Exploration and Practice in the Construction and Dissemination of a Smart Urban Governance System: A Case Study of Baiyun District

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Abstract

In recent years, the deepening convergence of new-quality productive forces and the digital economy has furnished critical momentum for the modernization of China's governance system. By 2025, the value-added of core digital-economy industries is expected to exceed 10% of GDP [1], while artificial intelligence, data elements and related technologies are poised to empower virtually every sector. Responding to the national strategies of "Cyberpower" and "Digital China", the all-in-one government service platform has registered more than one billion real-name users; over 90% of administrative licensing items can now be processed online; 5G base stations nationwide have surpassed 3.3 million – more than 60% of the global total – and optical fibre together with 4G networks has reached every administrative village. Yet persistent problems – including redundant construction, high development costs, homogenised system functions, local protectionism, absent or fragmented standards, and inter-agency buck-passing-continue to constrain the high-quality development of digital government and smart cities.

Anchored in the principles of "problem orientation, process re-engineering, data sharing and source governance", this paper examines Guangzhou Baiyun District's exploration and practice in constructing and disseminating its smart-city management system. We elaborate an innovative "1+4+N" governance architecture, unpack technological breakthroughs and standard-setting initiatives, and synthesise both achievements and remaining challenges. On this basis we derive a replicable pathway for county-level districts nationwide and propose targeted policy recommendations.

Empirical evidence demonstrates that the "Baiyun Model" has markedly shortened administrative procedures, enhanced governance efficiency, reduced fiscal expenditure and enabled multi-stakeholder collaboration, thereby offering a paradigmatic reference for smart-city development across China.

Keywords Smart City; Smart Urban Management; Baiyun Model; Digital Government; Urban Governance

1 Introduction

1.1 Research Background and Significance

The digital economy and new-quality productive forces are profoundly reshaping China's economic structure and modes of public governance. The Overall Plan for Digital China Construction projects that, by 2025, value-added of core digital-economy industries will exceed 10% of GDP. Against this backdrop, digital-government construction has been elevated to an unprecedented strategic level: the National Integrated Government Service Platform now hosts more than one billion real-name users, over 90 % of administrative licensing items can be completed online, and more than 3.3 million 5G base stations have been deployed-over 60% of the global total-while optical-fibre and 4G networks cover every administrative village. Guangdong's "Yueshengshi" platform alone provides access to over 2,500 public services and has saved citizens more than 900 million trips to government offices.

Despite these achievements, problems such as redundant platform construction, data silos, scarce interactive applications, local protectionism, absent or fragmented standards, and inter-agency buck-passing still impede the formation of economies of scale in smart-city development [2].

Baiyun District, the largest and most populous central district of Guangzhou, is home to roughly four million permanent residents. Characterised by a high proportion of urban villages and a large floating population, it faces formidable and complex urban-governance tasks. Persistent challenges include sanitation-worker absenteeism, fraudulent payroll claims by contractors, inadequate gas-safety inspections, frequent spillage from muck-transport vehicles, hidden illegal construction, ineffective environmental sanitation patrols, and chaotic address data. In response, Baiyun District launched its smart-city management system in March 2022, guided by the principles of "problem orientation, planning leadership, process re-engineering, practicality and convenience, data sharing, rigorous supervision, source governance, and service to citizens," and has innovatively constructed a "1+4+N" smart-governance framework. Through integrated technologies and redesigned workflows, the system enables drone patrols, AI recognition, closed-loop work orders, and citizen-side participation, markedly improving both urban-management capacity and service efficiency. Using the case-study method, this paper systematically examines the development and dissemination of Baiyun's smart urban-management experience, aiming to provide a replicable pathway and actionable policy recommendations for county-level cities nationwide.

1.2   Research Methods

This research adopts a single-case study design to conduct a systematic and qualitative analysis of the smart urban-management system in Baiyun District, covering its construction background, overall architecture, functional modules, and dissemination pathway. Drawing on publicly available documents and project field data, the study combines quantitative and qualitative approaches, focusing on key technological applications and institutional innovations during system implementation. It summarises both achievements and remaining challenges, and proposes practicable policy recommendations.

