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Intelligent Inspection and Closed-loop Management Innovation of Campus Fire Safety

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Abstract: As universities expand in scale and diversify in functions, traditional fire safety management faces challenges such as inefficient inspections and difficulty in tracing hazards. Technological innovation is key to enhancing efficiency, focusing on the core needs of campus fire safety. Intelligent inspection technology is applied to facility monitoring, hazard identification, and risk alerts, establishing a closed-loop system of monitoring, identification, disposal, and feedback. By leveraging the characteristics of IoT, AI, and big data technologies, the innovative solutions encompass technological integration, process optimization, and responsibility enhancement. This research aims to help universities overcome traditional bottlenecks, strengthen fire safety safeguards, and drive management transformation toward precision, intelligence, and efficiency.

Keywords: University campus; Fire safety; Intelligent inspection; Closed-loop management; Technological innovation

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1. Introduction

Higher education institutions, with their dense populations and concentrated teaching/research facilities, face critical fire safety challenges that directly impact faculty and student safety, property protection, and campus stability. Traditional manual inspections suffer from limited coverage, delayed hazard detection, and delayed corrective actions, making them inadequate for modern complex security management needs. With the rapid advancement of technologies like IoT, AI, and big data, intelligent inspection systems have emerged as a game-changer. These systems enable real-time facility monitoring, automatic hazard identification with precise location tracking, and closed-loop management to ensure full-process controllability of corrective actions. This represents an inevitable trend in fire safety management upgrades. This study focuses on relevant innovations to provide valuable references for optimizing fire safety management models in higher education institutions.

2. Current status and challenges of campus fire safety management in higher education institutions

2.1. The traditional inspection mode is inefficient and has prominent limitations

University campus buildings are dispersedly arranged, encompassing multifunctional zones such as teaching buildings, dormitories, laboratories, and libraries. The extensive yet scattered fire safety facilities require traditional inspection methods that rely on manual verification by staff, consuming substantial manpower and material resources while often leading to overlooked areas and human errors. The latent fire safety risks are difficult to detect through manual inspections in real time. Inspection results are typically recorded in paper ledgers or basic spreadsheets, with delayed information flow and hindered data sharing. This results in ineffective and non-targeted inspection work, failing to meet the demands of dynamic campus fire safety management [1].

2.2. The hidden danger rectification process is not closed-loop, resulting in disconnection of management

Currently, some higher education institutions face challenges in integrating hazard identification with corrective measures within their fire safety management systems. Inspections often lack a unified tracking mechanism, with ambiguous accountability and insufficient oversight during implementation, resulting in delayed feedback on remediation outcomes. Certain hazards persist due to delayed responses and incomplete rectifications, creating a vicious cycle of detection, neglect, and recurrence. The absence of systematic analysis of hazard data hinders comprehensive assessment of campus fire risks, prevents the formulation of targeted prevention strategies, and ultimately increases the likelihood of safety incidents.

2.3. Lack of precision in the maintenance and management of fire protection facilities

Higher education institutions maintain diverse fire safety systems, including automatic fire alarm systems, automatic fire suppression systems, emergency lighting, and evacuation guidance systems. Maintenance standards and cycles vary significantly across these facilities. Traditional maintenance approaches rely on fixed-frequency inspections and empirical judgments, lacking real-time monitoring of operational status, which often results in either excessive maintenance or neglect [2]. Outdated, malfunctioning, or damaged facilities are not promptly replaced, rendering them ineffective during emergencies and compromising campus fire safety. Incomplete maintenance records and inconsistent standards further hinder full lifecycle management, impeding subsequent maintenance efforts.

3. Technical support and application foundation of intelligent inspection for campus fire safety in universities

3.1. Real-time monitoring of fire protection facilities by using IoT technology

IoT technology equips fire protection systems with diverse sensors to collect operational data in real time. Fire hydrants and extinguishers are fitted with pressure sensors and position trackers, enabling real-time monitoring of pressure compliance and placement accuracy. The automatic fire alarm system incorporates temperature and smoke sensors, swiftly detecting anomalies and transmitting them to management terminals. Sensor data is wirelessly relayed to backend servers, enabling remote dynamic control of fire protection systems. This innovation eliminates the time and space constraints of traditional manual inspections, expands coverage, and enhances response efficiency, providing precise data support for fire safety management.

3.2. AI technology improves the accuracy of hidden danger identification

The image recognition and pattern analysis capabilities of artificial intelligence provide support for automatic identification of fire hazards in universities. Intelligent cameras deployed in critical campus areas utilize computer vision to automatically detect typical hazards such as improper use of fire and electricity, blocked fire exits, and obstructions to fire facilities [3]. By analyzing historical data through machine learning to build identification models, the system continuously improves detection accuracy and response efficiency. The intelligent system instantly delivers alerts to prompt administrators to take swift action, reducing human judgment errors and enabling early detection, timely warnings, and prompt resolution of hazards.

3.3. Big data technology helps to analyze risk situation

Big data technology integrates and analyzes campus fire safety data, including inspection records, hazard management archives, facility operational parameters, and real-time weather conditions. The analytical platform deconstructs this information through multidimensional analysis to identify high-risk zones, recurring hazard categories, and latent risk nodes. It generates risk assessment reports that enable management teams to develop targeted inspection and prevention strategies. This approach optimizes resource allocation, shifting from reactive responses to proactive prevention. The system provides data-driven support for fire facility maintenance planning and emergency response optimization, thereby enhancing the scientific rigor and predictive capabilities of campus fire safety management [4].

