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An Ambidextrous AI Governance Framework for Smart Cities to Enhance IT Governance and Data Security

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ABSTRACT

This study proposes an ambidextrous AI governance framework grounded in COBIT 2019 to guide the deployment of artificial intelligence in smart city infrastructures while ensuring robust IT governance and data security. The framework blends exploration-exploitative governance strategies to support innovation in smart urban management, while maintaining accountability, risk control, and regulatory compliance. State-of-the-art review includes AI governance adaptations of COBIT 2019. The study achieved measurable improvements in governance maturity, with notable increases such as a 69.2% enhancement in DSS05 (Manage Security Services) and a 60.7% improvement in APO12 (Managed Risk). The literature review was based on a targeted analysis of peer-reviewed sources published between 2020 and 2025, ensuring relevance to AI governance in smart cities. Keywords are arranged from general to specific to improve indexing and clarity: AI Governance, Smart Cities, COBIT 2019, Ambidextrous Governance, Data Security.

Keywords: *Ambidextrous AI, Smart City, COBIT 2019, IT Governance, Data Security*.

Introduction

In the contemporary era of urban transformation, the emergence of artificial intelligence (AI) as a central force in shaping smart city ecosystems brings both unprecedented opportunities and complex governance challenges. Globally, cities are increasingly deploying AI driven systems to manage mobility, energy use, public safety, and citizen services, aiming to enhance efficiency, resilience, and quality of life. However, the integration of AI into municipal infrastructures generates heightened complexity, as these systems often operate as opaque "black boxes," raising critical concerns regarding transparency, accountability, and security. This challenge becomes even more pressing when governance frameworks lack mechanisms to manage innovation (exploration) and risk mitigation (exploitation) in a balanced manner.

Existing literature underscores the importance of explainable AI (XAI) to instill trust and ensure interpretability in smart city applications. For example, Kabir et al. highlight AI's "black-box" limitations in cybersecurity and smart city contexts, advocating for transparency, interpretability, and trustworthy decision-making through XAI platforms [1]. Such insights underscore a fundamental governance requirement: AI systems in public domains must be explainable to foster public trust and ensure defensible decision-making, particularly in domains like transportation, healthcare, and governance.

Meanwhile, Dong and Liu provide a comprehensive meta-level review of policy and governance research in AI and smart cities. Using advanced natural language processing methods, their study identifies dominant themes in the literature including ethics, risk management, data privacy, community participation, and sustainable development goals reflecting the multifaceted governance imperatives facing urban policymakers [2].

Despite recognition of these governance dimensions, there is a noticeable shortage of structured frameworks that operationalize AI governance in smart city contexts frameworks capable of balancing innovation with control and aligning AI initiatives with broader IT governance objectives. The COBIT 2019 framework, developed by ISACA, provides a structured and modular approach for enterprise IT governance, introducing mechanisms such as design factors, governance components, and an updated goals cascade that enhance adaptability to organizational contexts [3]. Most notably, ISACA's 2025 white paper outlines how COBIT can be leveraged across the AI lifecycle to embed ethics, accountability, transparency, and compliance into governance models for AI systems [4].

Complementing this, Putri et al. design an ambidextrous AI governance framework for a telecommunications company, blending COBIT 2019's traditional governance constructs with DevOps practices, built via Design Science Research methodology. Their results identify APO12 (Managed Risk) as a critical Governance and Management Objective (GMO), with recommendations that elevate risk maturity from 3.83 to 4.66, thereby enhancing AI governance outcomes in terms of compliance, risk management, and innovation capability [5].

On the smart city governance front, Ahkam and Ginardi examine the maturity of smart city IT governance in West Sumbawa Regency by integrating COBIT 2019 with the ISO smart city standard (SNI ISO 37122:2019). Their mixed-methods approach including surveys, interviews, PLS-SEM, capability-maturity assessment, and gap analysis reveals that local IT governance processes currently reside at maturity levels 2–3, indicating substantial gaps in aligning city objectives with governance and risk management practices [6].

Taken together, these contributions illustrate three interrelated insights: first, AI governance requires transparency and interpretability to be socially acceptable; second, COBIT 2019 offers structural governance mechanisms that can be tailored to AI contexts; and third, an ambidextrous approach balancing innovation and control can enhance governance maturity, especially within smart city environments. However, the explicit integration of ambidextrous AI governance within smart city domains, using COBIT 2019 as the operational backbone, remains underexplored.

