Application of IoT Monitoring and Maintenance Management Systems in Urban Parks under the Background of Smart Landscaping

Fen YE

Heifei Runkai Real Estate Development Co., Ltd., Hefei, Anhui, 230000, China

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Abstract: As China's urbanization process advances towards a high-quality stage, urban parks, as core spaces for maintaining urban ecological balance and meeting residents' leisure needs, have seen innovation in their management models become an important component of smart city construction. Currently, national-level policies guiding the digital transformation of green spaces have been introduced, clearly identifying technological empowerment as a key path to enhance landscaping management efficiency, providing direction for urban parks to break free from the limitations of traditional management. This article focuses on smart landscaping construction, discussing the application of IoT monitoring and maintenance management systems in urban parks. It aims to effectively improve resource utilization efficiency, reduce management costs, enhance ecological quality and visitor recreation experience, thereby providing a feasible path for the intelligent development of urban parks.

1. Introduction

With the continuous acceleration of China's urbanization process, urban parks, as an important part of the urban ecosystem and public service system, increasingly highlight their functions such as ecological regulation, leisure recreation, and cultural display. However, traditional urban park management models rely on manual inspections and empirical decision-making, exposing many shortcomings when dealing with large-scale park green spaces. Meanwhile, national policies such as the "14th Five-Year Plan for Promoting Agricultural and Rural Modernization" and the "Smart Landscaping Construction Guide" have been successively introduced, explicitly proposing requirements to promote the digital and intelligent management of green spaces, providing policy support for the smart transformation of urban parks. In this context, building an IoT monitoring and maintenance management system for urban parks to achieve precision and intelligence in park monitoring and maintenance has become a key direction for smart landscaping construction. It is also of great significance for improving the quality of the urban ecological environment and meeting residents' needs for a better life.

2. The Core Connotation and Development Trends of Smart Landscaping

Smart landscaping is not merely a superimposition of technologies but a new development model that focuses on the ecological functions and public service value of landscaping, optimizing the entire management process through digital and intelligent means [1]. Its core connotation is reflected in three dimensions: first, the ubiquity of perception, breaking the limitations of traditional manual monitoring to achieve real-time capture of multi-dimensional information such as ecology, facilities, and services within the landscape; second, the scientific nature of decision-making, relying on data analysis to replace empirical judgment, making maintenance management and service optimization measures more aligned with the actual needs of the landscape; third, the synergy of operations, promoting the linkage between landscape management and urban ecological governance and public services, forming a positive interaction between "landscape-city-residents."

In terms of development trends, smart landscaping is moving stride towards "comprehensive system synergy," moving away from the limitations of previous "single-function intelligence." Early smart landscaping often focused only on technological applications in single links such as automatic

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irrigation or smart lighting, whereas now the emphasis is more on building a comprehensive smart management system. As ecological civilization construction deepens, the ecological orientation of smart landscaping becomes more significant, no longer merely pursuing management efficiency improvement but emphasizing the use of technological means to maintain the ecological balance of landscapes, promoting their transformation from mere "artificial landscapes" to "ecological carriers" with rich ecological functions, providing solid support for the sustainable development of cities.

3. Design Principles for Urban Park IoT Monitoring and Maintenance Management Systems

The design of an urban park IoT monitoring and maintenance management system needs to focus on meeting the actual needs of park management and ensuring the long-term stable operation of the system. Specifically, it should follow these four core principles.

3.1 Practicality Principle

System function design must closely revolve around the core needs of park monitoring and maintenance, resolute avoiding design tendencies that pursue technical complexity at the expense of practical application scenarios. During the function development stage, fully consider the daily operating habits and professional knowledge background of management personnel, simplify redundant operational steps—such as reducing unnecessary level jumps and optimizing function entry layout—ensuring that management personnel can master the system operation method in a short time, thereby effectively converting the technical advantages of the system into practical results that improve management efficiency and quality.

3.2 Compatibility Principle

The design process must comprehensively consider the access needs of existing park management equipment and the possibility of future technological upgrades and expansion. In setting key technical parameters such as hardware interface standards and data transmission formats, sufficient adaptation space should be reserved. For example, adopt universal interface types like RS485 and Ethernet, support mainstream data formats like JSON and XML, prevent compatibility issues arising from a closed system architecture during subsequent equipment updates or functional expansions, and ultimately achieve seamless integration with monitoring equipment and management platforms of different brands and models, ensuring efficient and smooth data flow between multiple systems.

