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# APPLYING ANALYTIC HIERARCHY PROCESS METHODOLOGY IN DETERMINING CRITICAL CHALLENGES OF URBAN BIG DATA IN A DEVELOPING CITY: THE CASE OF TEHRAN

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## *ABSTRACT*

*Although urban big data holds significant potential for transforming the way cities are managed, harnessing this potential requires overcoming major challenges, particularly in developing countries like Iran. Obstacles like policy gaps, legal barriers, limited resources for data management and infrastructure or even the low level of community engagement and the lack of technological capabilities could backward the development of becoming a real data-driven smart city. This study aims to address the understanding of this issue, by identifying and evaluating urban big data challenges critically, and to formulate policy-related support for governmental bodies in a country considered to be a developing information society. After thorough analysis of academic publications we identified 32 urban big data challenges in Iran, which then were systematically evaluated and ranked by Analytic Hierarchy Process (AHP) methodology based on expert surveys. Outcomes confirmed that although social, educational and financial challenges have been perceived, the most important ones are of political and governmental origin.*
Keywords: AHP methodology, big data, urban development, Iran
JEL codes: R58, O33

## INTRODUCTION

The integration of big data in urban smart city systems brings both opportunities and challenges, having a significant impact on technological advancement and application strategy innovation. A smart city environment is meticulously structured and is under constant surveillance through the pervasive integration of information and communication technologies (ICT) (*Neirotti et al.,* 2014). Over the last two decades, the notion of smart city has progressively gained eminence within scholarly discourse and international policy frameworks (*Albino et al.,* 2015). This growing recognition can be attributed to the forward momentum the smart city concept has garnered as a strategic vision aimed at enhancing urban economies, transportation networks, environmental equilibrium, societal well-being, quality of life, and municipal administration (*Abella et al.,* 2017). The recent widespread proliferation of extensive data resources has played a pivotal role in driving the metamorphosis of smart city environments (*Bibri,* 2019*; Rabari & Storper,* 2014). The term "big data" often signifies huge and intricate databases that include the digital imprints of human activities, and its aspects might be specified in terms of quantity or volume, analytical approaches, or organizational consequences (*Lim et al.,*

2018). Also, according to De Mauro et al. (2015) "Big Data is the information asset characterized by such a high volume, speed, and variety to require specific technology and analytical methods for its transformation into value" (*De Mauro et al.,* 2015, p. 102).

Urban Big Data, encompassing diverse datasets from urban environments, provides valuable insights into transportation patterns, environmental conditions, and social interactions. This information aids city planners, policymakers, and researchers in making informed decisions to enhance urban infrastructure and tackle challenges associated with urbanization. In the context of Iran, the utilization of urban big data comes with its set of challenges. Ensuring the quality and integration of data from disparate sources is pivotal. Addressing data requires compatibility across information from government agencies, private entities, and various sources. Furthermore, privacy concerns occur because of the collecting of personal information via urban big data. Finding a balance between collecting insights and protecting individual privacy requires considerable consideration and the construction of strong legal frameworks. The limited technological infrastructure and sanction in Iran pose obstacles to the efficient collection, storage, and processing of large volumes of urban big data. Therefore, overcoming these challenges requires significant investments in advanced technologies and data management systems.

Access to relevant urban big data in Iran may be restricted due to proprietary concerns or a lack of data-sharing mechanisms. Encouraging open data initiatives and developing policies to facilitate data sharing can foster transparency and collaboration among stakeholders. Furthermore, capacity building seems to be crucial for local professionals, government officials, and researchers to develop skills in data analytics and interpretation. Also, training programs and educational initiatives play a significant role in leveraging the potential of urban big data. Clear and robust regulatory frameworks are essential to govern the collection, storage, and usage of urban big data, while developing and enforcing policies that balance innovation with ethical considerations could help building public trust and ensuring the responsible use of data. On the other hand, understanding cultural and social factors influencing data generation and usage are also vital for effective urban planning in Iran. Tailoring strategies to the local context and considering community perspectives can enhance the relevance and acceptance of data-driven initiatives. Addressing these challenges is critical for Iran to fully harness the potential of urban big data, contributing to the creation of sustainable, efficient, and liveable urban environments.