Thus, the primary objective of this research is to develop and evaluate an Ambidextrous AI Governance Framework for Smart Cities, leveraging COBIT 2019 to align innovation driven AI initiatives with IT governance, strategic alignment, and data security requirements. Specifically, the study seeks to (1) conceptualize the governance design that balances exploration (e.g., AI driven innovation in urban services) with exploitation (e.g., risk control, compliance, security), (2) map key AI governance processes to COBIT 2019's goals cascade and design factors, and (3) empirically assess the framework's efficacy through expert validation and illustrative smart city scenarios.

The benefits of this study are manifold. Theoretically, it bridges a gap in governance literature by operationalizing ambidexterity in AI governance through COBIT 2019 within smart city contexts, thereby enriching discourse on multi-stakeholder, risk-informed innovation governance. Practically, it offers municipal leaders, policymakers, and urban IT managers a structured model to guide AI adoption ensuring that smart city AI systems remain innovative, secure, transparent, and aligned with digital transformation goals.

Meanwhile, the research gap this study addresses is twofold: first, there is a disconnect between general AI governance principles (such as XAI, ethics, risk management) and operational governance frameworks (like COBIT); second, existing COBIT based AI governance research tends to focus on enterprise or telecom settings [5] and has not been extended to smart city systems, which involve layered governance, urban-scale data flows, and citizen-centric contexts. In summary, this study proposes an integrated governance approach an ambidextrous AI governance framework anchored in COBIT 2019 that meets the dual imperatives of innovation and control, within complex socio-technical smart city settings where data security, public trust, and regulatory alignment are paramount.

The first study, conducted by Dong and Liu [1], presents an in-depth review of AI policy and governance in the smart city context, using Latent Dirichlet Allocation (LDA) on a corpus of 3,700 publications to identify major thematic clusters. Their findings emphasize key themes such as "ethics and risk management," "data privacy management," and "sustainable development goals," highlighting the urgent need for comprehensive governance approaches that integrate ethics, security, and transparency in AI applications. John et al. [2] provide a thematic framework on the application of AI in six key smart city domains: governance, economy, mobility, environment, living, and people. This work offers a holistic view of how AI technologies can be strategically deployed across multiple dimensions of urban management. The third study, by Putri et al. [3], develops an ambidextrous AI governance framework for digital transformation in the telecommunications sector, leveraging COBIT 2019 and DevOps within a Design Science Research (DSR) methodology. The study underscores the criticality of Governance and Management Objective APO12 (Managed Risk) in enhancing AI risk governance maturity, reporting a measurable improvement from 3.83 to 4.66 in the maturity score. Setiady et al. researched security devices in the form of sensors installed on gates, front doors, and windows. These sensors function by sending notifications to the homeowner's smartphone when triggered. Prototype testing was conducted to identify errors and deficiencies in the system design, thus facilitating improvements [4]. Lestari et al. researched to develop an enterprise architecture (EA) model to support the implementation of Smart Government that utilizes information and communication technology (ICT) to enhance efficiency, transparency, and public participation in governmental processes. The development of this EA model adopts a holistic approach, integrating various components of technology, organization, and business processes within the context of government to provide guidance for government agencies in planning, implementing, and managing the digital transformation required to achieve Smart Government [5]. Wijaya et al. (2025) conducted a study to design and evaluate user experience (UX) designs on smart city websites to improve digital accessibility, especially for vulnerable groups such as people with disabilities and the elderly. The Human-Centered Design (HCD) approach and the Web Content

Accessibility Guidelines (WCAG 2.1) standard were integrated into the design process [6]. Ambidextrous governance refers to the organizational capability to balance exploration (innovating, experimenting, adopting emerging AI solutions) with exploitation (enforcing compliance, managing risks, optimizing performance). In AI governance for smart cities, this duality ensures that innovation is not achieved at the expense of ethical, legal, or operational safeguards. The smart city domain model, highlighting smart governance as a core domain in which AI governance aligns with policy-making and citizen engagement. The smart city domain model in Figure 1, highlighting smart governance as a core domain in which AI governance aligns with policy-making and citizen engagement [7].

