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AI Data Management Strategies in Tehran: A Gap Analysis Approach

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ABSTRACT

Artificial intelligence (AI) is rapidly emerging as a primary driving force in the transformation of cities. This technology, by offering innovative solutions in various areas including transportation, energy, security, and urban services, has the potential to improve citizens' quality of life and enhance urban sustainability. Tehran, with its growing population and increasing complexities, requires novel AI-based data management strategies. Effective data management is the key to improving urban services, reducing traffic congestion, increasing resource efficiency, and elevating citizens' quality of life. Given AI's high potential in processing vast volumes of urban data, this study aims to identify and examine the gaps through a gap analysis between the current state of data management in Tehran and successful strategies in leading cities, thereby exploring AI-driven innovative solutions. This exploratory research includes a comprehensive review of upstream urban development documents, master and detailed plans, municipal performance reports, and related legislative approvals on data management, along with a systematic search and analysis of scholarly articles published in reputable databases (such as Scopus and Web of Science) in the fields of smart city management, AI applications in cities, and successful case studies in other metropolitan areas. The study is grounded on the assumption that by identifying strengths and weaknesses in urban data management and utilizing successful global patterns, the potential of AI can be maximized to enhance the quality of life for Tehran's citizens. The findings reveal the existence of significant challenges in urban management, strategic planning, and implementation when compared to cities such as Copenhagen, Stockholm, and Prague. While Tehran demonstrates a relatively acceptable performance in drafting urban strategies, a qualitative reassessment and fundamental revision in the depth and content of these strategies—tailored to local needs and aligned with international standards—appears to be essential.

Keywords: *Smart City, Gap Analysis, Data Management, Data Roadmap*

1. Introduction

The emergence of artificial intelligence (AI) as a transformative force in urban management has accelerated discussions on the future of smart cities. Over the past decade, cities worldwide have increasingly integrated AI-driven solutions to optimize urban systems, from transportation and energy to governance and citizen services. AI's role in shaping anticipatory governance models and building sustainable urban futures highlights both its opportunities and complexities (Xu et al., 2024). By embedding intelligent systems into urban infrastructures, cities are shifting toward data-driven ecosystems capable of predicting, managing, and responding to multifaceted challenges. This shift represents not only a technological transition but also a socio-political and institutional transformation requiring robust frameworks for implementation, regulation, and ethical consideration (Cugurullo, 2024).

AI's growing influence in cities aligns with the broader ambition of achieving the Sustainable Development Goals (SDGs). In particular, sectors such as construction, energy management, and public administration have demonstrated AI's potential to support sustainability initiatives, efficiency gains, and improved service delivery (Regona et al., 2024). Yet, the integration of AI is not uniform across regions or governance systems; rather, it reflects diverse trajectories shaped by institutional capacities, regulatory contexts, and societal expectations. In this regard, AI urbanism has emerged as a field of inquiry that investigates how AI interacts with spatial, social, and political dimensions of the city (Palmini & Cugurullo, 2023).

The foundation of AI in urban contexts rests upon the convergence of big data analytics, cloud computing, and the Internet of Things (IoT). Early studies emphasized the capacity of big data to act as the "nervous system" of the smart city, allowing decision-makers to monitor patterns and forecast future developments (Hashem et al., 2016; Li et al., 2014). The deployment of cloud-based platforms for big data processing further enhanced scalability and integration across urban subsystems (Khan et al., 2015). These technologies laid the groundwork for AI adoption, enabling real-time analytics and predictive modeling to optimize services and resources.

Contemporary scholarship highlights how environmentally sustainable smart cities are increasingly dependent on the convergence of AI, IoT, and big data solutions. This integrated approach enhances the capacity of cities to reduce energy consumption, lower emissions, and manage natural resources more effectively (Bibri et al., 2023). The complexity of this integration requires coordinated governance mechanisms to ensure that technologies are not only interoperable but also aligned with long-term sustainability objectives (Allam et al., 2022).

One of the most critical domains where AI exerts influence is urban governance. Algorithmic governance, or the reliance on algorithms to structure decision-making processes, has attracted increasing attention in recent years (Issar & Aneesh, 2022). The phenomenon of "algocracy," as conceptualized in case studies such as predictive policing in Berlin, underscores both the efficiency gains and the democratic risks associated with algorithmic decision-making (Lorenz et al., 2021). Similarly, research on UK local authorities has demonstrated how AI is reshaping bureaucratic processes, resulting in the rise of "algorithmic bureaucracy" where automated systems play a central role in resource allocation and service provision (Vogl et al., 2020).

Comparative perspectives across Europe show that AI's role in public sector governance varies considerably, shaped by local contexts, capacities, and levels of institutional readiness (Van Noordt & Misuraca, 2022). In decentralized systems, such as Indonesia, the capacity of local governments has been found to directly influence the quality of service delivery, emphasizing the need for institutional strengthening to harness AI effectively (Setiawan et al., 2022). At the same time, the integration of AI into public services in Australia and Hong Kong reflects how citizen perceptions shape trust, legitimacy, and the acceptability of AI-driven governance (Yigitcanlar, Agdas, et al., 2023).

While the potential of AI is widely acknowledged, the adoption and diffusion of AI technologies in urban contexts face significant barriers. Systematic reviews reveal that although AI adoption in public administration is expanding, its diffusion remains constrained by issues such as lack of expertise, regulatory gaps, and organizational inertia (Madan & Ashok, 2023). Similarly, the integration of AI of Things (AIoT) in the public sector encounters obstacles ranging from technological interoperability to concerns about data security and citizen privacy (Ishengoma et al., 2022).

