evacuation routes for individuals in danger are rapidly planned, synchronized with their mobile devices, and assist relevant personnel in swiftly escaping the disaster scene, ensuring the safety of lives and property. Please refer to Figures 13 and 14 for illustration.

5.3.3 Intelligent support for external rescue operations

By utilizing GIS (Geographic Information System) data, RS (Remote Sensing) imagery data, ROS (Robot Operating System) intelligent route planning system, optimal dispatch routes can be customized based on real-time traffic conditions. Through the PCMD communication network, vehicles are notified of the routes for swift clearance. Simultaneously, nearby mini fire stations are mobilized as a priority for rescue operations. Real-time sharing of rescue progress through cloud-based platforms enables collaborative efforts across multiple stages, facilitating rapid and precise execution of external rescue operations. Please refer to Figure 15 for illustration.

5.4 Summary

The operational rescue system based on the "intelligent decision-making" framework provides expedited, efficient, and precise point analysis strategies for fire rescue operations. It reduces decision-making time during fire incidents, enhances the likelihood of safe evacuation for individuals, and facilitates the achievement of a "5-minute" rapid response and multi-end collaborative operations. This system effectively improves the efficiency of rescue operations during emergencies.

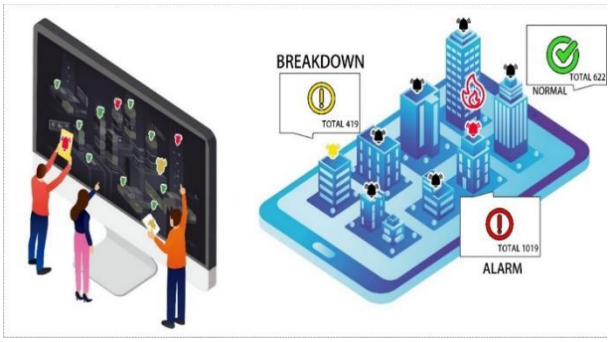

Figure 11. Fire detection and alarm synchronized with various communication endpoints

Figure 12. Fire alarm and firefighting command terminal

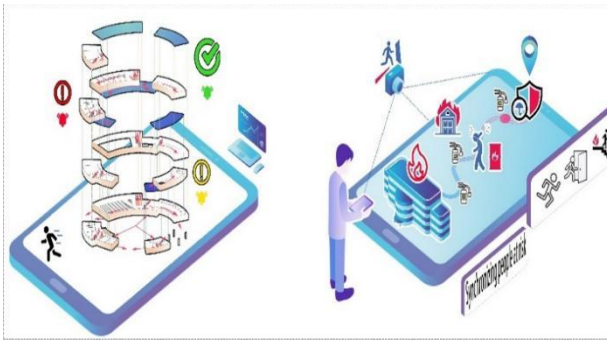

Figure 13. Intelligent generation of evacuation routes and synchronization with mobile devices of individuals in peril

Figure 14. Specialized command terminal for the evacuation of individuals in peril

Figure 15. Fig. 15 Integrate surrounding traffic conditions and the layout of fire stations swiftly generate the most optimal dispatch routes

6. A Diversified Fire Protection System Based on the "Comprehensive Interconnectivity" Perspective

6.1 Overview

This solution addresses the issue of the current single-dimensional fire protection force and proposes the establishment of a diversified fire protection system based on the "comprehensive interconnectivity" perspective. Through initiatives such as information sharing, the construction of a safety management system, and the introduction of insurance mechanisms, the aim is to transform the traditional role of the fire department into a more proactive and preventive approach. By leveraging information technology, this system encourages the active participation of both

organizations and individuals in fire safety, shifting from a solitary approach to hazard management towards a collective effort. It promotes a favorable environment where everyone is involved in ensuring fire safety.

6.2 Methods and Technological Pathway

The technological roadmap of the diversified fire protection system based on the "comprehensive interconnectivity" perspective is illustrated in Figure 16.

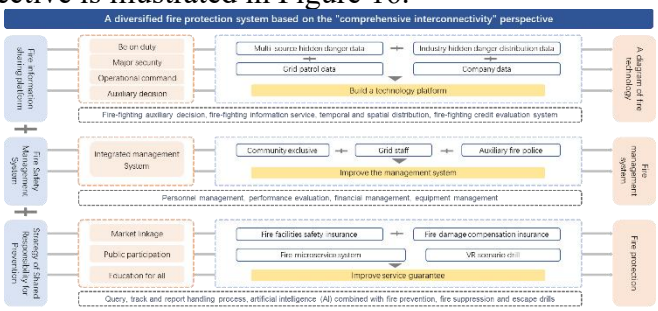

Figure 16. Methods and technological pathway

6.3 Implementation Plan

6.3.1 Fire information sharing platform - "one-map" of fire technology

Utilizing GIS and BIM (Building Information Modeling) technologies, the comprehensive presentation of various sources of hazard data, industry hazard distribution data, grid inspection data, and company data (including monitoring centers) within the jurisdiction is achieved. This forms "One-Map of Fire Supervision" to gain a comprehensive understanding of the fire safety situation in the area. The main functionalities include readiness duty, operational command, major security, and decision support. It addresses issues such as the lack of data in firefighting and rescue operations, lack of information sharing between different parties, and lack of transparency in the fire scene. It enables the "One-Map" command, coordination, analysis, and decision-making for firefighting and rescue operations. Please refer to Figure 17 for illustration.