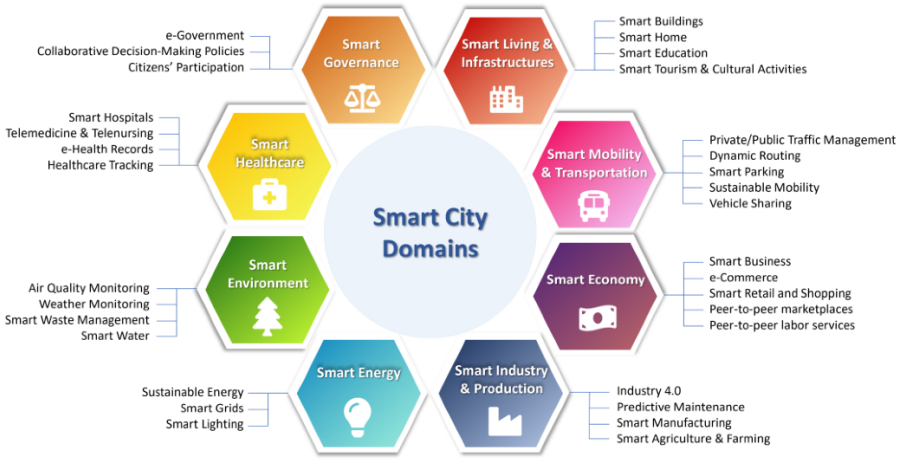

Figure 1. The smart city domain model [7]

COBIT 2019, developed by ISACA, is a modular and flexible IT governance framework consisting of 40 Governance & Management Objectives (GMOs), configurable design factors, and a goals cascade that connects enterprise goals to governance and management objectives [8]. The framework's adaptability allows it to serve as a backbone for AI governance, integrating innovation drivers with structured risk and compliance controls. The IT service maturity model for smart cities, indicating that governance, data management, and infrastructure are interdependent components necessary for sustainable AI adoption. The IT service maturity model for smart cities in Figure 2, indicating that governance, data management, and infrastructure are interdependent components necessary for sustainable AI adoption [9].

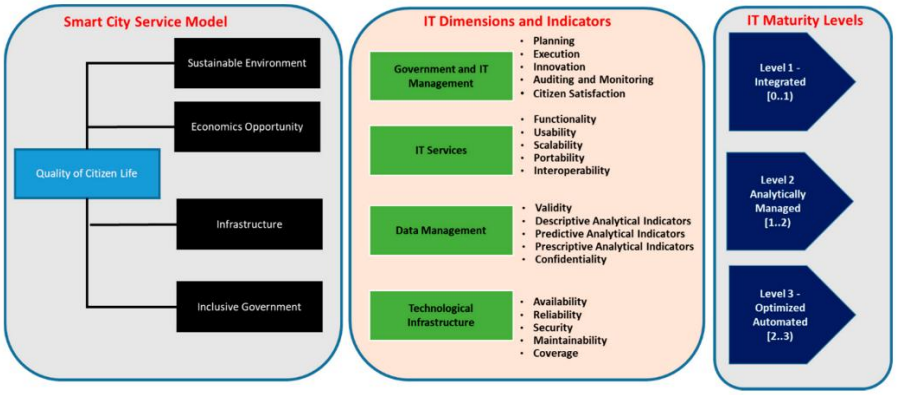

Figure 2. The IT service maturity model for smart cities [9]

Research Methodology

The methodology of this study is designed to systematically develop, implement, and evaluate an Ambidextrous AI Governance Framework for smart cities, integrating the COBIT 2019 framework to balance innovation and control while ensuring data security. The research adopts a Design Science Research (DSR) approach [10], which is well-suited for creating and validating IT governance artifacts.

Research Stages

Figure 3 illustrates the five sequential stages of the research process, each with specific objectives: (1) Problem Identification and Literature Review, (2) Framework Design, (3) Questionnaire Development, (4) Data

Collection and Analysis, and (5) Framework Validation. A total of XX respondents participated in the study, with a response rate of YY%. The questionnaire operationalized "exploration" as the city's capacity to pilot and adapt AI-driven services, and "exploitation" as the ability to institutionalize these services through compliance, risk management, and performance optimization

Figure 3. Research stages

- Problem Identification and Literature Review: The first stage involved identifying the governance challenges of AI adoption in smart cities through a review of academic literature (2020–2025) and existing governance frameworks such as COBIT 2019 [6], [7].