Despite these barriers, there are clear trajectories of growth. AI adoption in smart cities continues to accelerate, with applications spanning predictive maintenance, traffic optimization, energy management, and emergency response systems (Herath & Mittal, 2022). Reviews emphasize that these applications are not isolated technical interventions but part of broader institutional and societal changes, requiring new regulatory frameworks and ethical guidelines. The development of responsible AI in government contexts, for instance, illustrates efforts to

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balance innovation with legal and ethical safeguards (Brand, 2022).

Technological innovations underpinning AI in cities range from machine learning algorithms to digital twin models. Advances in machine learning have enabled predictive modeling for traffic, energy, and public safety, providing a paradigm shift from reactive to anticipatory governance (Dargan et al., 2020; Sarker, 2021). Digital twin technologies—virtual replicas of physical systems—represent another frontier in urban management, allowing for simulations that inform planning, crisis management, and infrastructural optimization (Fuller et al., 2020).

These technologies are not without challenges. The deployment of AI systems often raises questions about transparency, accountability, and inclusivity. The political economy of AI, particularly its alignment problem, underscores the socio-technical risks of embedding opaque systems into critical infrastructures (Cugurullo, 2024). The "obscure politics" of AI in urban contexts illustrates how technological systems are entangled with power relations, capital flows, and governance agendas. Scholarly work in AI urbanism has shown that these systems not only produce technical outcomes but also reshape urban form, social relations, and political structures (Cugurullo et al., 2023).

Effective data management forms the backbone of AI-driven cities. Internationally recognized frameworks, such as the DAMA-DMBOK, provide guidelines for handling data quality, governance, and interoperability (International Dama, 2017). Without robust data management, AI applications risk generating biased or inaccurate results that could misguide urban planning. Early contributions highlighted how data integration across municipal systems is necessary to overcome data silos and enable comprehensive analysis (Osman, 2019). Building on these insights, more recent work identifies the critical role of open data ecosystems in fostering transparency, innovation, and citizen participation (Lim et al., 2018).

For cities like Tehran, the challenge lies not only in collecting vast amounts of data but also in ensuring their reliability, security, and accessibility. Comparative studies across smart cities demonstrate how varying approaches to data governance lead to different outcomes in terms of efficiency, trust, and inclusivity (Allam & Dhunny, 2019). Thus, the creation of integrative platforms for data management is central to aligning AI infrastructures with broader governance objectives.

The concept of anticipatory governance has gained traction as cities seek to move from reactive to proactive management strategies. Evidence from China's "city brain" initiatives demonstrates how multi-scalar AI systems are deployed to anticipate traffic flows, public health risks, and environmental challenges (Xu et al., 2024). These approaches illustrate how AI is being leveraged not only to optimize immediate services but also to prepare for long-term uncertainties. AI-driven anticipatory governance also emphasizes resilience, sustainability, and adaptability, qualities that are increasingly indispensable in the face of global challenges such as climate change and rapid urbanization.

The role of AI in urban sustainability is further underlined by its alignment with SDGs. In the construction sector, AI applications have shown potential in reducing waste, optimizing material use, and enhancing safety, demonstrating AI's contribution to sustainable urbanization (Regona et al., 2024). Similarly, AI-driven environmental monitoring systems are being employed to track air quality, water consumption, and energy use, thereby supporting cities' efforts to reduce ecological footprints (Bibri et al., 2023).

The widespread integration of AI in cities also raises profound ethical, legal, and social questions. Concerns about surveillance, privacy, and bias underscore the need for comprehensive frameworks that ensure responsible AI deployment (Brand, 2022). The development of legal frameworks in contexts such as South Africa provides examples of how governments are attempting to regulate AI in ways that protect citizens while enabling innovation. Yet, these frameworks must contend with the global nature of AI technologies and the uneven distribution of technical capacities across cities (Allam et al., 2022).

Scholars have argued that AI governance cannot be divorced from broader questions of urban justice, democracy, and inclusion. The politics of AI systems—who designs them, who controls them, and who benefits from them—are integral to their societal impact (Cugurullo et al., 2023). As such, embedding principles of transparency, accountability, and fairness into AI design and deployment is critical for ensuring that smart cities do not exacerbate inequalities or reinforce existing power structures (Margareta et al., 2025; Pandian et al., 2025).

In summary, the integration of AI into smart cities is a multifaceted process that brings together technological innovation, governance transformation, and ethical deliberation. From big data analytics and digital twin simulations to anticipatory governance and AI urbanism, the literature reveals a rapidly evolving landscape where

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cities are experimenting with diverse models of AI adoption. While the potential benefits are immense—including improved efficiency, sustainability, and citizen well-being—numerous challenges remain, ranging from technical barriers and data management issues to ethical dilemmas and governance complexities.

This study contributes to the ongoing discourse by analyzing the role of AI data management strategies in Tehran through a gap analysis approach. By comparing Tehran's current practices with successful global models, the research seeks to identify both opportunities and constraints, ultimately proposing pathways for developing a sustainable, efficient, and citizen-centered AI urbanism in the Iranian context.

