

# Research on Digital Greening Management of Smart Gardens in Chenggong District, Kunming City

Yifang Sun<sup>1</sup>, Jia Gao<sup>2,\*</sup>, Chuanli Chen<sup>3</sup>

<sup>1</sup>Kunming Changshui International Airport Co

<sup>2,3</sup>Graduate School of Business (GSB), SEGi University

<sup>1</sup>sunyifang99@163.com; <sup>2,\*</sup>gaojia\_peter@163.com; <sup>3</sup>88278898@163.com

\*Correspondence Author

**Abstract:** *With the rapid urbanization in China, city scales have expanded, bringing numerous management challenges. The continuous expansion of urban green spaces highlights the difficulty of adapting traditional urban garden management to complex conditions. The solution lies in using AI and big data for smart city management, specifically termed 'Smart Gardens'. This system integrates modern information technology into daily urban garden management. Through platform management systems, it enables comprehensive planning, construction, maintenance, supervision, and service of urban green spaces. This ensures real-time data updates, visualized management, and dynamic services. This digital transformation is essential. This paper analyzes the current issues and future development strategies of digitalized garden management in Chenggong District, Kunming. Through literature review, field research, and data collection, it aims to enhance the green space management in Chenggong District and other regions.*

**Keywords:** Smart City; Smart Garden; Green Management; Chenggong District, Kunming City.

## 1. INTRODUCTION

In recent years, China's urbanization has accelerated, with the urbanization rate reaching 66.2% in 2023. From 2010 to 2020, this rate increased from 49.95% to 63.89%, an annual growth of approximately 1.4%. Urban management has always been a key government function. With the expansion of urban areas, management challenges have grown. Green space management is a crucial part of urban management, with some developed countries using it to measure city and national image and modernization levels. In China, President Xi Jinping emphasized in the 19th National Congress the importance of harmony between humans and nature, advocating the concept that "lucid waters and lush mountains are invaluable assets." Developing green eco-tourism and building eco-friendly garden cities have become collective goals (Gao et al., 2023). As cities expand, traditional garden management methods struggle to keep up. The widespread use of the internet, AI, IoT, big data, and satellite remote sensing has propelled smart city development, making digitalized garden management a standard approach. Since 2013, over 60 Smart Garden pilot projects have been established nationwide.

### 1.1 Problem of the Study

Chenggong District, Kunming's new administrative center, features vast green areas. In 2013, Kunming began exploring Smart Garden construction, initially in Wuhua and Panlong Districts. Despite early efforts in these districts, Chenggong only adopted integrated Smart City management for Smart Gardens in 2022. Previously relying on traditional green space management, Chenggong faces challenges such as inaccurate management information, low efficiency, and resource wastage. Incorporating digitalized Smart Garden management is essential to address these issues and enhance the precision and scientific nature of green space management.

### 1.2 Objectives of Study

This study will thoroughly analyze the construction and development of Smart Gardens in Chenggong District. Using new public management theory and systems management theory, it will investigate the deficiencies and underlying logic in Chenggong's Smart Garden development. The goal is to explore development paths and provide practical solutions for the construction and operation of Smart Gardens in Chinese cities.

## 2. LITERATURE REVIEW

### 2.1 Concept of Smart Garden

A Smart Garden utilizes advanced technology for intelligent service and management of gardens. This not only facilitates management but also enhances user engagement, awareness, and enjoyment (Zajadacz & Lubarska, 2023). Smart Gardens employ sensors, automatic irrigation, and other smart devices to monitor and manage plant growth (Alrawashdeh et al., 2024). These systems connect to smartphones or other devices, allowing remote control and monitoring to ensure optimal plant health and growth (Olawepo et al., 2020). In London, for instance, effective green space maintenance and water conservation are achieved through smart management, reducing labor and maintenance costs (Anh, 2021). Integrating gardens with smart cities aims for efficient urban management and seamless landscape-city development.

### 2.2 Key Technology for Smart Garden Management

Since the 1970s, urban landscaping in the United States has utilized computer systems to manage city forests by zoning and categorizing data such as tree count, species, age, location, and growth status. The University of Wisconsin has applied GIS technology to analyze landscape changes in the eastern part of the Michigan Peninsula, and park green space planning similarly uses GIS decision support systems. The National Parks Board of Singapore has established a digital information archive, creating an electronic record for each tree, enabling nationwide tracking of plant species, quantity, and growth conditions via computer systems. In Tokyo, Japan, high-resolution satellite imagery is used to build spatial databases, collecting green space data in central areas. As smart cities continue to develop and evolve, the concept of smart garden management, an integral component of smart cities, has gradually become more defined and refined (Yang, 2024).

