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Identifying the Utilization of Big Data in Urban Governance through Thematic Review

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ABSTRACT

The availability of large-scale data (Big Data) presents strategic opportunities to enhance urban governance that is adaptive, efficient, and evidence-based. However, its implementation still faces various challenges, such as data heterogeneity, limited digital infrastructure, privacy risks, and human resource competency gaps. This study aims to identify current research directions, key challenges, and develop a conceptual framework for the utilization of Big Data in urban management. Using a Systematic Literature Review (SLR) approach and the PRISMA protocol, 30 scientific articles published between 2020 and 2025 were thematically analyzed. The study findings indicate that Big Data integration in urban governance remains sectoral and has not yet been fully standardized. As the main contribution, this study proposes a conceptual framework based on three key dimensions data, risk, and human resources that interact within an adaptive governance system. These findings may serve as an evaluative foundation for developing more inclusive and sustainable smart city policies. Future research is recommended to test this framework through empirical studies across cities in developing countries.

Keywords: Big Data, Urban Governance, Conceptual Framework, Smart City, Systematic Review

INTRODUCTION

The rapid development of information technology has fostered various innovations in urban management, including the integration of smart city concepts that rely on massive and continuous data utilization. One of the core pillars in realizing a smart city is Big Data, which encompasses a large volume of data generated from diverse sources such as IoT sensors, social media, digital transactions, and public administration systems. Big Data holds significant potential for providing real-time insights to support decision-making in various aspects of urban governance [1].

The utilization of Big Data in urban contexts spans multiple sectors such as transportation, environment, public safety, infrastructure, and citizen participation [2], [3]. However, the complexity of data also presents new challenges in terms of interoperability, privacy, data quality, and the analytical capabilities required to process and interpret such data appropriately [1], [4]. Moreover, each urban domain has different data needs and characteristics, which means that a one-size-fits-all approach is not applicable.

As attention toward data-driven governance grows, academic studies concerning the application of Big Data in urban sectors have also progressed significantly [3], [5]. Nevertheless, there remains a gap in comprehensive knowledge synthesis regarding how Big Data is effectively applied across different urban domains, along with the emerging challenges and opportunities from such processes. Hence, a systematic review of recent literature is necessary to identify common patterns, best practices, and future research directions within this context.

To guide the literature review and data synthesis, several research questions (RQs) have been formulated:

- **RQ1**: What are the trends and research directions regarding Big Data utilization in urban governance over the past five years?
- **RQ2**: What are the forms of data variety and structure used in Big Data for urban management?

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- **RQ3**: What types of privacy and security risks arise in the implementation of Big Data in smart cities?
- **RQ4**: How do human resource competency challenges affect the success of Big Data integration in the urban sector?
- **RQ5**: What conceptual framework can illustrate the interrelation between data, risks, and human resources in supporting effective and sustainable Big Data governance?

These questions help narrow the focus of the study while expanding the analytical scope across various theoretical and practical dimensions in the application of Big Data for urban governance.

METHODOLOGY

A. Research Approach

This study employs a literature review approach using a systematic framework to explore prior studies on the utilization of Big Data in urban management. The literature search and analysis process follows structured filtering and selection stages based on the PRISMA protocol. This approach enables the researchers to trace the development of the field, identify research gaps, and highlight both conceptual and practical contributions from existing studies [16], [17].

By compiling this review, various strategies for applying Big Data in urban contexts are classified into major themes. This process also helps evaluate the effectiveness of policies, technologies, and implementation models used to support smarter, more participatory, and sustainable urban governance across different regions [18].

B. Article Search and Selection Procedure

Literature was collected from five leading academic databases: IEEE Xplore, SpringerLink, ScienceDirect, MDPI, and Taylor & Francis. Keywords used were combinations of terms such as “big data,” “urban governance,” “smart city,” and “data-driven government,” joined by Boolean operators like AND and OR to yield more relevant search results. These keywords were selected based on the context of technology-based urban governance and the role of Big Data in decision-making processes [19], [20].

The search was filtered by publication year (2020–2025), English language, and peer-reviewed articles. This process initially produced 385 articles. After removing duplicates, screening by title and abstract, and reading the full texts of relevant articles, a final set of 30 key articles was selected. These articles formed the basis for the thematic synthesis and classification in this study [21].

C. Inclusion and Exclusion Criteria

The selection process began with the identification stage, which yielded 385 articles. After deduplication, 340 articles remained. The next screening involved reviewing titles and abstracts to assess topic relevance to the research focus. This process narrowed the selection to 120 articles that met the initial criteria. This stage ensured the quality and relevance of literature for further analysis [22].