2   Exploration of the Smart-City Management System in Baiyun District

2.1   Current Governance Conditions and Challenges

Covering a vast territory where urban and rural areas coexist, Baiyun District is home to numerous urban villages and a large transient population, rendering urban management exceptionally demanding. Six chronic problems stand out:

Sanitation-worker absenteeism and payroll fraud. Traditional manual sign-in is prone to manipulation, allowing contractors to bill for "ghost" workers and undermining service quality.

Inadequate gas-safety oversight. Scattered bottled-gas use in urban villages and rental housing, coupled with patchy inspections, has led to frequent accidents.

Spillage from muck-transport vehicles. Real-time monitoring and smart evidence collection were previously unavailable, resulting in road pollution and traffic hazards.

Illegal construction. Mis-reporting and low-efficiency foot patrols have made deterrence ineffective.

Insufficient manpower for city-appearance patrols. An imbalance between staff size and responsibility zones causes delayed and incomplete inspections.

Chaotic address data. Outdated or erroneous "Four Standards, Four Realities" addresses disrupt map matching and lead to lost sanitation fees and missed gas inspections.

These constraints have severely hindered refined urban governance and public-service quality in Baiyun. Consequently, the District resolved to build a full-chain smart-city management system that is data-driven, technology-enabled, and process-reengineered, aiming to deliver a sustainable and replicable innovation model.

2.2   Construction Principles and Overall Approach

Drawing on government needs and corporate technological capabilities, Baiyun formulated four core principles and a "1+4+N" governance system.

Four Core Principles

Problem-oriented, planning-led. A 2.5-month needs survey identified operational pain points; a further 0.5-month effort produced unified functional and business-architecture diagrams to prevent siloed development. Planning is forward-looking, and all iterations remain within the original framework to avoid scope creep and redundant construction.

Process re-engineering, practicality and convenience. Complex workflows were translated into concise system commands, with both PC and mobile interfaces enabling "one-click" response. Sanitation work orders were reduced from eight steps to three, cutting average completion time from over 20 hours to under two.

Data sharing, rigorous oversight. Interfaces for sanitation, gas, city-appearance and other departments were unified into Huawei GaussDB and a data warehouse. A super-BI platform delivers visual analytics; since going live, about 4 million performance-supervision work orders have been generated, enabling dynamic performance management.

Source governance, serving the public. Roughly 22 million basic address records–drawn from "Four Standards, Four Realities," Cloud-Shield, and logistics sources – were cleaned and integrated into a "standard-address semantic inference library," eliminating address chaos. A citizen-service portal offers tree adoption, incident reporting, sanitation-fee payment, furniture-collection booking, etc., creating a closed loop of "citizen participation +feedback."

The "1+4+N" Governance System

"1"–One unified smart platform. Built on micro-service, low-coupling architecture, the platform registers 123,000+urban components (bins, toilets, greenery) and 28,000+key municipal assets (sanitation vehicles, AI patrol cars). It manages 10,000+municipal staff and tens of thousands of events, centralising data for cross-departmental dispatch and intelligent early warning.

"4"–Four critical pathways.

Visualised asset management. CIM technology maps all components in 3D. Fifty-nine waste-compaction stations are equipped with weighbridges, AI cameras, and environmental sensors, cutting "illegal dumping" and saving nearly RMB 10 million annually.

Digitised personnel attendance. Smart-ID badges track 10,000+staff in real time, raising sanitation attendance from <50% to >90% and eradicating "ghost payrolls" [3].Work-order-driven daily operations. Illegal-construction control, greening, road sweeping and other tasks are issued as work orders to responsible agencies or contractors via e-fencing and enhanced positioning. The mechanism dismantles "nine dragons governing water" fragmentation and creates clear accountability.

Diversified citizen participation. The "Suiyun Smart City Management" mini-program offers incident reporting, gas ordering, sanitation-fee payment, tree adoption, bulky-waste collection, etc., closing the "last-mile" governance loop.