The aim of our study is therefore to identify, understand and evaluate urban big data challenges critically and to formulate policy-related support for governmental bodies in a country considered to be a developing information society. The research aims to rely on expert inputs, offering a comprehensive overview of the issues, while it also aims to develop a prioritization framework for assessing the significance and prevalence of the identified challenges in Tehran and in a broader regional context.

## MATERIALS AND METHODS

Our study applies an exploratory technique to investigate the obstacles of utilizing urban big data in Iran, a topic that remains underexplored in regional scientific? discussions of Iran to date. When a phenomenon is underexplored or poorly

understood, exploratory research is especially useful, since it identifies major problems and challenges by asking "why" and "how" questions (*Creswell,* 2014). This methodology aligns with the study's goal of finding key concerns in urban big data without relying on predefined theoretical frameworks.

As indicated on the website of Numbeo, Tehran is the fifth city that wastes time in traffic jams. According to this website, Iran is the worst in the world. Tehran is the 218th city that loses the most time in traffic congestion out of 222. The neglect of vital issues, such as dynamic pricing based on pollution levels, the absence of infrastructure in that nation, and people's disobedient nature, aggravates this problem. The challenges mentioned above suggest that urban big data is essential for traffic management and city planning; thus, effective measures and data-backed solutions are required to combat these issues (*Bahrami et al.,* 2021).

To ensure the inclusion of people with pertinent experience in urban big data, a deliberate sampling methodology was used. For qualitative research that seeks to collect specific and relevant data from informed participants, purposeful sampling seems perfect (*Palinkas et al.,* 2015). By applying such expert choosing technique, our research could have identified the most important urban big data challenges and provided a thorough summary of those, as well as attempted to create a framework for prioritization to determine the importance and frequency of such issues in Tehran. Altogether 20 specialists were selected based on their expertise in areas such as urban geography, data collection, -storage, -analysis, -visualization and consultancy services. To guarantee a diverse range of viewpoints that encompass the multiple industries advancing urban big data in Iran, participants were selected from academic institutions, research parks, smart transportation systems, startups, and venture-backed projects (*Bahrami et al.,* 2021).

In the initial stages, just before performing the expert survey, our preparatory research identified 32 urban big data challenges in Iran, that were compiled after a thorough analysis of academic publications on urban big data and smart cities, as well as by studying of reports and documents from the Tehran Municipality and other pertinent institutions. Each of the 32 challenges was supported by references to relevant literature to maintain scientific rigor and to minimize subjectivity by explaining prior research approaches and confirming why it should be included in our study.

Once the 32 challenges had been identified, a survey was conducted with experts in the field to measure the relative importance of each challenge. Crucially, the procedure did not presume a set quantity of high-priority challenges. Instead, the issues that stood out in terms of urgency and relevance were identified by analyzing expert comments and the questionary. This assessment led to the identification of 17 difficulties as the most important ones in Tehran's urban big data setting.

To customize the ranking, our study applied *Analytic Hierarchy Process (AHP)* methodology, which is ideal for complicated decision-making and multi-criteria evaluation (*Boyd & Crawford,* 2012). The AHP method was implemented by structuring the problem (step 1), where the ultimate purpose was to prioritize urban big data concerns in Tehran. Out of 32 possible difficulties, based on expert inputs, only the 17 most important challenges, which served as alternatives, were chosen for further investigation. Prioritization factors, such as economic impact, policy relevance, and feasibility, were organized hierarchically to guide the review. Following that, experts