A key aspect of building a smart garden management system is the development of a smart garden management platform, which relies heavily on information technology. Current research on these technologies can be divided into the development of overall management platforms and the technical support for individual operational modules. This includes the use of technologies like Oracle 11g databases, GIS, and Web Services. By 2017, it was proposed that Kunming had the conditions to establish an information management system for landscaping. The Kunming Digital Geospatial Framework (Digital Kunming), completed in 2015, includes a Geographic Information Public Service Platform. Using the platform's interfaces, data can be accessed and utilized for development, with Microsoft Visual Studio .NET 2010 (C#.NET) serving as the programming language for building Kunming's landscaping information management system (Sun & Wang, 2023).

In general, current research has focused on how smart garden management can use technology to address specific operational issues, primarily aiming to improve efficiency and capability through reactive management. However, it has not fundamentally transformed urban greening management models, lacking top-level design from an industry management perspective, as well as systematic needs analysis and coordinated construction concepts. Future research should address these areas.

### 2.3 New Public Management Theory

This study primarily employs New Public Management theory, which represents a shift in public administration from traditional bureaucratic models to more market-oriented and performance-based approaches. This transition has been driven by the need to enhance the efficiency, effectiveness, and responsiveness of public services, influenced by economic theories and business practices (Paździor et al., 2023). In China, the rapid economic and social development necessitates innovation in ideological and political work, aligning with national prevention mechanisms. Enhancing public service satisfaction through increased public participation and effective engagement channels is essential (Xu, 2024).

## 3. CURRENT SITUATION OF SMART GARDEN DEVELOPMENT IN CHENGGONG DISTRICT, KUNMING, CHINA

Since 2013, the number of smart garden construction pilot projects across the country has steadily increased, offering valuable insights for the development of smart gardens in Chenggong District, Kunming. However, these

pilot projects have been implemented on a limited scale and have not yet been widely adopted, with some shortcomings observed during their operation.

### 3.1 Overview of Landscaping in Chenggong District

In the course of building a "Green and Beautiful City," we developed specific plans such as the "Chenggong District Green Space System Plan (2021-2035)." This plan established and optimized Chenggong's urban green space system and landscape pattern, forming lake park belts represented by Longlong Lake, Fanspring Lake, and Silver Lake; river green belts exemplified by Longlong River and Laoyu River Wetland Park; and park green belts represented by Longlong Park, Central Park, and Laoyu River Wetland Park. These efforts have harmonized the relationship between people, the city, and nature. Since 2011, Chenggong District has added 1,378.4 hectares of urban green space. By focusing on road nodes, park green spaces, and overpasses, we have created high-quality green landscapes that combine ecological function, aesthetics, and regional characteristics, promoting the connectivity of urban greenways into a network. Through the integration of three-dimensional flower beds, flower borders, and flower belts with traditional Chenggong culture symbols like "瓦猫" (Wamao) and "the Land of Fruits and Flowers," we have created and showcased Chenggong's unique green urban nodes, including five "Beautiful Nodes" such as "Wamao Garden" and "Land of Fruits and Flowers." We also beautified and landscaped the ventilation corridors on Caiyun Road, and at key nodes, we built seven different thematic three-dimensional flower beds, such as "Charming Chenggong, Harmonious Development" and "Spring City Flower Capital Exhibition Area," highlighting Chenggong's charm as a flower capital with "Flowers in Bloom All Year Round." Along Harmony Road, Caiyun Road, Liangwang Road, and Chunrong West Road, we planted 5,103 roses, cherry blossoms, and other flowers, quickly making these "One Road, One Scenery" themed roads the top choice for residents to enjoy flowers and take photos. We have intensified efforts to protect ancient and famous trees, creating boutique gardens in Chenggong District through refined management. Currently, Chenggong's green space covers 2,987.32 hectares, with 112 parks and an average of 18.71 square meters of park green space per capita, and a green space rate of 40.01%.