The Fire Information Sharing Platform enables in-depth analysis, interpretation, and integrated presentation of firefighting big data. It facilitates the seamless integration of data flows, business processes, and management flows. The platform plays a crucial role in supporting fire-related decision-making, providing firefighting information services, analyzing the spatiotemporal distribution of fires in a region, and establishing a fire credit evaluation system.

Furthermore, based on historical fire statistics in different regions, the platform conducts correlation analyses across various dimensions such as time series, spatial sequences, economic factors, causative factors, and energy consumption (electricity usage). These analyses aim to uncover patterns and rules governing fire occurrences in specific spatiotemporal units. The insights gained from this analysis can then provide valuable data support for targeted fire prevention and control measures. Please refer to Figure 18 for illustration.

6.3.2 Fire safety management system – "one-system" of fire management

Relying on dedicated community personnel, grid members, fire volunteer police, and other regulatory users within the region, combined with embedded fire safety information of units, actively receiving real-time hazard information from IoT monitoring, and integrating hierarchical alarm handling rules, the full potential of community personnel, grid members, and fire volunteer police is harnessed to establish a hierarchical prevention and control system, thus alleviating the supervisory burden on the fire brigade. Please refer to Figure 19 for illustration.

Simultaneously, based on the construction of the government extranet, a comprehensive fire service management system is established, utilizing technologies such as mobile internet and the Internet of Things (IoT). This system facilitates personnel management, performance evaluation, financial management, equipment management, and barracks management, allowing for a

comprehensive understanding of the basic situation regarding personnel, vehicles, and assets management. This ensures clear data and a transparent situation, thereby enhancing the precision and scientific level of the firefighting and rescue teams.

6.3.3 Strategy of shared responsibility for prevention and control – "one-unified front" of ensuring fire safety

Promote Market Linkage. Introducing fire facility safety insurance, fire loss compensation insurance, and other measures not only alleviate psychological pressure on property owners resulting from fires but also reduce government expenditure on fire management. Simultaneously, these measures effectively enhance the regulatory efforts of all stakeholders in fire prevention and control. Please refer to Figure 20 for illustration.

Enhance Public Engagement. Mobilizing the power of public opinion and citizen oversight, timely detection and prevention of fire-related violations, elimination of fire hazards, and prevention of major fire accidents, particularly those resulting in mass casualties. Citizens can report incidents through a dedicated WeChat public account by providing detailed information and tracking the progress of their reports (under review, in process, completed). The reporting system supports various formats, including images, videos, and text. Please refer to Figure 21 for illustration.

Promote Universal Education. Integrating virtual reality (VR), artificial intelligence (AI), and holographic projection technology with fire prevention, firefighting, and evacuation drills, a comprehensive system is established that includes VR devices, application systems, platforms, and content. This system creates highly immersive and interactive scenario-based training environments for fire prevention and evacuation, faithfully replicating fire scenes and enabling the practice of evacuation skills. The ultimate goal is to enhance public awareness of fire safety and improve the self-rescue capabilities of individuals in case of fire incidents.

6.4 Summary

From the perspective of "comprehensive interconnectivity," a diverse fire protection system is constructed. Firstly, by utilizing GIS and BIM technologies, a fire information sharing platform is established to provide data support for specialized fire governance. Secondly, various societal forces are mobilized to build a hierarchical prevention and control system, enabling a diverse organization of firefighting teams. Lastly, by leveraging economic elements such as insurance and finance, as well as emerging technologies like VR and AI, the aim is to enhance public awareness of fire safety and improve the fire protection system.