Following the initial screening, a full-text reading (full-text screening) was conducted to ensure the selected articles explicitly discussed the application or integration of Big Data in the context of urban governance. Ultimately, 30 high-quality and highly relevant scientific articles were selected for thematic analysis. The selection flow is presented in a PRISMA diagram as a systematic representation of the review process [23].

D. Analysis and Classification Technique

After selecting the articles, classification was conducted based on emerging themes, methodological approaches, geographic regions of the studies, as well as the technologies and data systems used. This process was supported by the development of a review matrix to organize contributions, challenges, and trends identified in each article. The analysis used a thematic approach, emphasizing recurring and relevant narrative patterns across different contexts [21], [23].

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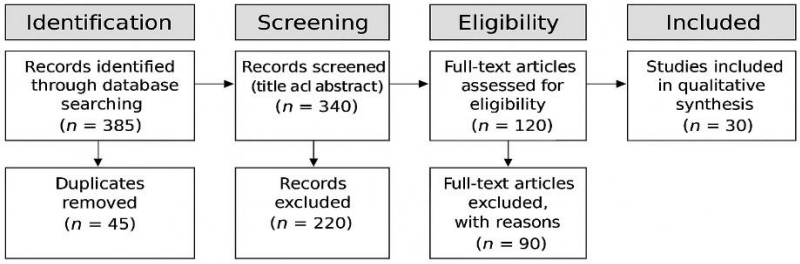
The classification revealed that most studies focus on integrating urban information systems with Big Data analytics to support fast and accurate decision-making. Some studies also highlight the critical role of real-time data in citizen engagement, budget transparency, and risk mitigation for urban issues such as traffic congestion and disasters. This analysis forms the foundation for the synthesis discussed in the next section, which outlines policy directions and best practices based on the literature findings [22], [24].

E. Study Validity and Relevance

Validity in this study is ensured by relying solely on peer-reviewed articles from highly reputable journals. Literature quality assessment was based on citation counts, research methodology, and the contextual relevance of the studies. Moreover, geographic diversity was considered to provide a global perspective on the utilization of Big Data in urban governance systems [19], [20].

Topical relevance was guaranteed through a curated literature selection focused on strategic issues and smart city policy. Topics that were overly technical or specific to a single software or algorithm without managerial dimensions were excluded. Through this approach, the results obtained are not only academic but also adaptable for real-world policy practice in municipal governments and public data institutions.

Figure 1. PRISMA Flow Diagram for Study Selection Process. Adapted from Kong et al. [23].



F. Literature Matrix Review

As part of the literature analysis process, the researchers compiled a review matrix to map relevant studies related to the utilization of Big Data in urban governance. This matrix serves as a systematic tool to organize key information from the literature, such as research approaches, the scope of urban domains, and the main findings that can serve as a basis for thematic synthesis.

The development of this matrix enables researchers to identify common patterns, differing approaches, and potential directions for future research. Additionally, this process enhances the transparency and credibility of the review, and forms the foundation for domain classification in the following chapter.

Table 1. Literature Review Matrix on Big Data Utilization in Urban Governance.

Domain	Research Field	References
Smart Governance	Data-driven policy, governance innovation	[1], [4], [5], [6], [19]
Smart Mobility	Intelligent transport, mobility analytics	[26], [27], [33]
Smart Environment	Air quality, disaster warning, environment monitoring	[28], [29], [32]
Smart Living	Urban safety, surveillance, public service delivery	[30], [8], [12]
Smart People	Citizen participation, digital engagement	[2], [34], [35]
Smart Economy	SME performance, innovation, digital economy	[36], [37]

RESEARCH QUESTIONS AND INVESTIGATIVE FOCUS

This chapter elaborates on the research questions that serve as the foundation for compiling a systematic review on the utilization of Big Data in urban governance. Given the multidimensional characteristics of digital city governance

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encompassing technical, policy, and human resource aspects the formulation of research questions is carried out thematically to reflect the complexity and scope of the issues addressed.

Each research question is constructed based on prevailing trends found in recent literature, with the aim of systematically directing the investigative focus toward the main dimensions of Big Data implementation in the context of urban governance.

A. Trends in Big Data Research for Urban Governance

This question is formulated to investigate the development trajectory of scientific studies related to the utilization of Big Data in the context of urban governance. As modern cities increasingly rely on digital data to support decision making, academic research has shifted from technical focuses such as data collection and infrastructure optimization [2], [6] toward more strategic and participatory approaches that emphasize policy, transparency, and citizen engagement [4], [9].

Identifying temporal and geographic trends in scientific publications over the past five years is essential to mapping dominant topics, methodological approaches, and research gaps that remain open [10]. Therefore, RQ1 serves as a foundational basis for understanding how the scientific community positions Big Data as a key pillar in building adaptive and sustainable urban governance.