2. Methods and Materials

Given the rapid expansion of urbanization and its associated challenges (such as traffic, pollution, and urban services), the use of AI data management strategies can contribute to improving the quality of life in cities. This research investigates these strategies in the management of Tehran and analyzes their challenges and opportunities. Accordingly, this study is descriptive–analytical in nature, employing gap analysis to identify and examine the differences or "gaps" between the current state of a city or process and its desired or expected state. This method helps cities identify their weaknesses and plan to improve performance and achieve their goals. The gap analysis method is based on the assumption that there is a gap between the existing and desired conditions in a system, which must be identified and addressed.

To compare Tehran with cities such as Copenhagen, London, Singapore, Tokyo, Jakarta, Stockholm, Sweden, Germany, Czech Republic, Korea, Canada, the United States, and Taiwan, it should be noted that these cities are at a higher level of development than Tehran in various fields (transportation, data analytics, urban governance, economy, etc.). Gap analysis helps compare the level of progress in these cities with Tehran to identify Tehran's strengths and weaknesses in AI data management strategies. Moreover, these cities have successful or developing models of effective data management and AI applications across different domains. They also have better access to open data or information resources, allowing researchers to conduct more accurate analyses for comparison with Tehran. Ultimately, studying these cities helps identify Tehran's strengths and weaknesses in various aspects of AI data management and suggests strategies to improve weaknesses.

Regarding AI data management strategies in Tehran, gap analysis helps identify the gaps between the visionary goals and the current capabilities in this field. These gaps may appear in different domains such as data infrastructure, human resources, laws and regulations, or general data management strategies. The philosophy of this method is to direct efforts toward closing these gaps and creating a coordinated and effective approach for developing AI data management strategies in Tehran.

Stages of the Gap Analysis Method

Definition of the domain: The domain of AI data management strategies in Tehran was precisely defined. This includes identifying the objectives, tasks, and constraints of the project. Examples of these domains include traffic management, crisis prediction, optimization of urban services, and more.

Identifying the desired state: Considering global best practices and successful models in other cities and organizations, the ideal desired state of AI data management strategies in Tehran was defined. This includes specifying objectives and key performance indicators (KPIs) for each domain, such as how much data should be collected, which algorithms should be used, and what levels of transparency and accountability should be present in the system.

Identifying the current state: Through field research, review of documents and records, and interviews with experts and stakeholders, the current state of AI data management strategies in Tehran was evaluated. This includes identifying existing data sources, technical infrastructure, workforce skills, related laws and regulations, and existing challenges in each domain.

Identifying the gaps: By comparing the desired state with the current state, gaps were identified. These gaps may exist in any of the domains defined in the first stage. For example, gaps in the volume of available data, lack of data analysis skills, absence of clear data privacy regulations, or lack of coordination between different organizations.

Prioritizing the gaps: The identified gaps were prioritized based on their importance and impact on the project objectives. The prioritization criteria included the degree of impact on goals, cost of resolving the gap, time required for resolution, and level of impact on citizens.

Planning to fill the gaps: For each prioritized gap, operational and feasible solutions were identified and planned. This included determining resources, scheduling, and assigning responsibilities for each solution.

By using this framework, the gaps in AI data management strategies in Tehran can be systematically and methodically identified and addressed, thereby contributing to sustainable and effective development in this domain.

Table 1

Current Status of Selected Factors for Data Management Systems

Requirement	Description	Sources
Scalable and resilient data infrastructure	The growing volume and fluctuating nature of data streams require the development of resilient networks in smart city infrastructures. These networks must be able to manage growing data demands while maintaining stability amid fluctuations.	(Hashem et al., 2016; Khan et al., 2015)
Data management	Smart cities inherently generate large amounts of data from various sources. The next challenge lies in the effective extraction, processing, and integration of this data from multiple sources.	(Hashem et al., 2016; Khan et al., 2015; Li et al., 2014)
Data storage	Data storage is a significant challenge in smart city ecosystems and requires exploring various solutions. Although data storage can be considered a subset of data management, its critical importance warrants separate attention.	(Hashem et al., 2016; Li et al., 2014)
Data processing	Big data analytics is recognized as the main area of application for big data in smart city contexts. This domain includes real-time capabilities that are clearly visible in optimizing transportation networks.	(Hashem et al., 2016; Li et al., 2014)
Data protection	Collected and processed data may contain sensitive or private information, either fully or partially. Therefore, implementing strong security measures in all aspects of smart city systems is essential.	(Lim et al., 2018)

3. Findings and Results

3.1. Determining the Current State

Table 2 presents global smart city strategies, which also include the issue of data management. The following categories, focused on specific applications of data management, were identified: (1) transportation, (2) data analytics (including public data analytics), (3) urban governance (urban planning, local government projects, urban development, policymaking), (4) economy and business, (5) technological references (including IoT, real-time data, AI, machine learning), (6) other data management factors (including management, engines, platforms, etc.), and (7) other specific domains (data application areas mentioned for a single city only).