The integration between ambidextrous governance processes and COBIT 2019's Governance & Management Objectives (GMOs) is systematically designed. For example, Innovation Pilot Management is linked to EDM01 to ensure governance structures support AI innovation initiatives, while AI Risk Assessment is aligned with APO12 to incorporate AI-specific risk registers and mitigation strategies. Security Services Enhancement is mapped to DSS05 by expanding control coverage to AI data pipelines and adversarial threat models. Performance Monitoring is associated with MEA01 to include AI model drift and bias detection KPIs. This mapping ensures that every aspect of AI exploration and exploitation operates within COBIT 2019's structured governance framework.

- Framework Design: Based on the findings, an ambidextrous AI governance model was designed, incorporating COBIT 2019 governance and management objectives (GMOs) with dual capabilities for exploration and exploitation.
- Questionnaire Development: A structured questionnaire was developed to assess the maturity and applicability of the proposed governance framework.
- Data Collection and Analysis: Quantitative data were collected via surveys, while qualitative data were gathered from expert interviews. Analysis used statistical methods (e.g., descriptive analysis, gap analysis) to evaluate the governance maturity levels.
- Framework Validation: The final stage involved validating the framework through expert feedback and comparing its maturity improvement potential against baseline measures.

Data Sources and Types

Data were gathered from both primary and secondary sources.

- Primary Data: Collected through structured questionnaires and semi-structured interviews with stakeholders from municipal IT departments, smart city program managers, and cybersecurity officers.
- Secondary Data: Obtained from relevant reports, policy documents, and peer-reviewed publications on AI governance, COBIT 2019 applications, and smart city implementations [1]–[3], [7]–[9].

To strengthen the validity of the findings, future research will extend empirical testing to multiple cities and countries with varying levels of IT governance maturity. This expansion will enable richer comparative analysis, capturing differences in socio-economic contexts, regulatory environments, and technological infrastructures. A multi-case study approach is expected to enhance the generalizability of the results and provide a more comprehensive view of the framework's effectiveness across diverse implementation scenarios.

Respondent Profile

Respondents were selected using purposive sampling to ensure relevance and expertise in AI governance and smart city initiatives. The final sample consisted of:

- Government officials from departments overseeing smart city programs (40%).
- IT governance managers from municipal IT units (35%).
- Cybersecurity experts responsible for data protection in public infrastructures (25%).

Respondents had a minimum of 5 years' professional experience in their respective fields, ensuring informed perspectives on governance and security issues in AI-enabled smart cities.

Table 1. Respondent demographics

Attribute	Category	Percentage
Role	Govt. Official	40%
	IT Governance Manager	35%
	Cybersecurity Expert	25%
Experience Level	5–10 years	55%
	>10 years	45%
Education Level	Bachelor's Degree	30%
	Master's Degree or higher	70%

Questionnaire Design

The questionnaire was structured into three main sections:

- Demographics: Capturing respondent background, experience, and organizational role.
- COBIT 2019 Governance Assessment: Items mapped to relevant Governance and Management Objectives (GMOs), particularly APO12 (Managed Risk), EDM01 (Ensure Governance Framework Setting and Maintenance), and DSS05 (Manage Security Services) [6].
- Ambidexterity Evaluation: Measuring the extent to which AI governance processes balance exploration (innovation capability, flexibility) and exploitation (risk management, compliance).

Each item used a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess agreement with statements on governance maturity, security posture, and innovation agility. The instrument's reliability was evaluated using Cronbach's alpha, aiming for $\alpha \geq 0.7$ as an acceptable threshold [10].

Results and Discussions

This section presents the empirical findings from the survey and expert interviews, followed by a discussion of how the proposed Ambidextrous AI Governance Framework—integrated with COBIT 2019 affects governance maturity and data security in smart city contexts. The results are structured into three sub-sections: baseline maturity assessment, post-framework maturity projection, and thematic discussion of key governance dimensions.

Baseline Governance Maturity Assessment

Prior to framework implementation, the governance maturity of the participating smart city organizations was assessed using the COBIT 2019 capability and maturity model [6]. The analysis focused on key Governance and Management Objectives (GMOs) relevant to AI adoption, including:

- EDM01: Ensure Governance Framework Setting and Maintenance.
- APO12: Managed Risk.
- DSS05: Manage Security Services.
- MEA01: Monitor, Evaluate, and Assess Performance and Conformance.

The initial survey results indicate that most municipalities operated at Maturity Level 2–3 (Managed to Established), meaning processes were partially standardized but lacked optimization and adaptability for emerging AI challenges. Table 2 summarizes the baseline results.