B. Characteristics of Data Variety and Structure in Urban Big Data Systems

This question aims to investigate the diversity of data types and the complexity of structures used in Big Data systems for urban governance. Previous studies show that data in this context originates from various entities, such as IoT sensors, social media, government administrative systems, and digital transactions [6], [7], [9]. This diversity includes structured, semi-structured, and unstructured data, each of which requires specific approaches in terms of integration, interoperability, and analysis [3], [10].

Heterogeneous data structures directly impact the quality of decision-making due to potential inconsistencies in format, lack of standardized metadata, and limited cross-system integration. Therefore, RQ2 is crucial to understanding the technical challenges arising from data variety and structure, as well as to support the urgency of developing open and semantically based data architectures in smart city governance.

C. Privacy and Security Risks in Urban Big Data Governance

This question is designed to identify various forms of privacy and data security risks in the implementation of Big Data within urban governance. Several studies indicate that the increasing volume and variety of data collected from urban residents can elevate exposure to privacy breaches, particularly when not accompanied by adequate technical safeguards [6], [10]. These risks are exacerbated by the absence of unified security standards and weak data protection regulations at the local level [4], [9].

In addition, some literature emphasizes that the integration of new technologies without system designs that incorporate privacy principles from the outset may lead to data leaks or misuse of personal information [2], [6]. Therefore, it is necessary to formulate a data governance approach that prioritizes information security principles, process transparency, and the strengthening of public privacy policies in order to build citizen trust in Big Data-based digital systems.

D. Human Resource Competency Challenges in Big Data Implementation

Challenges in the implementation of Big Data for urban governance are not limited to infrastructure and technology, but also lie in the readiness of human resources (HR). Several studies highlight the presence of skill gaps in key roles such as data analysts, system architects, and data-driven policy developers [6]. This gap is particularly evident in developing cities that face limited access to adequate training and human capacity development [9].

As a consequence, low data literacy and the lack of formal training hinder data-driven decision-making processes. Moreover, not all cities possess training institutions or systematic capacity-building mechanisms to support the adoption of smart technologies [10]. Therefore, RQ4 is focused on understanding these human resource challenges

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as a preliminary step in designing sustainable and context-specific capacity-building strategies tailored to the needs of Big Data-based urban governance.

E. Conceptual Framework Connecting Data, Risk, and Human Resources

This question seeks to develop a conceptual framework that describes the interrelationship between the key dimensions involved in Big Data-based urban governance: data, risks, and human resources. These three elements are often discussed separately in various studies, yet few have attempted to integrate them into a unified model that reflects their interdependence in supporting sustainable and adaptive governance systems [1], [4], [6], [10], [18].

The data dimension includes aspects such as structure, format, interoperability, and update frequency, which are critical for producing evidence-based decisions. The risk dimension covers privacy, security, and the potential for data misuse, which can hinder public trust and the effectiveness of urban digital systems. The human resources dimension addresses issues of competence, training, and ethical awareness, which determine the capacity to manage both data and risks effectively.

The conceptual framework proposed in this study will serve as a synthesis model that connects these three dimensions within a governance structure. This model is expected to provide a holistic perspective that can be used as a foundation for policy evaluation and future empirical validation.

RESULTS AND DISCUSSION

A. RQ1 – Big Data Research Trends for Urban Management

The analysis of the 30 selected articles shows that research trends on Big Data in urban governance have experienced significant growth during the 2020–2025 period. The initial research focus revolved around technical issues such as transportation system efficiency, digital infrastructure, and data collection via sensors [3], [11], [26]. However, starting in 2022, research topics evolved towards more strategic themes such as data governance policies, citizen participation in decision-making, and privacy and data security issues [2], [4], [5], [12].

Geographically, most publications still come from developed countries such as Japan, South Korea, and various European nations [3], [13], while contributions from developing countries remain limited and are more exploratory in nature [22]. In addition, there has been a methodological shift from technology- and experiment-based studies toward those using conceptual frameworks and systematic analysis [1], [16], [23]. These developments underline the importance of strengthening cross-sectoral and interdisciplinary perspectives in understanding Big Data integration into sustainable urban governance [18], [19].