Table 2

Global Smart City Strategies

SCI 2023 Rank	City	Country	Strategy Format	Transportation	Data Analytics	Urban Governance	Economy & Business	Technological References	Other Data Management	Other Factors
4	Copenhagen	Denmark	Presentation	1	0	1	0	0	Waste Management	
6	London	United Kingdom	Text	1	1	0	0	0	x	
7	Singapore	Singapore	Text	0	1	0	0	0	x	
10	Stockholm	Sweden	Text	1	1	0	0	1	1	x
11	Hamburg	Germany	Text	0	1	1	0	1	0	x
13	Abu Dhabi	United Arab Emirates	Presentation	0	1	0	0	0	1	x
14	Prague	Czech Republic	Presentation	1	1	0	1	0	0	Tourism, Social Media, Energy
16	Seoul	Korea	Presentation	0	0	1	0	0	x	
19	Hong Kong	Hong Kong	Text	0	1	0	0	1	0	x

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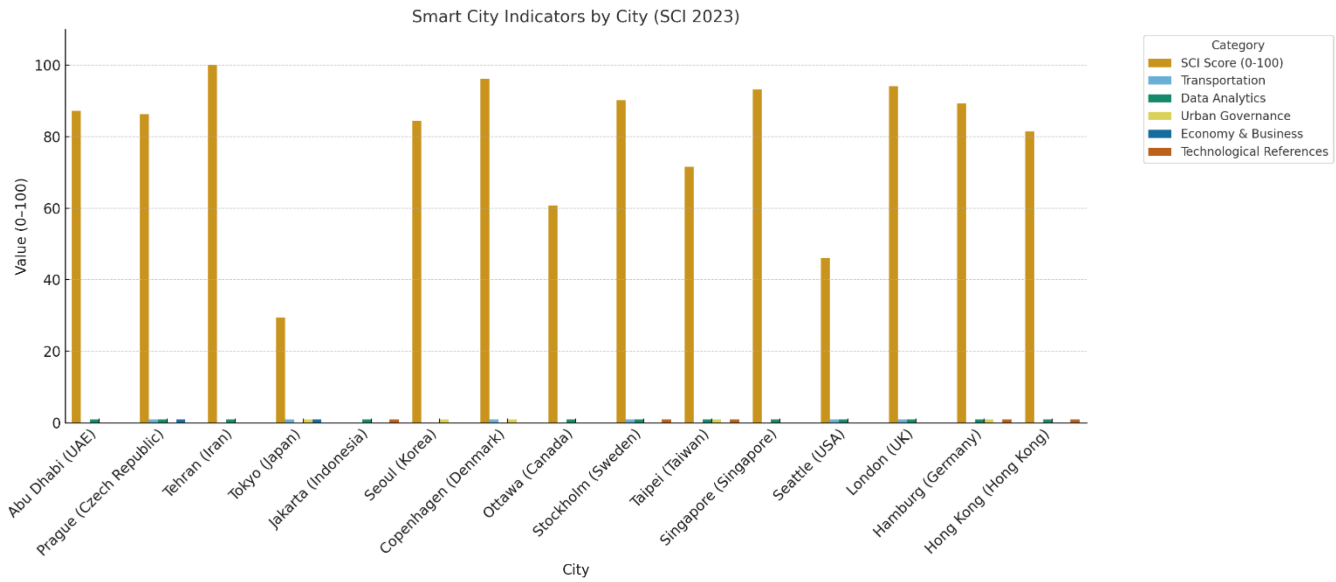
29	Taipei	Taiwan	Text	0	1	1	0	1	0	Water Supply Management
40	Ottawa	Canada	Text	0	1	0	0	0	x	
55	Seattle	United States	Text	1	1	0	0	0	1	x
72	Tokyo	Japan	Presentation	1	0	1	1	0	0	Research
102	Jakarta	Indonesia	Presentation	0	1	0	0	1	0	x
–	Tehran	Iran	Presentation	0	1	0	0	0	0	Waste Management

Figure 1

Evaluation of Tehran's Status Compared to Other Global Cities



To analyze the current state of Tehran using gap analysis based on the given table, it is first necessary to compare Tehran's position across each of the listed indicators and identify the gaps between the current state and the desired state (as shown in the table for other cities). In this analysis, Tehran can be compared with advanced cities with higher ranks. Many cities such as Copenhagen, Stockholm, and Prague use the presentation strategy format, which appears to reflect structured and clear programs and strategies. Tehran, in this regard, is relatively well-positioned compared with advanced cities like Copenhagen, London, and Stockholm, which use both text and presentation formats. This indicates that Tehran is active in presenting specific strategies for urban development. However, compared to some cities that apply more specialized methods for formulating strategies, there is still room for improvement.

Copenhagen and Tokyo benefit from advanced and organized transportation systems (ranked 1). Transportation in Tehran, due to infrastructural problems and congestion, is weaker. This indicator reflects the lack of focus and modern strategies in transportation infrastructure in Tehran. Many advanced cities such as Copenhagen and Stockholm are highly developed in sustainable public transportation. In Tehran, greater investment in infrastructure and intelligent transportation systems is necessary to reduce congestion, improve air quality, and enhance public transport services.

In many cities, data analytics is considered one of the key components, as seen in London and Stockholm, which rank 1 in this indicator. This highlights the use of big data in Tehran, which, compared with many other cities, still has room for progress. Tehran relatively uses this technology for decision-making and urban analysis, but compared to cities like London and Seoul, which employ more advanced big data utilization, Tehran must develop updated tools and stronger management structures to better exploit these data.

Some cities such as Hamburg and Taipei benefit from strong urban governance, while Tehran is weaker in this regard. In terms of governance, Tehran needs to improve governmental and municipal structures. This indicator is highly important in advanced cities like Singapore and Stockholm, where effective governance and management systems contribute to solving urban problems and achieving sustainable growth. Tehran must move toward strengthening transparency, public participation, and reducing corruption.

In cities such as Stockholm and Prague, the economic and business sector is more active and advanced. Tehran's economy, due to sanctions and restrictions, faces challenges compared to these cities. This indicator in Tehran requires significant reform and strengthening. Cities like Seoul and London have been much more successful in creating appropriate business infrastructure, attracting investors, and establishing an environment conducive to economic growth. Tehran must adopt programs to attract investment, develop the private sector, and improve the business environment to strengthen its urban economy.