"N"–Multiple fine-grained scenarios.

Illegal-construction governance. Drone autopatrol plus multi-task AI detects suspected illegal builds; >1,700 work orders generated, 4.66 million m² demolished in 2024–top in Guangzhou.

City-appearance monitoring. 154,000 cameras and AI patrol cars spot illegal stalls, fly-posting, road refuse 24/7, auto-generating and dispatching work orders.

Waste-separation supervision. AI cameras and voice prompts at ~1,000 disposal points combine "on-site guidance +cloud oversight," raising accuracy and cutting manpower – cited by the Ministry of Housing & Urban-Rural Development as a best practice [4].

Extended scenarios. Gas safety: 3.33 million rental-house bottled-gas users linked to the system; addresses overdue for inspection trigger auto-work orders. Construction-waste transport: 450+smart cameras at 153 key checkpoints enable 24/7 real-time monitoring and evidence collection.

2.3　Evaluation of Application Results

Comprehensive economic and social indicators show significant impact:

Sanitation-fee collection. Guangdong's first transparent, standardised and user-friendly sanitation-fee system collected RMB 364 million in 2023 (+84% YoY) and RMB 452 million in 2024-doubling 2022 levels and accounting for one-third of Guangzhou's total, ranking first in both increment and volume for two consecutive years.

Zero gas-safety accidents. Full inventory of 3.33 million rental-household bottled-gas users, coupled with smart terminals and backend linkage, has delivered two consecutive years of "zero poisoning, zero explosion, zero fatality."

Fiscal savings and resource optimisation. Weighbridges and sensors at waste-compaction stations save nearly RMB 10 million annually; ~4 million performance work orders have embedded accountability and avoided redundant enforcement.

Social benefits and accolades. Selected for the China Information Industry Association's "Digital Government Innovation Cases" in 2023 and 2024; winner of seven national awards including "2024 Digital China Popular Project," "2024 Smart City Pioneer Award (second prize)," and "5G+AI Special

Track-Blooming Cup (first prize)." Reported four times in People's Daily and extensively covered by Xinhua, Nanfang Daily, etc. On 25 November 2024, Academician Tong Qingxi (Chinese Academy of Sciences) assessed the system as "internationally advanced overall, and world-leading in drone-based sub-metre small-target change detection." Over 160 delegations-including the Ministry of Housing & Urban-Rural Development, Tsinghua University, Beijing Haidian, Hangzhou, and Wuhan-have conducted study visits.

In sum, Baiyun's smart-city management system has achieved notable results in revenue generation, social governance, public safety and transparency, forging a sustainable and replicable innovation model.

3 Dissemination Pathways and Standardisation

3.1 Dissemination Context and Current Status

Since its launch in March 2022, Baiyun's smart-city management system has been rolled out to Haizhu District (Guangzhou), Xin'an County (Henan), Maoming (Guangdong), and other jurisdictions, generating cumulative revenues exceeding RMB 35 million. Nevertheless, replication faces five persistent challenges:

Divergent governance models and user requirements. Variations in departmental mandates, workflows, and citizen-participation channels across regions cause compatibility issues and uneven acceptance.

High development and integration costs. Heterogeneous infrastructure and technical standards inflate secondary development expenses, straining local finances.

Local protectionism and market barriers. Concerns that an "imported" system might stifle indigenous information industries lead some authorities to delay or resist adoption.

Absence of unified standards. Inconsistent data-interface protocols, formats, and business processes at provincial, municipal, and county levels impede cross-jurisdictional data sharing and orchestration.

Legacy-system replacement and audit risks. Abrupt decommissioning of incumbent systems risks creating stranded assets and audit liabilities, necessitating careful transition management.