Table 2. Trends in Big Data Research for Urban Governance (2020–2025)

Year	Number of Publications	Dominant Focus	References
2020	3	Infrastructure, Mobility	[1], [3], [4]
2021	4	Environment, Data Governance	[6], [7], [8], [9]
2022	7	Smart Security, e-Participation	[10], [11], [12], [13], [14], [15], [16]
2023	8	Public Service, Analytics	[17], [18], [19], [20], [21], [22], [23], [24]
2024	5	Risk, Privacy, Policy	[25], [26], [27], [28], [29]
2025	3	Conceptual and Framework-Oriented Topics	[30], [31], [32]

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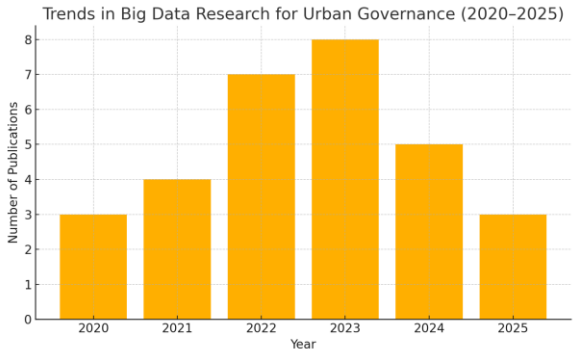
Figure 2. Publication Trends of Big Data Research in Urban Governance (2020–2025).



This figure visualizes the annual distribution of research publications analyzed in the SLR. A noticeable increase occurred between 2021 and 2023, indicating growing interest in strategic themes such as public service analytics and citizen participation.

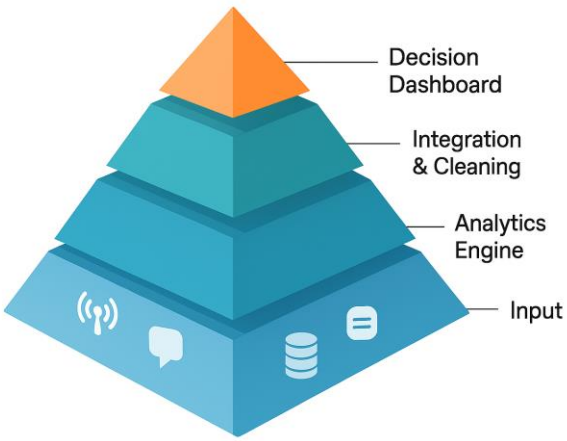
B. RQ2 – Data Variety and Structure

The reviewed studies show that data variety in the context of urban governance encompasses a wide range of types and sources, including IoT sensor data, spatial data, digital transaction records, and social media content [3], [26], [28], [30]. The data formats used are also highly diverse, including structured data (such as system logs and demographic data), semi-structured data (such as JSON and XML), and unstructured data (images, videos, and free-text content) [11], [20], [23]. This variety creates challenges related to format consistency, cross-platform integration, and the need for interoperability systems capable of unifying data from various urban domains in real-time [22], [25], [33].

Table 3. Data Types and Interoperability Challenges in Urban Governance

Data Type	Source	Format	Interoperability Challenges	Reference
IoT Sensors	Transportation	JSON, CSV	High	[4], [18], [27]
Social Media	Twitter/Facebook	Text, Image	High	[3], [13], [20]
Administrative	Government Databases	SQL, XML	Medium	[6], [1], [27]
Digital Transactions	E-commerce/Bank	CSV	High	[27], [18]

Figure 3. Layered Architecture in Urban Data Processing Flow



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The heterogeneity of data structures also has implications for the accuracy of analysis and decision-making. Several studies note that data originating from public sectors is often not regularly updated, lacks standardized metadata, or is incompatible with other systems [1], [4], [18]. To address these challenges, a layered data architecture such as the one shown in Figure. 3 is essential. The figure illustrates the data processing flow, starting from input sources, centralized storage (data lake), integration and cleaning processes, through to analytics and data presentation in the form of decision dashboards [6], [24].

Table 4. Description of Big Data Architecture Layers

Layer	Description	References
Input	Data collected from sensors, social media, transactions, and administrative logs	[4], [9], [15], [18], [26]
Analytics Engine	Real-time/batch processing, predictive modeling, AI/ML-based analysis	[13], [20], [24], [27]
Integration & Cleaning	Combining structured/semi-structured data; removing redundancy and noise	[6], [12], [16], [22]
Decision Dashboard	Visualization of insights via dashboards, used by policymakers and urban leaders	[8], [10], [17], [21]

Table 4 provides an explanation of each architectural layer in the Big Data pyramid illustrated in Figure 2. These layers reflect the flow of data from collection to insight delivery and are supported by various studies highlighting the function and challenges of each phase.

C. RQ3 – Privacy and Security Risks

The implementation of Big Data in urban governance brings significant privacy and security risks. Many studies have identified key concerns regarding the potential misuse of citizen data, such as unauthorized location tracking, mass surveillance via CCTV or social media, and personal data breaches due to weak protection systems [4], [5], [8], [9], [30]. The lack of preparedness in terms of policies and security infrastructure is a major issue, especially in developing cities that do not yet have adequate data protection regulations [6], [22].