While cities such as Stockholm and Singapore are pioneers in using modern urban technologies, Tehran needs fundamental progress in this field. This area includes employing innovative technologies for urban management, smart city development, and improving citizens' quality of life. For Tehran, strengthening information technology infrastructure and developing intelligent urban systems is a necessity.

In cities such as Jakarta and Prague, terms related to data and process optimization hold importance. Tehran can improve in this indicator by focusing on specific sectors such as water resource management, clean energy, and tourism, which are emphasized in other cities. Tehran has a particular focus on waste management, which is one of the most significant global urban challenges. This demonstrates Tehran's attention to environmental and waste-related issues compared to many other cities. However, in other areas, Tehran still requires improvement and innovation. By comparing Tehran's status with advanced cities across various indicators, it becomes clear that Tehran needs significant progress in domains such as transportation, data analytics, urban governance, and technology. The gaps are evident, and careful planning and investment in these areas can lead to Tehran's growth and development on a global scale.

3.2. Identifying the Desired State

In smart cities, the "desired state" refers to an ideal urban environment characterized by high efficiency, improved quality of life, and sustainable development. Data management plays a vital role in achieving this state. This management involves collecting, processing, storing, and sharing data from various sources to optimize urban functions. The main stages of data management include:

Data collection and acquisition: Data are collected from sensors, Internet of Things (IoT) devices, and mobile applications.

Data processing and analysis: Data are processed and analyzed to identify patterns and predict trends.

Data sharing: Sharing data among institutions is required for effective decision-making and improved services.

Data storage and infrastructure: Scalable storage infrastructure is necessary to manage large data volumes.

Data-driven decision-making: Data analytics are used to optimize services and support urban decision-making.

Security and privacy: Ensuring data security and protecting citizens' privacy are essential.

Data management helps cities improve public services, enhance citizens' well-being, and drive economic growth. Projects such as healthcare monitoring wristbands for the elderly and air quality monitoring systems are examples of such initiatives that contribute to improving quality of life in smart cities.

The desired state of Tehran (general vision) can be defined as follows: a smart, efficient, and sustainable city in which a safe, fast, and highly accessible public transportation system exists for all citizens; optimal management of water, energy, and the environment is implemented; urban services are high-quality, accessible, and responsive to citizens' needs; the economy creates job opportunities through technology and innovation; citizens have access to welfare, educational, and cultural services; and the collection, processing, and use of data are fundamental to improving performance and decision-making in all urban domains.

The analysis of Tehran's desired state reflects a long-term goal, for which attention to critical areas such as public transportation, resource management, the environment, and urban services is necessary. Problems such as traffic and air pollution can be addressed through the development of public transportation infrastructure, the use of advanced technologies such as tracking applications

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and autonomous vehicles, and energy optimization. Moreover, the use of renewable energy, particularly solar power, to supply electricity and improve air quality is essential. In this regard, collecting data on energy consumption, air quality, and traffic can improve urban management and crisis prediction. Creating appropriate public spaces, enhancing healthcare and educational services, and ensuring equal access to welfare services across the city are also among the goals of this vision. Using modern technologies in various industries and developing research infrastructures can contribute to economic growth and improved quality of life for citizens. Overall, achieving this vision requires the application of modern data and technologies for optimal urban management.

Table 3

Assessment of the Desired State

Indicator	Current State	Desired State	Gap
Air Quality (AQI)	153 (Polluted)	Less than 50 (Clean)	103 units
Metro line length	296 km	400–500 km	100–200 km
Number of metro stations	160 stations	250 stations	90 stations
Number of active wagons	1,514 wagons	2,500–3,000 wagons	986–1,486 wagons
Number of daily metro trips	More than 2.5 million	5–6 million trips	2.5 million trips
Number of clean air days	5 days per year	300 days per year	295 days
Number of unhealthy days for sensitive groups	71 days per year	Less than 10 days	61 days
Urban electricity consumption (GWh)	1,500	1,000	500
Percentage of renewable energy consumption	5%	20%	15%
Daily water consumption (liters per capita)	250 liters	150 liters	100 liters
Use of open data for urban app development	Very limited	Extensive and active (at least 50 functional apps developed based on open data)	Significant increase in use and app development
Accuracy of traffic prediction using AI (%)	70%	90%	20% improvement
Percentage reduction in response time to reported urban problems using AI	10%	50%	40% reduction
Use of AI in energy management of government buildings	Limited (only in a few buildings)	Extensive (in all government buildings)	Increased use and coverage
Percentage reduction in air pollution using AI-based early warning systems	5%	20%	15% reduction
Average delay time on metro lines (minutes)	5 minutes	Less than 1 minute (using smart management systems)	4 minutes reduction
Citizen satisfaction with public transport services (via smart survey)	60%	85%	25% increase
Number of electric vehicles	50,000 vehicles	500,000 vehicles	450,000 vehicles
Quality of traffic management system (TMS)	Basic systems	AI-based systems	Systems must become fully intelligent
Number of EV charging stations	150 stations	1,000 stations	850 stations
Volume of daily data generated in the city	20 terabytes	200 terabytes	180 terabytes
Number of smart energy management systems	30% of smart grid	100% of smart grid	70%
Public transportation usage	20%	50%	30%
High-speed internet coverage in Tehran	60% of areas	100% of areas	40%

3.3. Identification of Gaps (Gaps)

In the gap analysis for Tehran in the domain of smart-city data management, multiple challenges can be identified that impede the effective implementation and utilization of these data. Especially in cities such as Tehran, which are developing and expanding urban technologies, these challenges are clearly observable.