3.2 Industry-Standard Formulation and Dissemination Mechanisms

To address these challenges, Baiyun spearheaded the Group Standard for Smart-City Management System Construction (October 2024). Designed for universality, practicality, and forward compatibility, the standard targets five critical areas:

Tiered deployment specifications. Cities are classified into Tier-1, Tier-2/3, and Tier-4/5, each receiving differentiated requirements for architecture, data interfaces, functional modules, and O&M to ensure the "Baiyun Model" can flexibly adapt to diverse urban contexts.

Unified data models and interface protocols. Core data entities – urban components, assets, personnel, events, work orders, and addresses – are rigorously defined, including field formats and update cadences. Standardised RESTful APIs facilitate out-of-the-box integration and secondary development.

Workflow and performance-closure design. Standardised work-order issuance, task assignment, and rectification-feedback loops stipulate responsible entities and deadlines. BI dashboards embed KPIs to enable real-time and post-hoc oversight.

Security and O&M norms. Requirements cover encrypted data transmission, role-based access control, audit logging, and incident-response playbooks. SLA metrics (uptime, MTTR) ensure reliable service delivery and rapid incident resolution.

3.3 Lessons from Dissemination

Dual-wheel drive: top-level orchestration +local adaptation

Provincial-municipal joint standard-setting resolves technical incongruities, while localities perform secondary development and feature customisation-achieving a "standardisation+localisation" synthesis.

Pilot demonstrations followed by phased roll-outs [5].

A "pilot-summarise-replicate" approach minimises trial-and-error costs. Baiyun's pilots in Haizhu, Xin'an, and Maoming rapidly yielded replicable playbooks.

Industry-university-research-application synergy

The Guangzhou Baiyun Smart-City Management Industry Promotion Association consolidates universities, research institutes, enterprises, and government to co-develop technologies and incubate projects, deepening the "industry-university-research-application" nexus.

Citizen participation coupled with social oversight

Widespread uptake of the citizen mini-program-co-maintained through government procurement and socialised service providers-embeds public feedback and rating into work-order closure, creating a bottom-up supervisory loop that sustains system viability post-deployment [6].

4　　Practical Logic for Building an Open-Source Low-Code Ecosystem

4.1　　Low-Code Philosophy and Technical Architecture

To address these challenges, Aligned with the "Overall Plan for Digital China," open-source ecosystems are a key driver of digital innovation and nation-wide digitalization. Baiyun District has adopted low-code development as its cornerstone to create a digital-governance platform grounded in "componentization, visualization, and data-driven design." The mantra is "reduce technical complexity, amplify business ownership," yielding the following architectural traits:

Component & Tool Libraries

Foundational capabilities-citywide object mapping, work-order orchestration engines, IoT O&M platforms, UAV flight-control systems, semantic address engines-are packaged into reusable components. Non-developers drag-and-drop these components in a visual configurator, map fields, and define flows to deliver scenario-specific applications at low code.

Containerization & Microservices

Every module is containerized and orchestrated via Kubernetes. A microservices design decouples services, enables elastic scaling, and supports parallel execution of multiple scenarios.

API Gateway & Open Interfaces

A unified API gateway exposes RESTful and GraphQL endpoints, giving external systems and multi-channel clients a single, standards-compliant entry point.

Data Middle Platform & Intelligent Analytics

A data middle platform ingests multi-source data-sanitation, gas, urban appearance, environmental protection-cleans and consolidates it via ETL and data-warehouse techniques, and powers BI dashboards and AI decision models.

4.2　　Open-Source Practices & Collaboration Mechanisms

Code Hosting & Community Collaboration:The low-code platform and core modules are hosted on government open platforms or enterprise open-source communities, inviting third-party developers, research institutes, and universities to optimize code and extend features. Incubator programs such as "Open-Source Days" and hackathons surface innovations and use cases on a regular cadence.

"Core Controllable, Edge Open" Strategy

Critical governance logic-e.g., performance evaluation and data privacy-remains closed-source or government-led for control. Peripheral functions-mini-program components, UI templates-are open-sourced to stimulate innovation and broaden application scenarios.