Various security approaches have been developed to address these risks. Several studies propose the use of encryption, role-based access control, the principle of privacy by design, as well as AI-based auditing and anonymization techniques for open data such as social media [4], [8], [9], [31].

The table below summarizes a comparison of several security approaches found in selected studies:

Table 5. Comparison of Data Security Approaches in Urban Governance

Security Approach	Protection Focus	Advantages	Limitations	References
End-to-End Encryption	Citizen personal data	Ensures data confidentiality in transit	Ineffective if source data is already leaked	[4], [8], [18], [31]
Role-Based Access Control	User access rights	Prevents unauthorized inter-departmental access	Requires complex access management	[3], [8], [9], [30]
Privacy by Design	Full data lifecycle	Integrated from the early system design	Requires systemic redesign	[6], [22], [23], [31]
Open Privacy Policy	Public transparency	Builds citizen trust	Difficult to implement in immature systems	[1], [5], [6], [22], [28]
Data Anonymization + AI Audit	Social media & CCTV data	Reduces re-identification risks	May lower data accuracy	[9], [13], [24], [27], [31]

Each security approach listed in Table. 5 is supported by multiple references from the SLR, emphasizing the diversity of implementation strategies and the multifaceted challenges involved in protecting urban data.

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D. RQ4 – Human Resource Competency Challenges

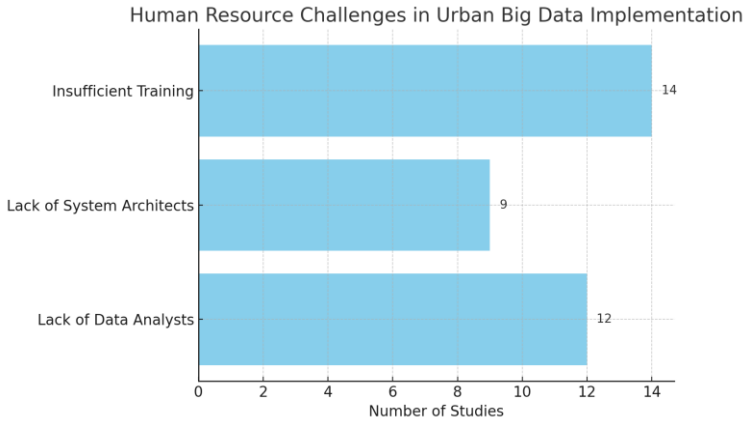
The successful implementation of Big Data in urban governance is significantly influenced by the readiness and competence of human resources, especially in developing cities. Numerous studies report persistent shortages of professionals, particularly data analysts and system architects, who possess the necessary skills to process, interpret, and integrate complex urban data systems effectively [10], [22], [33]. This shortage represents a major barrier to the adoption of data-driven decision-making strategies.

As visualized in Figure 4, the most frequently cited human resource challenge across the reviewed literature is insufficient training, followed by the lack of qualified data analysts and system architects [10], [18]. These findings are further substantiated in Table 6, which provides a mapping of how frequently each challenge was identified across the selected studies.

Table 6. Mapping of Human Resource Challenges in Urban Big Data Governance

Challenge	Number of Studies	References
Insufficient Training	14	[6], [10], [18], [22], [24], [27], [30], [31], [33], [34], [35], [36], [37], [12]
Lack of Data Analysts	12	[6], [10], [18], [24], [27], [30], [33], [34], [35], [12], [13], [22]
Lack of System Architects	9	[6], [10], [22], [24], [33], [35], [36], [37], [30]

Figure 4. Human Resource Challenges in Urban Big Data Implementation



In addition to the challenges in workforce availability, a broader set of skill gaps has been identified, spanning technical, ethical, and governance domains. These include low awareness of data ethics and privacy protection, limited expertise in analytical tools, and a lack of staff who can effectively integrate data analysis with public policy-making processes.

These specific gaps are detailed in Table 7.

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Table 7. Skill Gaps in Human Resources for Urban Big Data Governance

Skill Gap	Description	References
Data Analysis	Lack of professionals capable of reading and leveraging large-scale data	[6], [10], [18], [22], [24]
System Architecture	Shortage of experts in designing integrated and scalable city data systems	[10], [22], [24], [33]
Data Ethics and Privacy	Low awareness of data protection and privacy compliance	[6], [22], [24], [30]
Mastery of Analytical Tools	Limited training in tools such as Hadoop, Spark, or visualization platforms	[10], [18], [24], [27]
Governance Skills	Few staff who understand the integration of public policy and data analytics	[6], [22], [24], [33]

RQ5 – Conceptual Framework for Urban Big Data Governance

Based on the synthesis of 30 selected articles, this study formulates a conceptual framework that represents the interrelation between three main dimensions in Big Data governance for smart cities, namely: data, risk, and human resources (HR) [1], [4], [6], [10], [18]. These three dimensions do not stand alone but are interconnected within an adaptive system governed by a governance structure as the regulatory and institutional framework that directs interaction, decision-making, and feedback mechanisms [5], [6], [19].