Insufficient financial resources: One of the main problems in Tehran—and many other large cities—is the lack of budget for investment in information-technology infrastructure and data collection. This problem is particularly evident in long-term projects such as building smart sensor networks and big-data processing systems. If Tehran intends to enter the era of smart cities properly, it must allocate financial resources specifically for intelligent infrastructure projects.

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Absence of sustainable business models: For the sustainable development of smart cities, business models are needed that not only cover the costs of IT projects but also support their growth and continuity. In Tehran, there are substantial challenges in finding appropriate business models to finance smart-city projects. Given economic constraints, it is essential to employ private-sector–based models and establish public–private collaborations to secure financial resources.

Data silos: One of the principal barriers in Tehran is the prevalence of data silos. Many governmental organizations and agencies store their data separately, and access to these data for joint analysis and decision-making is difficult. This lack of data integration can reduce the efficiency and effectiveness of smart-city projects. There is a clear need to develop integrated platforms for collecting and sharing data across municipal departments and government bodies.

Cybersecurity risks: With the increasing use of digital technologies in smart cities, cybersecurity threats have also intensified. In Tehran, cyberattacks and data breaches can create major public-security problems. Especially where urban systems are connected to the internet, protecting data and securing infrastructure are essential. Greater effort is also required to train and strengthen cybersecurity teams and to update software and protective systems.

Privacy concerns: Smart cities typically collect large volumes of personal data such as geolocation, daily behaviors, and other sensitive citizen information. In Tehran, concerns related to privacy and the protection of personal data must be prioritized. It is critically important to formulate and enforce clear and precise regulations regarding the collection and use of such data to safeguard citizens' privacy.

Interoperability challenges: In Tehran, as in many other cities, numerous data systems rely on different formats, creating problems for communication and data integration. To solve this problem, specific standards for data formats and communication protocols should be defined to enable information exchange among different entities.

Shortage of skilled professionals: In Tehran, the shortage of skilled human resources in data, digital technologies, and big-data analytics is a major challenge. This talent gap can diminish the quality of decision-making and the development of smart projects. Education and recruitment of specialists, the creation of tailored training programs to develop smart-city skills, and collaboration with universities and educational institutions can help address this issue.

Data quality and accuracy: Effective use of data in urban decision-making requires confidence in high data quality and accuracy. In Tehran, some data may be collected incompletely or inaccurately, which can lead to faulty analyses and misguided decisions. Establishing rigorous data-collection processes, employing new technologies such as machine learning to correct incomplete data, and creating oversight mechanisms to assess data quality can mitigate this problem. Ultimately, to resolve these gaps and challenges, Tehran needs a comprehensive strategy and cooperation among government, the private sector, and civil society to collect, analyze, and apply data effectively to improve citizens' quality of life.

3.4. *Proposed Plans to Bridge the Gaps (Solutions to Bridge the Gaps)*

Given the gap analysis in the previous section, the following proposals are presented to bridge these gaps.

Addressing insufficient financial resources:

a) Establish an urban investment fund: Create a dedicated investment fund for smart-city projects with participation from the municipality, the private sector, and foreign investors. Mechanism: attract capital through issuing participation bonds, equity stakes, and profit-sharing. Advantages: establish a stable and reliable financial source, attract foreign and domestic investment, and ensure professional capital management.

b) Public–private partnerships (PPP): Delegate smart-city projects to private companies under PPP contracts. Mechanism: private companies finance, design, build, and operate the projects and, in return, receive a portion of revenue or profit. Advantages: reduce the municipality's financial burden, transfer knowledge and technology domestically, and create jobs.

c) Cost optimization: Description: review and reduce the municipality's operating and administrative costs and allocate part of these savings to smart-city projects. Mechanism: use modern technologies (such as automation and e-services) to reduce costs and improve productivity. Advantages: optimal use of existing resources, increased efficiency and effectiveness, and reduced corruption and rent-seeking.

Creating sustainable business models:

a) Establish an urban data marketplace: Create an online platform for buying and selling urban data (with strict respect for citizens' privacy). Mechanism: private firms, public organizations, and researchers can purchase needed datasets from this platform. Advantages: generate a

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sustainable revenue stream for the municipality, incentivize the collection and production of high-quality data, and facilitate public access to data.

b) Provide data-driven services: The municipality can use its data to offer new, innovative services to citizens and charge fees in return. Mechanism: provide consulting, data analytics, forecasting, and reporting services to companies and organizations. Advantages: create new revenue, increase citizen satisfaction, and improve service quality.

c) Encourage innovation: Organize innovation competitions and events centered on urban data and support the best ideas. Mechanism: offer cash prizes, facilities, and workspace to top teams. Advantages: attract top talent, generate innovative and practical ideas, and develop the urban innovation ecosystem.

Achieving data integration:

a) Establish a municipal data center: Create a centralized data center for storing, processing, and managing urban data. Mechanism: collect data from diverse sources, clean and standardize datasets, and build a unified system for data access. Advantages: faster and easier access to data, more accurate analyses, and data-driven decision-making.

b) Adopt data standards: Formulate and enforce data standards for all urban organizations and entities. Use standardized data formats, create a shared glossary, and define data-exchange protocols. Advantages: facilitate inter-organizational data exchange, reduce errors and inconsistencies, and improve data quality.

c) Create a data-exchange platform: Build an online platform for data exchange among urban organizations and entities. Mechanism: organizations can share their datasets on the platform and use data from others. Advantages: increase collaboration and synergy, prevent data duplication, and create added value from data.