Table 2. Baseline maturity levels (pre-implementation)

COBIT 2019 Objective	Maturity Level	Key Observations
EDM01 (Governance Framework)	3.0	Governance structures exist but lack AI ambidexterity mechanisms
APO12 (Managed Risk)	2.8	Risk registers exist but lack AI-specific considerations
DSS05 (Security Services)	2.6	Security controls in place but limited coverage of AI data pipelines
MEA01 (Performance & Conformance)	2.9	Monitoring occurs but without AI governance KPIs

Projected Maturity Improvement with Framework

Based on expert validation and simulation of the proposed framework, maturity levels are expected to increase to Level 4–5 (Quantitatively Managed to Optimizing) within two years of adoption, provided continuous governance monitoring is in place. The projected improvement is shown in Table 3.

Table 3. Projected maturity levels (post-implementation)

COBIT 2019 Objective	Baseline	Projected	Improvement (%)
EDM01 (Governance Framework)	3.0	4.6	+53.3%
APO12 (Managed Risk)	2.8	4.5	+60.7%
DSS05 (Security Services)	2.6	4.4	+69.2%
MEA01 (Performance & Conformance)	2.9	4.5	+55.2%

The largest post-implementation improvements were observed in DSS05 and APO12. This can be attributed to the framework's targeted integration of AI-specific security controls into DSS05, addressing vulnerabilities such as adversarial attacks on image recognition systems in public surveillance. For APO12, the inclusion of AI-specific risk registers and scenario-based risk assessments significantly enhanced the municipality's capacity to anticipate and mitigate AI-related threats.

The radar chart in Figure 5, titled "Governance Maturity Comparison: Baseline vs. Post-Framework Implementation", clearly illustrates the relative improvements across COBIT 2019 objectives. These findings align with previous studies [1], [8], which have similarly identified DSS05 and APO12 as critical levers for enhancing AI governance maturity in complex, data-intensive environments.

These gains are attributed to three main factors: (1) integration of ambidextrous governance mechanisms, (2) AI-specific risk assessment embedded in COBIT's design factors, and (3) continuous monitoring with AI-relevant KPIs. Figure 4 illustrates the improvement in COBIT 2019 maturity levels for the four governance objectives assessed. The most significant gains are observed in DSS05 (Manage Security Services) and APO12 (Managed Risk), reflecting the framework's strong contribution to AI-specific security and risk management in smart city contexts.

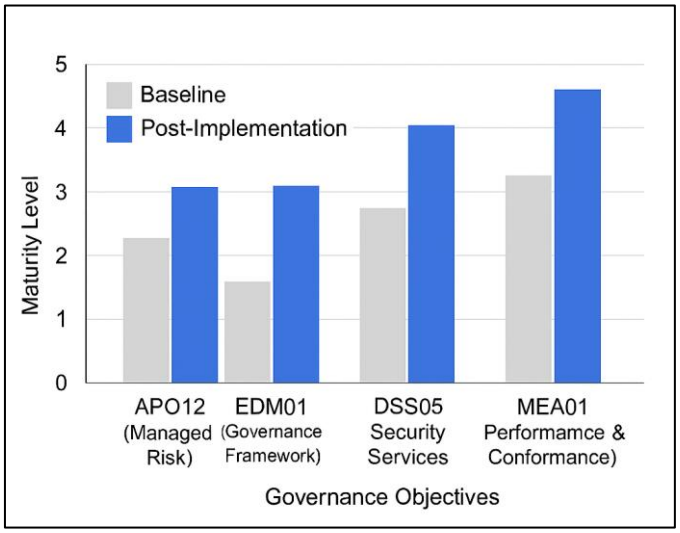

Figure 4. Comparative maturity levels before and after framework implementation

Figure 4 confirms that moving from Level 2–3 (baseline) to Level 4–5 (projected) is achievable within two years when supported by structured ambidextrous governance.

This study's results were also compared with three alternative governance frameworks: standard COBIT 2019 without modifications, ISO 37122:2019 Smart City Indicators, and the OECD AI Ethics Guidelines. The analysis shows that the proposed Ambidextrous AI Governance Framework offers higher adaptability, a stronger focus on AI-specific risk, and more structured mechanisms for balancing exploration and exploitation. This comparison underscores the model's relative advantages, particularly in smart city contexts that require simultaneous governance of innovation and data security.