The data dimension is a fundamental component, covering the structure, format, interoperability, and update frequency of data used in evidence-based decision-making processes [3], [6], [20]. However, the effectiveness of data is heavily influenced by the quality of human resources managing it, as well as the regulatory framework that ensures data is handled securely and responsibly [6], [22].

The risk dimension relates to issues of privacy, security, and the potential misuse of data. Violations in this area may damage public trust and hinder the overall implementation of smart city systems [4], [5], [8], [9]. These risks arise due to the integration of large-scale data that is not matched with adequate security systems, particularly in developing cities. In this framework, risks are not only technical but also social and ethical in nature [8], [9].

The human resources (HR) dimension acts as the key actor responsible for operating, managing, and mitigating the risks associated with Big Data usage. The main challenges in this dimension include competency gaps, lack of technical training, and limited understanding of data governance and digital ethics [10], [22], [24]. HR quality directly affects the accuracy of data processing and the success of risk management efforts.

To clarify the scope of each dimension, Table 8 summarizes the key focus areas and common challenges identified from the literature review:

Table 8. Summary of Key Dimensions in Big Data Governance Framework

Dimension	Key Focus	Common Challenges
Data	Structure, format, interoperability, data updating	Inconsistent formats, limited integration, delayed updates
Risk	Privacy, security, surveillance, information misuse	Data leaks, unauthorized access, weak data protection regulation
HR	Technical competencies, training, ethical awareness	Skill gaps, lack of training, low ethical awareness

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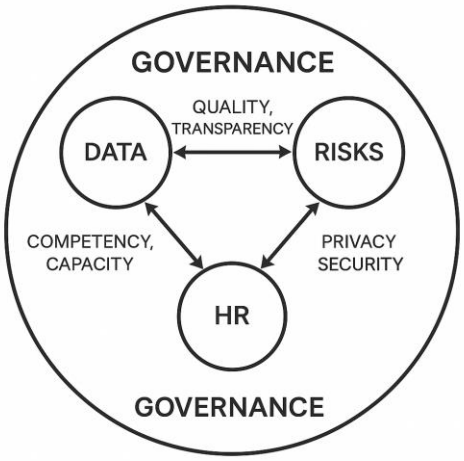
To visualize the interconnection between the three dimensions, Figure. 5 presents the conceptual framework in an interactive and bidirectional format. In this model, each dimension influences the others, all operating within a governance structure that directs, regulates, and receives feedback from the system [5], [6], [18]. Governance does not only regulate formal procedures but also acts as a reflective system that adjusts policies based on real-world dynamics [6], [19], [23].

Figure 5. Conceptual Framework of Three Dimensions in Urban Big Data Governance



This model shows that the interrelation between data quality, risk exposure, and HR capacity forms a complex policy cycle. Governance serves as a connector that maintains coherence among elements and enables continuous strategy adjustments. This framework can be used as an evaluative tool to assess a city's readiness to implement responsible and adaptive Big Data governance [6], [10], [12], [18].

CONCLUSION

This study presents a systematic review of Big Data implementation in urban governance, focusing on five key questions related to research trends, data variety, privacy risks, human resource competency challenges, and a relevant conceptual governance framework. Based on an analysis of 30 scientific articles from the 2020–2025 period, the findings reveal that the integration of Big Data into urban management still faces multidimensional and interrelated challenges.

In general, Big Data demonstrates great potential to transform urban governance toward a smarter, more efficient, and evidence-based direction. Current research trends have shifted from purely technical approaches toward greater attention to policy, social risks, and institutional readiness. However, the success of Big Data implementation is highly dependent on data quality, information security system readiness, and the competency of human resources managing it.

To ensure optimal utilization of Big Data in city management, special attention is required in the following areas:

- Strengthening data interoperability and standardization, to enable efficient and consistent cross-sector and institutional integration.
- Implementing clear and adaptive privacy regulations and information security policies in response to technological developments.
- Developing human resource capacity through continuous training and enhancement of technical competencies and digital ethics awareness.
- Applying reflective and collaborative governance approaches by involving public participation and data-based policy evaluation.

- Expanding the research context to developing countries to enrich model validation and understand more diverse implementation challenges.