were asked to conduct pairwise comparisons (step 2) of the 17 challenges using a nine-point scale, evaluating their relative importance concerning the criteria. Each comparison involved evaluating the relative significance of one difficulty against another, with numerical values representing varying degrees of importance. Then, the calculation of priority weights was done (step 3), for which a pairwise comparison matrix ($A$) was constructed, with each element ($a_{ij}$) showing the relative importance of challenge $i$ compared to challenge $j$. For example, if $a_{ij}=3$, it means that challenge $i$ is moderately (namely three times) more important than challenge $j$. Moreover, priority weights ($w_i$) are calculated by normalizing the matrix and solving for the eigenvector corresponding to the largest eigenvalue ($\lambda_{max}$). This eigenvector provides the relative priority of each challenge in the set. The consistency ratio ($CR$) indicates reasonable consistency and is computed as $CR=CI/RI$, where $CI$ is the consistency index, where $CI=(\lambda_{max} - n)/(n - 1)$, with n being the matrix size, and $RI$ is the Random Index, based on the size of the matrix (e.g., for n=10, RI=1.49). A $CR$ value lower than 0.1 indicated acceptable consistency, confirming that the evaluations were reliable. The final prioritization ranks the challenges in order of importance and assists decision makers improve urban management and use big data (*Selmi et al.,* 2016).

For final prioritization and categorization of difficulties the ranked list of the 17 most important challenges was created by adding the weighted values for each criterion. Following that, these difficulties were categorized into four groups: socio-cultural, educational, political, and economic. Although our initial perception of the underlying nature of the challenges led to this categorization, it has now been further improved through a review of pertinent literature. As per these models, every dimension denotes unique yet connected elements that significantly impact the incorporation of technology and data in urban management systems. The economic dimension encompasses issues such as resource allocation, investment adequacy, cost-benefit efficiency, and overall financial sustainability, which determine whether cities possess the necessary resources to develop, maintain, and scale big data infrastructures (*Thakuriah et al.,* 2017). In parallel, the political dimension involves governance, policymaking, regulatory frameworks, and inter-agency coordination; research indicates that unclear policies and insufficient political will can obstruct the deployment of even the most advanced technical solutions (*Razavian et al.,* 2024). Moreover, the socio-cultural and educational dimensions focus on public attitudes, community engagement, cultural readiness, and trust in data-driven governance, underscoring that the success of urban data initiatives depends not only on technological capabilities but also on the willingness of citizens and stakeholders to embrace a data-centric approach (*Kitchin & Lauriault,* 2018).

This four-group approach is supported by empirical and comparative evidence from a variety of interdisciplinary research and policy evaluations. Complex policy models, such as those created by *Alkin & Christie* (2004), demonstrate the inextricable link between economic, political, and social aspects, with sociocultural and political challenges frequently having a bigger impact on the success of urban data efforts than technical issues alone. Case studies evaluating urban policy challenges - such as those examining five-year development plans in Iran - reveal that governance and cultural barriers frequently receive higher priority over purely technical issues, highlighting the need for targeted interventions that address these critical areas (*Razavian et al.,* 2024).

This comprehensive framework not only facilitates a nuanced analysis of the obstacles to effective big data integration but also informs the development of strategic, context-specific policies that can enhance the sustainability and efficiency of urban management systems (*Jiang et al.,* 2020).

## RESULTS AND DISCUSSION

*Table 1* presents 32 key challenges associated with the implementation and management of urban big data in Iran, based on library studies. These challenges cross several dimensions, including legal, technical, economic, and socio-cultural factors. Among the most outstanding challenges are legal constraints, the lack of a strategic urban planning framework, and limited resources for data management and infrastructure. Moreover, the challenges of data complexity, competition with large companies, and a lack of mentorship highlight the structural and operational barriers within the ecosystem. The coverage of sanctions, government policies, and social attitudes toward technology further underscores the intricate interplay between external pressures and internal capabilities in the urban big data landscape of Iran (*Govindan et al.,* 2015).