Strengthening cybersecurity and privacy:

a) Establish a municipal cybersecurity center: Create a specialized center to monitor, prevent, and respond to cyber threats in the city. Mechanism: deploy advanced technologies to detect cyberattacks, train staff on cybersecurity, and establish a rapid incident-response system. Advantages: enhance the security of data and urban infrastructure, reduce losses from cyberattacks, and increase citizen trust.

b) Develop privacy laws and regulations: Formulate and enforce comprehensive regulations to protect citizens' privacy in data collection, use, and dissemination. Mechanism: establish a supervisory authority to enforce privacy laws, educate citizens about their rights, and provide tools for controlling personal data. Advantages: safeguard citizens' rights, increase public trust in the municipality, and prevent data misuse.

c) Use privacy-enhancing technologies (PETs): Employ technologies such as encryption, anonymization, and synthetic data to protect privacy in data analysis and use. Mechanism: apply advanced algorithms to transform data so that personally identifiable information is not disclosed. Advantages: enable data use for analysis and decision-making without compromising citizens' privacy.

Developing a specialized workforce:

a) Create specialized training centers: Establish training centers to develop experts in data management, data analytics, and smart-system development. Mechanism: offer short-term and long-term courses, hold workshops and seminars, and invite leading scholars and experts. Advantages: cultivate a skilled workforce, strengthen the municipality's capacity to implement smart-city projects, and create new job opportunities.

b) Collaborate with universities and research centers: Build close ties with universities and research institutes to leverage their scientific and research capacity. Mechanism: define joint research projects, support student theses, and run internship programs. Advantages: tap academic knowledge and expertise, solve urban problems using scientific methods, and train specialized human resources.

c) Attract foreign specialists: Recruit foreign experts in data management and smart-city development to transfer knowledge and experience domestically. Mechanism: provide necessary facilities and incentives, create attractive job opportunities, and ensure suitable working environments. Advantages: transfer knowledge and technology, increase competitiveness, and accelerate the development of smart-city projects.

By implementing these plans, the existing gaps in Tehran's smart-city data management can be bridged, moving the city toward a smart, efficient, and sustainable future.

4. Discussion and Conclusion

The findings of this study highlight significant gaps in Tehran's smart city data management strategies when compared to global benchmarks. The analysis of SCI 2023 indicators showed that while Tehran has made some progress in establishing data analytics as a core component of urban planning, it remains substantially behind cities such as Copenhagen, Stockholm, and Tokyo in critical

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domains including transportation systems, urban governance structures, economic integration, and the deployment of advanced technological references. Tehran's primary emphasis has been on limited applications of data collection and waste management, which demonstrates a narrow scope of AI integration compared to the multi-dimensional approaches taken in global leading cities.

One of the most salient results is the disproportionate emphasis on data analytics without equivalent attention to interoperable infrastructure, robust governance frameworks, or advanced AI-enabled services. Cities like London and Singapore illustrate how embedding data analytics into governance structures creates a synergistic effect, improving both efficiency and accountability (Van Noordt & Misuraca, 2022; Yigitcanlar, Agdas, et al., 2023). Tehran's reliance on fragmented strategies, however, has contributed to persistent gaps in urban mobility, environmental monitoring, and citizen engagement.

The gap analysis further revealed that Tehran suffers from infrastructural bottlenecks, particularly in transportation. Cities like Copenhagen and Tokyo, which scored highly on SCI transportation metrics, demonstrate how AI-driven predictive models for traffic optimization, autonomous mobility platforms, and intelligent public transport systems can significantly reduce congestion and emissions (Fuller et al., 2020; Xu et al., 2024). Tehran's lack of equivalent infrastructure not only hinders progress toward sustainability but also diminishes quality of life. The study also observed weak performance in urban governance metrics, suggesting the absence of algorithmic and anticipatory governance structures that are becoming standard in advanced contexts (Issar & Aneesh, 2022; Lorenz et al., 2021).

In terms of economic and technological integration, Tehran shows limited evidence of AI-driven business ecosystems, digital twin technologies, or sustainable AI-enabled platforms. Comparatively, Stockholm and Singapore have developed strong economic linkages that leverage AI for entrepreneurship, innovation, and job creation (Bibri et al., 2023; Regona et al., 2024). This divergence reflects both infrastructural deficiencies and policy constraints in Tehran. Finally, the analysis identified emerging concerns related to cybersecurity, data privacy, and institutional capacity, all of which pose risks to sustainable AI adoption in the Iranian context (Brand, 2022; Herath & Mittal, 2022).

The results of this study align with a growing body of literature that emphasizes the uneven development of AI in smart cities worldwide. Previous research has consistently highlighted that AI integration is contingent upon institutional capacity, governance readiness, and societal acceptance (Madan & Ashok, 2023; Yigitcanlar, Li, et al., 2023). Tehran's struggles with fragmented governance and limited technical infrastructure echo findings from decentralized systems such as Indonesia, where local government capacity has been shown to directly influence the quality of urban service delivery (Setiawan et al., 2022). This suggests that strengthening institutional arrangements is as critical as technological adoption.