3.3 Real-time Principle

For scenarios requiring immediate response, such as dynamic changes in park ecological environment parameters and real-time fluctuations in facility equipment operating status, the system needs to build an efficient data processing pipeline. By optimizing data transmission protocols and improving the efficiency of data analysis algorithms, ensure the transmission and processing of data from collection terminals to analysis modules is highly timely, enabling management decisions to accurately keep up with on-site dynamic changes. This avoids issues like delays in maintenance measures or declines in visitor service quality due to information transmission lag.

4. Practical Application Scenarios of the IoT Monitoring and Maintenance Management System

4.1 Ecological Environment Monitoring and Dynamic Regulation

In the practical practice of urban park ecological management, the IoT monitoring and maintenance management system takes key ecological indicators of the park as the monitoring core, gradually building a park-wide ecological environment perception network through continuous data collection. This network is not a simple pile-up of devices but achieves precise coverage of the monitoring scope based on the park's topographic zoning and ecological sensitive points. In this application scenario, the system functions focus on the dynamic change process of the park's micro-environment. Specifically, it can use multi-dimensional sensing devices to capture core elements affecting ecological balance in real-time, thereby providing managers with comprehensive and accurate environmental status references, avoiding decision-making delays caused by complex data interpretation.

4.2 Precision Plant Maintenance Management

The precision plant maintenance management scenario is guided by the core principle of "adapting to the needs of the plant's entire growth cycle." It relies on the IoT system to build a closed-loop management system of "monitoring-analysis-decision-execution," achieving dynamic tracking of plant growth status and scientific optimization of maintenance measures [2]. Different from the "unified management" of traditional maintenance, this system emphasizes starting from the differentiated needs of individual plants and communities, supporting personalized maintenance through refined monitoring. Specifically, the system can break through the limitations of "relying on manual empirical judgment" in traditional maintenance models. Instead of carrying out maintenance in the manner of "fixed-cycle fertilization and unified time irrigation," it uses data drive to develop personalized maintenance plans adapted to different plant species and growth stages. Thus, through a "dynamic adjustment" mechanism, it ensures that maintenance measures closely fit the actual needs of plants, avoiding over-maintenance or under-maintenance problems, and improving the accuracy and effectiveness of plant maintenance.

4.3 Intelligent Operation and Maintenance Management of Facilities and Equipment

In the park facility and equipment management scenario, the IoT system focuses on the real-time monitoring of facility operating status and improving operational efficiency, building a management system covering the entire lifecycle of facilities from "procurement-installation-operation-maintenance-disposal." By deploying specialized sensing modules on landscape facilities, the system collects key data during facility operation in real-time, dynamically grasps the operating status of facilities, and timely identifies abnormalities in facility operation. Once the system detects a facility failure or potential failure risk, it immediately issues an early warning signal through platform alerts, SMS notifications, etc., synchronizing information such as fault location, fault type, and impact scope to management personnel. This facilitates quick problem localization and allows for arranging maintenance personnel to handle it promptly, thereby reducing safety hazards caused by long-term operation of facilities in faulty conditions.

5. Application Strategies for IoT Monitoring and Maintenance Management Systems in Urban Parks under the Smart Landscaping Background

5.1 Building a Technology Adaptation System Tailored to Park Scenarios

In the implementation of urban park IoT systems, technology adaptation must take the uniqueness of the park scenario as the core starting point, resolute avoiding the problem of insufficient scenario adaptability caused by the "standardized application" of technical solutions.

In the initial planning stage of the system, systematic research on the characteristics of the park scenario must be conducted first, focusing on clarifying the spatial attributes, ecological composition, and management needs of the park. Based on this, the monitoring priorities and maintenance differences of different functional areas should be defined. For example, ecological conservation areas require strengthened monitoring of indicators such as soil moisture and vegetation growth status, while leisure activity areas need to focus on real-time tracking of facility operating status and visitor flow.

At the software level, the actual operational needs of management personnel should be the guide. The system usage threshold should be lowered through function module optimization and operational process simplification, avoiding decreased management efficiency due to excessive pursuit of technical complexity. In the data presentation link, use visual interactive interface design to transform multi-dimensional monitoring data into intuitive forms such as line charts, bar charts, and heat maps, or use "normal/abnormal" status indicators and warning pop-ups to help managers quickly grasp key information and reduce the time cost of data interpretation. In the function design link, focus on the core needs of park management, prioritize the development of core modules such as ecological monitoring data query, intelligent maintenance task reminders, and automatic facility fault warnings. Eliminate redundant functions with low relevance to daily management to avoid dispersing the operational attention of managers. Ensure the system can undergo functional iteration and performance upgrades along with the advancement of smart landscaping construction, long-term adapting to the dynamic changes in park management needs [3].