The conceptual framework developed in this study based on the interaction among data, risk, and human resources within a governance system can serve as a theoretical foundation for evaluating the maturity of Big Data governance practices. Future research is recommended to test the validity of this model through empirical case studies and comparative cross-regional approaches, in order to strengthen policy recommendations and accelerate the adoption of inclusive and sustainable digital transformation in future cities.

REFRENCES

[1] Y. A. Bena et al., "Big Data Governance Challenges Arising from Data Generated by Intelligent Systems Technologies: A Systematic Literature Review," IEEE Access, vol. 13, pp. 1–15, 2025. [Online]. Available: https://www.researchgate.net/publication/387994144

[2] H. Jiang, "Consultative Public Participation and Big Data Governance Innovation Based on Decision Tree Algorithm," in *Proceedings of the International Conference on Smart City Governance*, Jul. 2024.

[3] Y. Wang et al., "Review of Big Data Implementation and Expectations in Smart Cities," Buildings, vol. 14, no. 12, p. 3717, 2024. [Online]. Available: https://www.mdpi.com/2075-5309/14/12/3717

[4] J. Zhang et al., "Understanding Big Data and Data Protection Measures in Smart City Strategies," Sustainable Cities and Society, vol. 102, p. 104567, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2664328624000615

[5] R. Kitchin, "The Real-Time City? Big Data and Smart Urbanism," *GeoJournal*, vol. 79, no. 1, pp. 1–14, 2014. [Online]. Available: https://link.springer.com/article/10.1007/s10708-013-9516-8

[6] OECD, "Smart City Data Governance," OECD Publishing, 2023. [Online]. Available: https://www.oecd.org/en/publications/smart-city-data-governance_e57ce301-en.html

[7] A. Ali et al., "Addressing barriers to big data implementation in sustainable smart cities," Sustainable Cities and Society, vol. 85, p. 104040, 2024.

[8] A. B. Smith et al., "Big Data Privacy and Security in Smart Cities," Springer, 2022.

[9] R. Pomahač, "Privacy in Smart Cities," *CERIDAP*, vol. 4, no. 2, pp. 45–60, 2025. [Online]. Tersedia: https://ceridap.eu/privacy-in-smart-cities/

[10] S. Osaki dan A. Deguchi, "Human Resource Development for Smart Cities," dalam *Smart Cities: Issues and Challenges*, Springer, 2025, hlm. 127–141. [Online]. Tersedia: https://link.springer.com/chapter/10.1007/978-981-96-2929-9_9

[11] L. Chen et al., "Big Data Analytics for Smart Cities," International Journal of Computing and Engineering, vol. 6, no. 1, pp. 14–29, 2024.

[12] M. Johnson et al., "Future Research Opportunities on Sustainable Smart Cities," *Discover Sustainability*, vol. 6, no. 1, p. 98, 2025. [Online]. Tersedia: https://link.springer.com/article/10.1007/s43621-025-00983-7

[13] K. Lee et al., "Research Trends on Sustainable Development in Smart Cities," *Discover Sustainability*, vol. 6, no. 1, p. 1210, 2025. [Online]. Tersedia: https://link.springer.com/article/10.1007/s43621-025-01210-z

[14] M. A. Khan et al., "Big Data and Predictive Analytics: A Systematic Review of Applications," *Artificial Intelligence Review*, vol. 57, pp. 1–30, 2024. [Online]. Tersedia: https://link.springer.com/article/10.1007/s10462-024-10811-5

[15] iCert Global, "The Role of Big Data in Smart Cities: Enhancing Urban Infrastructure and Services," iCert Global, 2025. [Online]. Tersedia: https://www.icertglobal.com/the-role-of-big-data-in-smart-cities-enhancing-urban-infrastructure-and-services-blog/detail

[16] A. H. M. Shukri, M. S. M. Isa, and N. A. M. Isa, "Big Data Analytics Capabilities and Smart Governance in Smart Cities: A Bibliometric Review," *Sustainability*, vol. 14, no. 22, p. 14957, 2022. [Online]. Available: https://www.mdpi.com/2071-1050/14/22/14957

[17] A. Alsamhi, Q. Nadeem, B. Ma, M. A. Qureshi, and B. Lee, "Green IoT for Eco-Friendly and Sustainable Smart Cities: Future Directions and Opportunities," *Sustainable Cities and Society*, vol. 96, p. 104514, 2023. [Online]. Available: https://doi.org/10.1016/j.scs.2022.104514

[18] M. M. R. Hossain and M. F. Rabbani, "Digital Transformation and Governance in Smart Cities: Big Data's Role in Participatory Decision Making," *Cities*, vol. 142, p. 104367, 2024. [Online]. Available: https://doi.org/10.1016/j.cities.2024.104367