The observed reliance on data analytics without equivalent investments in transportation or governance frameworks mirrors global critiques of narrow technological adoption. Scholars have cautioned against "AI solutionism," where isolated technical interventions fail to address systemic urban challenges (Cugurullo et al., 2023). Tehran's current focus resembles this pattern: while analytics provide useful insights, the lack of accompanying investments in transportation, governance, and economic ecosystems limits transformative impact. This finding is consistent with previous warnings that the success of AI urbanism depends on its integration across multiple domains rather than its confinement to technical silos (Allam et al., 2022; Palmini & Cugurullo, 2023).

The study's findings on weak transportation infrastructure align with research demonstrating the transformative potential of AI in mobility systems. For instance, predictive models supported by machine learning can drastically reduce urban congestion (Dargan et al., 2020; Sarker, 2021). Digital twin technologies, when applied to transportation planning, enable simulation of future mobility patterns and proactive adjustments (Fuller et al., 2020). Tehran's lack of investment in these areas not only explains its weak SCI ranking but also reinforces concerns that without anticipatory governance frameworks, cities cannot effectively address systemic challenges (Xu et al., 2024).

Governance gaps identified in Tehran correspond with global literature on algorithmic and anticipatory governance. Scholars have shown that algorithmic decision-making can improve efficiency but also requires safeguards for transparency and accountability (Issar & Aneesh, 2022; Lorenz et al., 2021). Tehran's absence of such systems reflects the institutional inertia that other studies have also documented in emerging economies (Ishengoma et al., 2022). In contrast, European and East Asian models of anticipatory governance, particularly

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China's "city brain" projects, highlight how AI can be harnessed to prepare for long-term uncertainties such as environmental crises and demographic changes (Xu et al., 2024).

The weak economic and technological performance of Tehran also reflects global disparities in AI-driven urban ecosystems. Research shows that AI can significantly enhance sustainability by supporting smart construction, energy optimization, and business innovation (Bibri et al., 2023; Regona et al., 2024). Studies on AI adoption in local government contexts reveal that public perceptions and trust are pivotal in ensuring acceptance and effectiveness (Yigitcanlar, Agdas, et al., 2023). Tehran's limited engagement with citizens in co-designing AI services exacerbates its difficulties in scaling AI adoption.

Data management challenges in Tehran are consistent with literature that identifies data silos, quality issues, and privacy concerns as common obstacles (Hashem et al., 2016; Lim et al., 2018). The DAMA-DMBOK framework emphasizes standardized data governance as a prerequisite for effective AI integration (International Dama, 2017). Tehran's fragmented data management practices confirm these theoretical insights, demonstrating the urgent need for interoperable platforms and governance standards. Studies further highlight that open data ecosystems, such as those in Singapore, enhance innovation and citizen trust by providing transparency and accessibility (Allam & Dhunny, 2019; Osman, 2019).

The results also highlight Tehran's vulnerability to cybersecurity risks and privacy concerns. Scholars stress that the proliferation of AI technologies raises new challenges related to surveillance, bias, and algorithmic accountability (Brand, 2022; Cugurullo, 2024). Tehran's weak cybersecurity frameworks mirror concerns in other developing contexts where rapid technological adoption outpaces regulatory safeguards (Herath & Mittal, 2022). This finding aligns with comparative studies that underline the necessity of embedding privacy-enhancing technologies and legal frameworks into AI governance (Allam et al., 2022).

Collectively, the results and their alignment with prior research underscore three key insights: (1) AI adoption in cities is not merely technical but institutional and socio-political; (2) Tehran's narrow adoption of data analytics reflects global critiques of fragmented AI strategies; and (3) addressing data governance, institutional capacity, and citizen engagement is essential for achieving sustainable AI urbanism.

Despite offering significant insights, this study is not without limitations. First, the analysis is constrained by the availability and reliability of secondary data sources, including SCI rankings and municipal reports. Tehran's transparency in publishing official datasets remains limited, which may affect the accuracy of comparative analysis. Second, the study employed a gap analysis framework that, while useful for identifying differences between current and desired states, does not fully capture the complex causal mechanisms driving those gaps. Third, the study's reliance on cross-city comparisons means that contextual differences—such as cultural norms, governance structures, and economic conditions—may not be fully accounted for. Finally, the study is geographically limited to Tehran and does not include comparative insights from other Iranian cities, potentially narrowing the generalizability of the findings.

Future research could extend this study by employing primary data collection methods, such as surveys and interviews with policymakers, experts, and citizens, to provide richer insights into perceptions and readiness for AI integration. Longitudinal research could also help track how Tehran's AI strategies evolve over time, particularly in response to economic shifts, policy reforms, or international collaborations. Comparative studies between Tehran and other cities in the Global South could illuminate shared challenges and best practices, while mixed-method approaches could provide deeper insights into the socio-political dimensions of AI urbanism. Additionally, future research should explore the ethical and cultural implications of AI adoption in Middle Eastern contexts, which remain underrepresented in global smart city literature.

For practitioners and policymakers, this study highlights the urgent need to adopt integrative strategies for AI urbanism in Tehran. Investments in smart transportation systems, anticipatory governance frameworks, and digital twin technologies could close critical gaps. Establishing robust data governance mechanisms, aligned with international standards, is essential for ensuring interoperability, data quality, and citizen trust. Policymakers should also prioritize cybersecurity and privacy protections to safeguard against emerging risks. Most importantly, fostering collaboration between government, private sector, and civil society will be crucial for creating inclusive and sustainable AI-enabled urban futures.

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Authors' Contributions

All authors equally contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

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Declaration of Interest

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The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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