### 3.2 Development and Application of Digital Green Space Management Systems

#### 3.2.1 Establishment of a Green Space Database and IoT

In March 2022, the first phase of Kunming's "Smart Chenggong" project passed its acceptance inspection. In Chenggong District, each ancient and famous tree now has an "identity code," allowing for one-click access to maintenance and inspection records. AI-enabled high-definition cameras combined with "video image algorithms" can measure vehicle weight without stopping; if an overloaded vehicle is detected, evidence is immediately collected, making evasion impossible. The "City AI" system can intelligently detect 12 types of urban issues, such as illegal parking and material piles, making city management more efficient. The first phase of the "Smart Chenggong" project established a foundational platform (including a big data platform and a spatial information platform), a city operations management center, and multiple smart application systems, covering areas such as urban governance, public services, and industrial economy. To date, the big data platform has collected over 530,000 records from 31 committees and offices in Chenggong District and more than 130,000 records from municipal offices, achieving unified government data aggregation, sharing, and openness across city and district levels. The IOC digital cockpit has built five major sections-Panoramic Chenggong, Digital Governance Chenggong, Colorful Chenggong, Grassroots Chenggong, and Computing Power Chenggong-with 28 command screens, covering 1,342 data indicators from 34 departments in Chenggong. The system has collected data on 377,000 urban management components across the district, solving persistent urban problems such as city appearance, environmental sanitation, garden maintenance, and road health. Through AI applications integrated with police video feeds and city management's self-built video channels, "City AI" can "instantly detect" 12 types of urban issues. Based on past experience, smart detection typically accounts for about half of all reported events. The advent of "City AI" has transformed the mode of urban management. Previously, issues required on-site detection by grid staff, but now they can be identified through unattended, intelligent sensing, reducing management processes and communication costs.

#### 3.2.2 Access to Smart City Management System

Chenggong District has integrated its green space management with the smart city's urban appearance system, utilizing "City AI" to focus on monitoring, maintenance, damage control, and natural disaster management. This system enables round-the-clock digital, grid-based, and visual management. The newly constructed digital cockpit

covers 1,704 data indicators across 34 units, allowing for comprehensive real-time monitoring of the district's green spaces. The big data platform has accumulated 90 million data entries from both city and district levels, which are immediately shared with the relevant departments for prompt action. This approach ensures more orderly and efficient management, effectively preventing delays and omissions in task execution.

### 3.2.3 Installation of Environmental Monitoring Sensors

To enable real-time monitoring and precise regulation of the garden environment, Chenggong District has installed advanced environmental monitoring sensors in select areas. These sensors collect key parameters such as soil moisture, temperature, and light intensity in real-time, providing scientific data for green space management. For soil moisture monitoring, the sensors can penetrate deep into the soil to accurately measure moisture content. When soil moisture falls below a preset threshold, the system automatically issues a watering reminder to prevent poor plant growth due to water shortage. Temperature sensors monitor changes in ambient temperature in real-time (Dong et al., 2024). During hot summers, when temperatures rise too high, the system can automatically activate misting equipment to create a suitable growth environment for plants. In cold winters, when temperatures drop too low, the system issues warnings to prompt managers to take protective measures, shielding plants from frost damage. Light intensity sensors accurately measure sunlight exposure. Based on light data, managers can adjust plant layouts and pruning methods to ensure each plant receives adequate sunlight, thereby enhancing photosynthesis efficiency and promoting healthy plant growth.

## 4. ISSUES WITH DIGITAL GREEN SPACE MANAGEMENT IN CHENGGONG DISTRICT

### 4.1 Lack of Harmonised Criteria

According to policies and regulations published on the official website of the Kunming City Management Bureau (<http://cgj.km.gov.cn/>), current laws, regulations, ordinances, and measures in Kunming only mention the application of "urban garden greening management information technology" as a grading assessment indicator in the "Urban Garden Greening Evaluation Standards" (GB/T50563-2010). Article 38 of the "Kunming Urban Greening Regulations" (2019 Edition) mentions that the "city and county (city, district) greening administrative departments shall establish a digital management system, and urban greening information data shall be made public." However, Kunming has not yet established standardized guidelines for the smart garden framework.