Figure 17. The fire information sharing platform

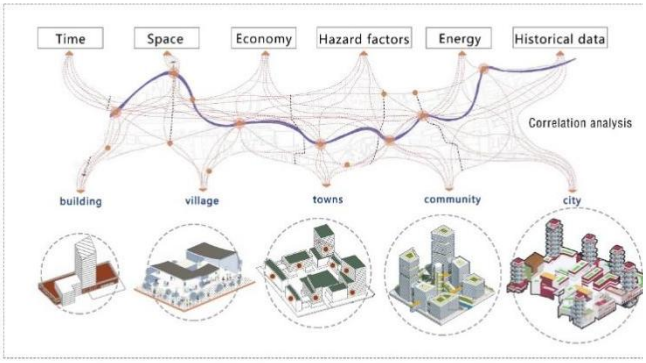

Figure 18. The fire information sharing mechanism

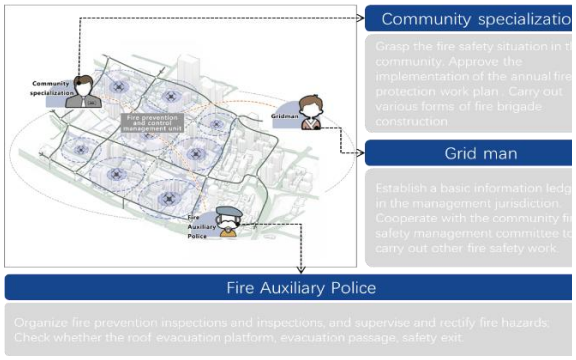

Figure 19. Grid-based management model

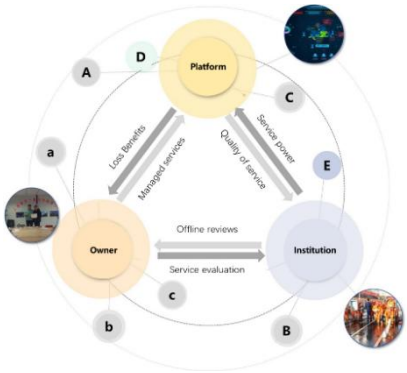

Figure 20. Illustration of the Insurance Mechanism

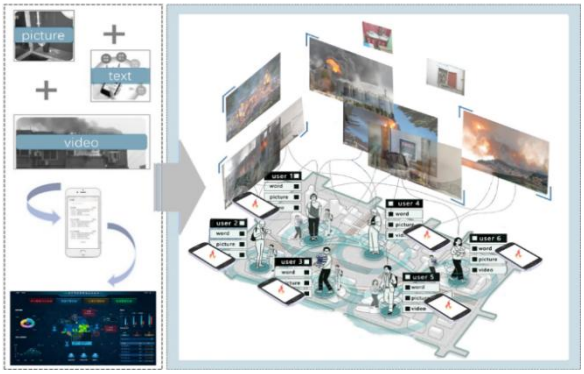

Figure 21. Construction of public participation mechanism

7. Conclusion

The research of this paper can provide a new idea of intelligent and perfect integrated security system research for fire inspection and monitoring, response and decision making, and multi-terminal coordination of comprehensive fire prevention and control. The project analyzes the current painful problems in the field of firefighting at three levels: day-to-day situations, emergencies and security systems, and discusses in depth the construction and feasibility of three systems, namely intelligent fire hazard inspection, efficient combat. The seminar will discuss the construction and feasibility of three systems, namely intelligent fire hazard inspection, efficient combat rescue and comprehensive fire protection, and form a smart fire protection system with the core of intelligent technologies such as Internet of Things, data visualisation and intelligent algorithmic decision-making, which can provide a new way of thinking and system concept for the construction of smart city fire protection.

References

[1] Z. Yao, "Construction and application of urban "intelligent firefighting" system," China Emergency Rescue, no. 06, pp. 25-29, 2022.

[2] Y. Ma, "Analysis of the construction of intelligent firefighting platform in the context of smart city," Science and Technology Perspectives, no. 06, pp. 12-14, 2022.

[3] R. Gao, "Fire prevention and control applications based on the Internet of Things platform for smart cities," Firefighting World (Electronic Edition), vol. 7, no. 24, pp. 51+53, 2021.

[4] M. Tian, "SWOT analysis of intelligent fire protection construction in the context of smart city," Fire Science and Technology, vol. 40, no. 03, pp. 446-448, 2021.

[5] T. Pu, G. Lu, "Discussion on the construction of intelligent fire protection in modern cities," People's Forum-Academic Frontier, no. 05, pp. 50-55, 2019.

[6] C. Cheng, X. Huang, S. Xie, D. Wu, W. Jiang, "The development and future of smart city and smart firefighting," Fire science and technology, vol. 37, no. 06, pp. 841-844, 2018.

[7] M. H. Mozaffari and Y. Li and Y. Ko, "Real-time detection and forecast of flashovers by the visual room fire features using deep convolutional neural networks," Journal of Building Engineering, vol. 64, 2023.

[8] Y. Zhang and X. Zhang and X. Huang, "Design a safe firefighting time (SFT) for major fire disaster emergency response," International Journal of Disaster Risk Reduction, vol. 88, 2023.

[9] G. Zhang, "Smart firefighting construction in China: Status, problems, and reflections," Fire and Materials, vol. 44, no. 4, pp. 479-486, 2020.

[10] J. Hu, Z. Lv, D. Yuan, B He, D. Yan, "Intelligent Fire Information System Based on 3D GIS," Virtual Reality & Intelligent Hardware,vol. 5, no. 2, 2023.

[11] G. Mitri, S. Saba, M. Nader et al., "Developing Lebanon's fire danger forecast," International Journal of Disaster Risk Reduction, vol. 24, 2017.

[12] C. Marcello, A. Bachisio, L. Giovanni, et al., "Integrated Platform for Wildfire Prevention and Management: The S2IGI Project," Environmental Sciences Proceedings, vol. 17, no. 1, 2022.