5.2 Promoting Deep Integration of Management Processes and System Functions

The key to system application lies in the organic combination with the existing park management system, rather than forming a separated state of "technology and management operating in parallel."

First, it is necessary to systematically review and optimize traditional park management processes. Identify inefficient links and information breakpoints through process decomposition, thereby clarifying the intervention nodes and functional boundaries of the IoT system in the entire management chain of "data collection-analysis decision-execution feedback." Taking the maintenance management process as an example, the system deployment can replace the "fixed-time fixed-point recording" mode of traditional manual inspections. Use sensing devices to achieve real-time collection of data such as plant growth status and soil environment, solving the lag and error problems of manual records. Rely on the built-in data analysis models of the system to generate scientific maintenance suggestions that conform to plant growth patterns based on monitoring data, replacing the decision-making method reliant on managerial experience. Simultaneously, use the system's feedback module to track the execution progress and effect of maintenance measures in real-time, building a closed-loop management mechanism of "monitoring-decision-execution-evaluation," promoting the transformation of park maintenance management processes from traditional "experience-driven" to precise "data-driven" [4].

Second, addressing the management barriers between internal park departments, a data collaboration mechanism based on the IoT system needs to be constructed. Under the traditional park management model, departments such as ecological monitoring, plant maintenance, facility management, and visitor services often operate in a state of "each acting on its own." Data from each department is stored in independent ledgers or systems, resulting in poor data sharing and easily leading to low management synergy efficiency. By building a unified data sharing platform through the IoT system, departmental data barriers can be broken down, achieving real-time interoperability and efficient flow of data from various management links: the facility management department can obtain dynamic visitor flow data through the platform to optimize the inspection frequency and maintenance priority of facilities like fitness equipment and lighting equipment based on peak hours; the ecological monitoring department can share environmental data such as air temperature, humidity, and soil nutrients in real-time with the plant maintenance department, providing quantitative basis for formulating irrigation and fertilization plans for different vegetation; the visitor service department can optimize service resource allocation based on facility operating status data, thereby significantly enhancing the overall synergy and decision-making accuracy of park management.

5.3 Establishing Long-term System Operation and Risk Prevention Mechanisms

The long-term value of the system relies on a sound operational guarantee and risk prevention system, which needs to be built from multiple dimensions. In the dimension of daily operation and maintenance, a standardized operation and maintenance management system needs to be established, ensuring the continuous and stable operation of the system through clear processes and cycles. Firstly, an all-element operation and maintenance regulation covering equipment, data, and network should be formulated, specifying the specific cycles and operational procedures for perception device inspection, system data maintenance, and transmission network debugging.

In the dimension of cost control, a full-cycle cost balance mechanism for "construction-operation" needs to be established to avoid unsustainable system operation due to excessive investment. In the equipment selection stage, a "performance-cost" evaluation model should be established, prioritizing products with high cost-effectiveness and low later stage maintenance costs. For example, use low-power solar-powered equipment in non-core monitoring areas to reduce cable laying and electricity consumption costs. In the technology upgrade link, upgrade priorities need to be establish based on the actual needs of park management, avoiding cost waste caused by blindly chasing new technologies. For instance, when existing data analysis functions meet basic decision-making needs, there is no need to enforce introduce complex AI modeling technologies. In terms of controlling operation and maintenance labor costs, improve individual operational efficiency by optimizing operational processes and conducting skills training for management personnel, thereby reducing labor input.

6. Conclusion

In summary, under the background of smart landscaping, the application of IoT monitoring and maintenance management systems in urban parks is not merely a technical introduction but a systematic innovation of park management models. The three strategies proposed in this article—technology adaptation, management integration, and long-term operation—provide feasible paths for system implementation from different dimensions. These three aspects connect and support each other, jointly promoting the system's transition from "function building" to "value realization" [5]. In the future, with the further integration of IoT with big data, artificial intelligence, and other technologies, urban park IoT monitoring and maintenance management systems can develop towards deeper intelligence. It is necessary to ensure that intelligence truly serves the sustainable development of parks, thereby providing strong support for creating ecological and livable urban spaces.

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