Investigations revealed that the development of the smart garden in Chenggong District is led by the Chenggong District Greening Office, a unit under the former District Gardening and Greening Bureau. The command center serves as the primary control platform, acting as the brain of the smart garden, with all information gathering, resource integration, decision-making, scheduling, supervision, and communication depending on this center. The green space information management platform merely serves as a repository for green space asset and maintenance information, feeding data into the command center for decision-making, scheduling, and supervision. The smart garden is currently in a semi-intelligent phase, transitioning from information digitization to intelligent management. The main goal of this construction is to achieve accurate collection and utilization of green space information, addressing the issue of over-reliance on human experience in management. Since administrative approval is handled by the former Chenggong District Gardening and Greening Bureau, the development of the platform is led by the Chenggong District Smart City Operations Center, which did not include the administrative approval function in its development. Additionally, the platform lacks features such as performance evaluation, public services, disaster warnings, integration with other departments, and planning guidance, leading to slow processing and untimely handling of issues from detection to resolution.

### 4.2 Limitations of Technology Application

Although Chenggong District has installed environmental monitoring sensors in certain areas, the coverage remains limited. Some remote or large green spaces are not included in the monitoring network, making it impossible to obtain real-time data on key environmental parameters like soil moisture and temperature in these regions. This limitation affects the overall precision of green space management. Additionally, the accuracy of monitoring data is an issue. Soil moisture sensors may be influenced by factors such as soil texture and groundwater levels, leading to measurement errors. Over time, sensors may malfunction or degrade, affecting the accuracy and continuity of data. Furthermore, as only the first phase of "Smart Chenggong" has been developed, the digital green space management is still in its early stages. The analysis and utilization of garden data are

insufficient, preventing the full potential of big data from being realized, and only allowing for basic monitoring and feedback.

#### 4.3 Lack of top-level design

According to New Public Management theory, the government should act as a service provider, with administrative departments for urban greening taking a proactive role in guiding development and establishing standards for the construction of smart garden management systems. This would involve comprehensive coordination, unified management, and breaking down internal information barriers within the government. Smart garden management represents a breakthrough in traditional urban garden management methods, concepts, and processes. However, a review of the official website of the Chinese Society of Landscape Architecture (<http://www.chsla.org.cn/>) reveals that there are no existing laws, regulations, or standards specifically addressing the construction of smart gardens. The Ministry of Housing and Urban-Rural Development's "National Garden City Series Standards" (Document No. [2016] 235) mentions the application of "urban garden greening management information technology" as a basic requirement, calling for the establishment of a digital information management system and a dynamic supervision platform for urban greening. However, this focuses on information technology usage rather than smart garden management and lacks a complete standard. Similarly, Kunming has only briefly mentioned the introduction of information technology for establishing a digital management system, without advancing to the level of smart garden management. There is no definition of a localized smart garden management system, and existing policies and regulations are insufficient to effectively standardize work processes and management behaviors. The construction of the smart garden management system is largely based on experience and immediate needs, without long-term planning. There is a lack of policy support and unified construction standards at both the national and local levels to guide this process.

#### 4.4 Insufficient Funding

When smart city management was initially developed, urban greening was included as one part of the overall management system. However, the smart city management system, as a broader and more comprehensive framework, only supports limited functions related to green management, such as handling and dispatching grid cases and processing feedback. Comprehensive smart management of urban green spaces, including green space planning, asset management, maintenance reminders, record keeping, industry integration, and smart services, has been overlooked. Relying solely on the smart city management system is inadequate for achieving the "one-map" strategy of urban green space management. While informatization is an inevitable trend in urban garden management, and smart management is the direction for future development, urban greening has long been in a disadvantaged position, lacking integrated information from different fields. Green spaces are often sacrificed for road networks, buildings, and public facilities during urban development, leading to continuous encroachment (Cheng et al., 2024). Funding for maintenance has also been continuously reduced, with the costs of maintaining green spaces and street trees falling short of standard maintenance quotas. The collection of IoT data requires a large number of sensors, which need to measure various factors such as soil temperature, moisture, fertility, pH, air temperature, wind direction, sunlight, precipitation, spatial humidity, and microclimates. These sensors need to be combined into sensor groups for measurement and data collection. However, the high cost of sensor groups, along with issues such as corrosion, natural damage, and the need for precision upgrades in product iterations, have resulted in insufficient initial funding, failing to meet the required number of sensor groups.