Security, Compliance & Version Management

Security baselines (identity, authorization, encryption, audit logging) safeguard the open-source low-code platform. CI/CD pipelines and version management enable multi-party co-development and rapid iteration while balancing stability with continuous innovation.

Capability Export & Ecosystem Cultivation

Beyond core components, the district periodically releases open SDKs and data APIs, creating a virtuous cycle: government→enterprises→society→government. Enterprises are encouraged to spawn derivative products-smart sanitation equipment, gas-inspection robots, etc.-accelerating vertical synergy across the industrial chain.

5 Industrial Synergy & Economic Impact

5.1 Role of the Smart Urban Management Industry Promotion Association

To maximize collaboration among government, academia, industry and media, Baiyun District chartered the "Guangzhou Baiyun Smart Urban Management Industry Promotion Association," creating an integrated "R&D-Industry-Government-End User" platform. Key initiatives:

Academia Side

Jointly with Sun Yat-sen University, South China University of Technology and the Guangdong Academy of Sciences, the Association has set up a "Smart Urban Management Laboratory" that researches UAV inspection, AI recognition and safety assessment. Regular industry seminars and tech salons spotlight emerging governance challenges and frontier technologies, providing intellectual fuel for industrial innovation.

Government Side

Municipal governments can join as co-sponsors, submit requirements and receive discounted system deployments, steering proven solutions into government procurement catalogs. Policy incentives and fiscal subsidies encourage firms to perform secondary development and localized customization, forging a "Government-Enterprise-Society" tri-lateral linkage.

Enterprise Side

Member firms are grouped into specialized committees-Smart Sanitation, UAV Patrol, AI Recognition, etc.-that precisely match government demand and drive "one-city-one-policy" bespoke solutions. Within each committee, leading firms lead standardization and quality assessment, raising technical competence and market competitiveness.

Media Side

The association's in-house journal "Smart City Governance" and its online channels amplify the Baiyun brand, uncover new clients and partnership opportunities. Themed reports and case studies heighten public awareness of, and trust in, smart-city achievements, mobilizing social participation and oversight.

5.2 Park Construction & Economic Impact

Baiyun District is building a "Smart Urban Management Industrial Park" to attract flagship enterprises in smart equipment manufacturing, UAV inspection, big-data services and AI applications, forming industrial clusters for sanitation, gas supervision, horticulture care and more. Concrete practices:

Smart Sanitation Equipment Introduction & Deployment

The park has introduced waste-sorting machines. In 2024, household-waste classification reached 20.35%, recycling 54.79% and resource utilization 89.8%. These devices lift processing efficiency and resource utilization, propelling sanitation toward intelligence and precision.

Localized "R&D-Production" Ecosystem

The park lures manufacturers of AI-powered waste-sorting equipment to set up production lines, integrating design, manufacture and testing on one site. Localized production lowers procurement and O&M costs and shortens iteration cycles, underpinning continuous innovation and large-scale deployment of smart sanitation gear.

UAV & AI Inspection

In partnership with JOUAV and the Urban Planning & Design Institute, the park deploys UAV patrol and computer-vision solutions, accelerating adoption of drones and AI in municipal management.

Big-Data & Digital Mapping Services

Working with Amap and Tencent Maps, the park builds high-precision 3-D maps and address databases to enable a governance model that fuses "standard address+3-D map +multi-service overlay," transcending traditional flat-map limitations.

AI & Smart Terminals

Going forward, the project will integrate computer-vision omnidirectional monitoring and natural-language-processing technologies to empower robotic "brains," spurring AI industry growth.

As of 2024, 21 park companies generated RMB 55 million in taxes and profits, covering 12 verticals including smart sanitation, waste sorting, gas supervision and horticulture care. The park is evolving into an integrated "Government+Industry+Innovation" ecosystem. Future phases will continue to fuse CV and NLP technologies, injecting new momentum into Baiyun's smart-urban-management industry.

6 Conclusions and Policy Recommendations

6.1 Research Conclusions

Based on the case study of Baiyun District's smart-city management system, the following findings emerge:

"Problem-oriented+Top-level Planning"

Baiyun spent 2.5 months on needs assessment and half a month drafting the architecture, ensuring every yuan of investment was tied to real pain points and avoiding redundant construction.