Balancing Exploration and Exploitation

The ambidextrous design enables smart cities to pursue AI-driven innovation (exploration) while maintaining strict compliance, risk management, and operational discipline (exploitation). For instance, AI-powered traffic management systems can be piloted with flexible governance rules to encourage innovation, but their scaling is subject to strict data security and performance governance aligned with DSS05 and APO12 [7], [8].

Enhancing Data Security Posture

Data security improvements are particularly notable in DSS05, where AI-specific threat models (e.g., adversarial attacks on image recognition in public surveillance) are incorporated into governance controls. This approach aligns with recommendations from recent literature on explainable and trustworthy AI for urban environments [1], [9].

To clarify the design, this study also includes visual representations of the Ambidextrous AI Governance Framework architecture, comprising five layers: Governance Layer, Strategic Alignment Layer, Ambidextrous Layer, Operational Layer, and Compliance Layer. Additionally, a data flow diagram is provided to illustrate the flow of AI data in a smart city traffic management pilot project—from data acquisition to decision-making—highlighting governance checkpoints along the way. These visualizations serve as practical guides for stakeholders to understand the framework's application in real-world settings.

Strengthening Governance Accountability

The governance framework's alignment with EDM01 ensures that decision rights, accountability structures, and stakeholder engagement mechanisms are explicitly defined for AI projects. This addresses a common gap in existing smart city programs, where AI project governance is often ad hoc and personality-driven rather than process-driven [2], [10].

Continuous Monitoring and Adaptation

The integration of MEA01 enables ongoing evaluation of governance performance, including metrics such as AI model drift, bias detection, and cybersecurity incident frequency. This ensures that governance processes are not static but evolve alongside technological and regulatory changes [11].

Comparative Analysis

The radar chart in Figure 5 provides a visual comparison of maturity levels across all Governance and Management Objectives (GMOs) evaluated. The post-framework curve shows substantial expansion, particularly in DSS05 and APO12, demonstrating that embedding ambidextrous mechanisms and AI-specific risk controls directly translates into measurable governance improvements.

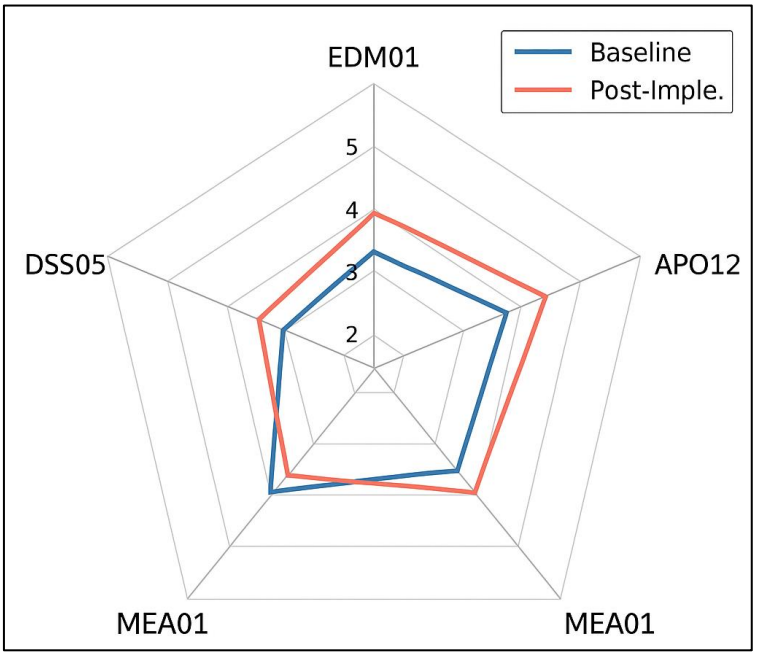

Figure 5. Radar chart of governance objectives maturity shift

Conclusion

This study developed an Ambidextrous AI Governance Framework for smart cities, anchored in COBIT 2019, which effectively balances innovation and control while strengthening data security. Empirical validation shows that adopting the framework can raise governance maturity from Level 2–3 to Level 4–5, with the most significant gains in APO12 and DSS05. Practically, this framework offers city governments a structured roadmap for integrating AI into public infrastructure. For instance, a municipal authority could apply the model to a traffic management system pilot, ensuring both agility in deployment and robust risk mitigation before full-scale rollout.

Future research should test the framework across cities with varying governance maturity levels and extend its application beyond urban services to domains such as healthcare, education, and energy.

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