### 5. COUNTERMEASURES TO OPTIMISE THE CONSTRUCTION OF INTELLIGENT GARDEN MANAGEMENT SYSTEM IN CHENGGONG DISTRICT OF KUNMING CITY

For smart garden management to truly become a modernized management model for urban greening, it must form a scientifically effective governance system. The government, acting as the "helmsman," should establish goals and strategies for urban management, ensuring that data drives decision-making, technology sustains operations, science informs decisions, service manages outcomes, and innovation enhances services. This will create a smart, humane, comprehensive, and normalized management system that improves efficiency, upholds a people-centered service philosophy, increases public participation, and promotes the smart transformation of cities like Kunming. The goal is to achieve a refined level of greening management, akin to delicate embroidery, by implementing the following optimizations:



### **5.1 Strengthening Policy Support**

Current standards and regulations do not adequately address the establishment of digital management systems for urban greening. The implementation of a smart garden management system requires policy support. At the national level, a construction standard framework should be promoted and established. Local governments can refer to Beijing's guidelines, supplement local regulations, and create application manuals. In Chenggong District, coordination among smart garden departments is insufficient, necessitating the establishment of a municipal-level coordination office to oversee management. Given the complexity of urban green space management, the government must clarify departmental responsibilities, integrate resources, ensure data sharing, and provide additional sensors for the greening authority to enhance data collection and sharing.

### **5.2 Strengthening technology application and research and development**

Chenggong District should strengthen research and development collaboration with research institutions and enterprises to address technical challenges related to sensor accuracy, reliability, and stability. There should be an increased focus on big data processing and analysis, and the development of data centers, enabling comparisons between historical and real-time data, and generating precise green space management plans and decision-making recommendations. Additionally, the application of artificial intelligence in areas such as pest and disease prediction and plant growth modeling should be enhanced to improve the scientific and forward-looking aspects of green space management.

### **5.3 Improving the Construction of the Smart Management Platform**

The government should establish standards and conduct top-level design during the initial phase of smart garden construction. This includes creating unified standards that cover platform architecture, functionality, and other aspects to ensure compatibility, connectivity, and data sharing across different levels of platforms. The construction process should have clear objectives, consider the interrelationships and hierarchy of subsystems, and develop them in stages based on practical circumstances. Currently, the government is the primary developer, relying on public funds. Both short-term and long-term goals should be balanced, such as initially improving the information database, utilizing existing equipment and platforms, and later adding functions to develop comprehensive services. Kunming's three districts have already begun exploring this area, and future development should be unified to avoid waste and data silos.

### **5.4 Increasing Investment in Management Funds**

Chenggong District in Kunming should actively apply for special financial funds from relevant departments to support the construction and development of smart garden digital greening management. By creating detailed project plans and budget proposals, the government can be shown the importance and feasibility of smart garden construction, increasing the likelihood of securing more financial support. Additionally, communication and coordination with government departments should be strengthened to ensure timely and proper use of funds. Beyond government financial support, efforts should be made to broaden funding sources. Social capital should be attracted to participate in smart garden construction through PPP models, franchises, and partnerships with enterprises to jointly promote project implementation. Encouraging corporate and individual donations and sponsorships, and establishing a greening fund, can also provide financial security for smart garden construction.

## **6. CONCLUSION**

The digital management of smart gardens represents the future trend in urban green space management. While Chenggong District in Kunming has made some progress in this area, there are still issues and shortcomings that need to be addressed. By improving the data management system, deepening policy planning, enhancing technology research and application, and increasing financial investment, the level of smart garden digital management in Chenggong District can be further improved, contributing significantly to creating a beautiful and livable urban environment.

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## Author Profile

**Yifang Sun** Kunming Changshui International Airport Co., Ltd. Nationality: China. Her research interests include Urban Greening, Environmental Planning and Smart Garden.

**Jia Gao** School of Literature and Law, Yunnan Technology and Business University, Kunming, 651700, China; Graduate School of Business (GSB), SEGi University, Kota Damansara, 47810, Malaysia. Nationality: China. His research interests include Tourism, Sustainability, Smart Cities, Education management and Marketing.

**Chuanli Chen** Graduate School of Business (GSB), SEGi University, Kota Damansara, 47810, Malaysia. Nationality: China. His research interests include Finance, Economics and Management.