4. Intelligent inspection and closed-loop management system construction of campus fire safety in colleges and universities

4.1. Constructing a multi-level intelligent inspection system architecture

The campus fire safety intelligent inspection system adopts a four-layer architecture: perception layer, transmission layer, platform layer, and application layer. The perception layer utilizes sensor devices, smart cameras, and mobile inspection terminals to comprehensively capture data on fire facilities, environmental parameters, and personnel activities. The transmission layer ensures data flow through wireless communication networks and IoT gateways. The platform layer coordinates data storage, analysis, processing, and sharing while enabling centralized management and scheduling. The application layer provides diverse services, including task allocation and hazard reporting to meet campus fire safety management needs.

4.2. Establish a closed-loop management process for monitoring, identification, disposal, and feedback

Closed-loop management forms the core foundation for intelligent inspection. Smart equipment continuously monitors fire protection systems and environmental conditions, ensuring real-time data updates. AI automatically identifies potential hazards, with manual verification to guarantee accuracy. The rectification process clearly defines responsibilities, standards, and timelines, while the platform dynamically assigns tasks and tracks progress. Managers provide real-time supervision, and upon completion, executors upload progress reports. The system verifies, accepts, and archives the results, with data incorporated into big data analytics to support future optimizations, forming a closed-loop process.

4.3. Improving the responsibility and coordination mechanism of closed-loop management

The implementation of a closed-loop management system requires clear delineation of responsibilities and coordinated collaboration. It is essential to define the roles of the school's fire safety management department, secondary units, and individuals, with inspection, rectification, and maintenance responsibilities progressively assigned to ensure accountability at every level. A cross-departmental collaboration platform should be established to strengthen coordination between fire safety, logistics, student management, and academic departments, enabling information sharing, resource integration, and joint response. Hazard rectification should be led by the logistics department for facility maintenance, with student management departments assisting in regulating student conduct. The performance evaluation mechanism should incorporate fire safety management effectiveness into departmental and individual assessments, motivating proactive performance and ensuring the stable operation of the closed-loop system.

5. Innovative path of intelligent inspection and closed-loop management of campus fire safety in colleges and universities

5.1. Technology integration and innovation enhance the overall efficiency of the system

The deep integration of IoT, AI, and big data technologies drives the functional optimization of intelligent inspection systems. AI-powered image recognition and IoT sensor data mutually reinforce each other, expanding the scope of hazard identification and enhancing detection accuracy. Big data analytics thoroughly examine inspection and rectification data, providing scientific support for fire safety risk prediction and decision-making. Mobile internet technology enhances the functionality of inspection terminals, enabling real-time task acceptance and instant hazard reporting. This improves inspection convenience and efficiency while facilitating seamless coordination with smart fire protection equipment for remote control and intelligent resource allocation, ultimately elevating campus fire safety emergency response capabilities.

5.2. Innovation in management models to optimize resource allocation efficiency

Intelligent inspection and closed-loop management are revolutionizing fire safety management models in universities. By transcending traditional decentralized frameworks, they establish centralized intelligent control platforms to facilitate streamlined and refined management. Leveraging big data analytics, these systems optimize inspection routes and frequencies, delineate risk zones, conduct intensive checks in high-risk areas, and allocate resources scientifically in low-risk zones, thereby enhancing targeted and efficient inspections. The framework also establishes a full lifecycle management system for fire protection facilities, systematically documenting procurement, installation, and other process information. This promotes precise standardization of maintenance, reduces costs, and optimizes resource allocation.

5.3. Concept and cultural innovation to strengthen the safety awareness of all staff

The implementation of technology and closed-loop management requires a safety-oriented culture. Universities should enhance fire safety education by utilizing platforms such as official websites, WeChat accounts, and smart inspection systems to disseminate fire safety knowledge, share case studies of hazards, and showcase rectification outcomes. This strengthens faculty and students' awareness and self-protection capabilities. The intelligent platform introduces a hazard reporting channel to facilitate feedback on campus fire risks, fostering a collaborative

environment where everyone participates in governance. Integrating fire safety culture into the overall campus culture, activities like themed events, knowledge contests, and emergency drills reinforce responsibility. This approach transforms fire safety awareness and active participation into a natural habit, laying a solid ideological foundation for the smooth advancement of related initiatives.

6. Conclusion

The intelligent inspection and closed-loop management innovation in campus fire safety is pivotal to addressing complex challenges and advancing modern management standards. Empowered by technologies like IoT, AI, and big data, these systems overcome traditional limitations by enabling dynamic monitoring of fire facilities, precise hazard identification, and proactive risk alerts. The closed-loop system of monitoring, identification, response, and feedback ensures full-chain controllability in hazard rectification. To enhance management effectiveness, universities must align with their specific contexts, fostering collaborative innovation in technology, management, and safety culture while refining relevant mechanisms. With continuous technological advancements, campus fire safety management will become increasingly intelligent, refined, and efficient, creating a secure environment for faculty and students and providing robust support for the high-quality development of higher education institutions.

Disclosure statement

The author declares no conflict of interest.

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