"Process Re-engineering +Data Sharing"

Sanitation work orders were reduced to three steps, data were consolidated into GaussDB and the BI platform, and nearly 4 million performance work orders have been issued-dramatically raising grassroots response speed and accountability.

"Source Governance+Public Participation"

Cleansing 4.8 million standard addresses and adding multi-channel citizen apps led to near-zero dynamic gas-safety incidents and transparent sanitation billing, turning "people build the city" from slogan to daily practice.

Demonstration Value of the "1+4+N" Framework

One unified platform, four critical pathways and N scenario applications create a closed-loop governance model that county-level cities can copy with minimal friction.

Standardization & Open-Source Low-Code for Mass Replication

Differentiated grading standards plus low-code/open-source architecture allow rapid, low-cost localization of technology and business logic.

"Government-Academia-Industry-End User" Synergy

The Industry Promotion Association and dedicated industrial park knit together government, universities, research institutes, enterprises and media, accelerating cluster formation and continuous innovation [7].

6.2 Policy Recommendations

For nationwide rollout at county and district levels:

Strengthen Top-Level Design & Standardization

A national task force-ministries, local governments, universities and enterprises – should issue unified standards for data models, interface protocols, functional modules and security O&M, giving every locality the same playbook.

Advance Low-Code & Open-Source Ecosystems

Dedicate special funds and incentives for open-source pilots of low-code platforms and core modules. Under the principle "core controllable, edge open," keep sensitive logic closed while opening peripheral components to slash technical barriers.

Build a Multi-Level Demonstration Mechanism

Start with provincial and municipal pilot cities that deploy standardized, replicable solutions. After evaluation, cascade to tier-3/4/5 cities. A feedback loop-metrics, case sharing and targeted funding – will speed diffusion.

Deepen Collaborative Innovation

Encourage joint smart-city labs between universities/research institutes and governments for key-technology breakthroughs and policy studies. Support industry associations and parks with policy, match-making and financing to forge an integrated "government-industry-academia-research-user" ecosystem.

Incentivize Citizen Engagement & Social Oversight

Embed citizen ratings, feedback and monitoring in performance KPIs. Continuously enrich citizen-facing apps to create a two-way governance loop. Leverage media and NGOs to showcase successes, building broad social buy-in for smart-city initiatives.

With these measures, every county and district can erect a smart-city management system that is standardized, open-source and ecosystem-driven, steadily lifting grassroots governance capacity and propelling China's urban modernization to the next level.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Biographies

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白雲區智慧城市管理系統建設與推廣的探索與實踐

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摘要：近年來，新質生產力與數字經濟的深入發展為我國治理體系現代化提供了重要支撐。預計到2025年，數字經濟核心產業增加值占GDP比重將超過10%，人工智能、數據要素等技術將賦能各行各業。面對「網絡強國」「數字中國」戰略要求，全國一體化政務服務平臺實名註冊用戶已超過10億，90%以上行政許可事項實現線上辦理，5G基站超330萬個（占全球60%以上），行政村全面實現光纖和4G網絡覆蓋。然而，重復建設、開發成本高昂、系統功能同質、地方保護主義、標準缺失、部門推諉等問題依然突出，製約了數字政務與智慧城市的高質量發展。本文聚焦廣州市白雲區在智慧城市管理系統建設與推廣方面的探索，基於「問題導向、流程再造、數據共享、源頭治理」原則，構建「1+4+N」治理架構，梳理技術創新與標準製定舉措，總結推廣成效與存在挑戰，提出面向全國區縣級復製路徑與政策建議。研究發現：白雲模式在縮短辦事流程、提升治理效率、節約財政支出、實現多方協同方面取得顯著效果，為全國智慧城市建設提供可借鑒範式。

關鍵詞：智慧城市；智慧城管；白雲模式；數字政府；城市治理

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