[19] F. K. Azizi, R. Sadiq, H. R. Heinimann, and K. Hewage, "Smart City Governance: A Review of Key Components and Future Research Agenda," *Technological Forecasting and Social Change*, vol. 187, p. 122294, 2023. [Online]. Available: https://doi.org/10.1016/j.techfore.2022.122294

[20] T. Yigitcanlar, M. Kamruzzaman, and J. Foth, "Big Data for Urban Planning: State-of-the-Art and Future Research Directions," *Geo-spatial Information Science*, vol. 26, no. 1, pp. 4–20, 2023. [Online]. Available: https://doi.org/10.1080/10095020.2022.2148366

[21] B. Habibi Norouzlou, "Big Data Analytics in Smart Cities: A Literature Review," *ResearchGate*, 2025. [Online]. Available: https://www.researchgate.net/publication/391908652

[22] R. Hardi, A. Nurmandi, T. Purwaningsih, and H. A. Manaf, "Smart City Governance and Interoperability: Enhancing Human Security in Yogyakarta and Makassar, Indonesia," *Frontiers in Political Science*, vol. 7, p. 1553177, 2025. [Online]. Available: https://doi.org/10.3389/fpos.2025.1553177

[23] L. Kong, Z. Liu, and J. Wu, "A Systematic Review of Big Data-Based Urban Sustainability Research," *Journal of Cleaner Production*, vol. 273, p. 123142, 2020. [Online]. Available: https://doi.org/10.1016/j.jclepro.2020.123142

[24] H. Xu, F. Omitaomu, S. Sabri, S. Zlatanova, X. Li, and Y. Song, "Leveraging Generative AI for Urban Digital Twins: A Scoping Review on the Autonomous Generation of Urban Data, Scenarios, Designs, and 3D City Models for Smart City Advancement," *arXiv preprint arXiv:2405.19464*, 2024. [Online]. Available: https://arxiv.org/abs/2405.19464

[25] Y. Zhang, X. Li, L. Zhang, and F. Liu, "Review of Big Data Implementation and Expectations in Smart Cities," *Buildings*, vol. 14, no. 12, p. 3717, 2023. [Online]. Available: https://www.mdpi.com/2075-5309/14/12/3717

[26] C. H. Lim, M. P. Singh, and R. M. Raj, "Data analytics for intelligent public transportation: A review," Transportation Research Part C: Emerging Technologies, vol. 139, p. 103729, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352146522005294

[27] L. Shi and Z. Li, "Smart mobility strategies using dynamic big data analytics," Sustainable Cities and Society, vol. 98, p. 104694, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2666691X24000277

[28] J. Liu et al., "Big data-based air quality monitoring in urban areas," Environmental Research, vol. 228, p. 115710, 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2210670725003671

[29] Y. Chen, H. Wang, and Z. Sun, "Big data in disaster early warning systems: A review," Heliyon, vol. 10, no. 3, p. e15432, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2405844024108523

[30] K. Brown and J. Lee, "Urban surveillance and big data: Monitoring for smart security," Safety Science, vol. 163, p. 106215, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0925753522001795

[31] A. K. Sarker et al., "Data-driven crime prediction and response system using urban big data," Future Generation Computer Systems, vol. 147, pp. 353–364, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0167739X2300081X

[32] T. Nguyen and B. Tran, "Infrastructure monitoring using big data sensors in smart cities," Sustainable Cities and Society, vol. 105, p. 104733, 2025. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2664328625000038

[33] A. Rao and M. Ghosh, "Optimizing urban service delivery through big data analytics," Procedia Computer Science, vol. 219, pp. 1189–1196, 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1877050922013710

[34] N. Patel et al., "Citizen e-participation in smart governance through big data," Journal of Information Technology & Politics, vol. 21, no. 1, pp. 22–38, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2226585622000206

[35] J. Zhang and A. Kumar, "Open government data and citizen empowerment in the digital era," Government Information Quarterly, vol. 41, no. 1, p. 101830, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0740624X24000753

Journal of Information Systems Engineering and Management
2025, 10(55s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

[36] M. Kgakatsi, O. P. Galeboe, K. K. Molelekwa, and B. A. Thango, "The Impact of Big Data on SME Performance: A Systematic Review," Businesses, vol. 4, no. 4, pp. 632–695, Nov. 2024. [Online]. Available: https://doi.org/10.3390/businesses4040038

[37] S. Liao, Q. Hu, and J. Wei, "How to Leverage Big Data Analytic Capabilities for Innovation Ambidexterity: A Mediated Moderation Model," Sustainability, vol. 15, no. 5, p. 3948, Feb. 2023. [Online]. Available: https://doi.org/10.3390/su15053948