**Table 1: Identified urban big data challenges in Iran**

| Challenge | Description | Reference |
|---|---|---|
| **Legal issues** | Lack of clear, consistent laws governing big data usage | Neirotti et al. (2014)<br>Supreme Council of Cyberspace (Iran) (2018)<br>European Commission (2020) |
| **Lack of supportive government policies, government policies** | Inadequate strategic frameworks to promote big data initiatives | Albino et al. (2015)<br>Supreme Council of Cyberspace (Iran) (2018)<br>European Commission (2020) |
| **Insufficient data privacy laws** | Outdated or weak privacy rules that hinder data sharing | European Union Agency for Fundamental Rights (FRA) (2018)<br>Kitchin (2016) |
| **Data security concerns** | Risks related to unauthorized access and data breaches | Kitchin (2016)<br>European Commission (2020) |
| **Lack of interoperability standards** | Difficulties in integrating diverse systems and data formats | Shadroo & Rahmani (2018) |
| **Lack of data digitization** | Insufficient conversion of analogue records into digital formats | World Bank (2017) |
| **Fragmented data sources** | Data stored in isolated silos with little integration | Janssen et al. (2012) |
| **Data quality issues** | Inconsistent, incomplete, or inaccurate data that hinders analysis | Keyvanpour & Moradi (2014) |
| **Absence of online big data and their free sharing** | Absence of centralized systems for integrating and analyzing data | Keyvanpour & Moradi (2014) |
| **Limited resources for data management and infrastructures** | Insufficient hardware, networks, and computational capacities to support big data | Keyvanpour & Moradi (2014)<br>Kitchin (2014)<br>Neirotti et al. (2014)<br>Bolici & Mora (2015) |
| **Insufficient skilled personnel** | A shortage of professionals trained in big data analytics and management. | Shadroo & Rahmani (2018)<br>McAfee & Brynjolfsson (2012) |
| **Lack of urban big data professional training** | Limited educational initiatives to build big data expertise | McAfee & Brynjolfsson (2012) |

| | | |
|---|---|---|
| **Lack of knowledge about urban big data improvement potentials in government services** | Stakeholders' limited understanding of the advantages of big data | Janssen et al. (2012)<br>McAfee & Brynjolfsson (2012) |
| **Low culture of organizations in recognizing big data importance and sharing knowledge** | Organizational inertia and reluctance to adopt new technologies | Davenport (2014) |
| **Economic and funding obstacles** | Limited funding for big data projects and innovation | Davenport (2014)<br>McAfee & Brynjolfsson (2012)<br>Neirotti et al. (2014) |
| **Lack of tax incentives** | Insufficient funding mechanisms and support for startups and innovation | Davenport (2014) |
| **Lack of a strategic and urban planning plan** | Inadequate policies and procedures for managing data quality, ownership, and usage | Janssen et al. (2012)<br>European Commission (2020)<br>Albino et al. (2015)<br>Bibri (2019)<br>Bolici & Mora (2015) |
| **Lack of data digitalization in some data generation resources and failing to aggregate them** | Challenges in merging heterogeneous data from diverse sources | Keyvanpour & Moradi (2014)<br>Kitchin (2014) |
| **Insufficient data analytics tools** | Lack of advanced platforms for processing and analyzing data | Shadroo & Rahmani (2018) |
| **Complex and heterogeneous data types** | Managing varied data formats (structured and unstructured) increases complexity. | Kitchin (2014) |
| **Inadequate sensor and IoT infrastructure** | Limited deployment of sensors and IoT devices needed for comprehensive data collection | Keyvanpour & Moradi (2014) |
| **Lack of international relations in the urban big data context** | Weak cooperation among government, industry, and academia | Neirotti et al. (2014)<br>Cardullo & Kitchin (2019) |
| **Lack of technical context for developing open data** | Insufficient collaboration across different sectors for integrated solutions | Neirotti et al. (2014)<br>Bolici & Mora (2015) |
| **Insufficient public-private collaboration** | Limited joint initiatives between government agencies and private companies. | Neirotti et al. (2014) |
| **Poor citizen engagement** | Low levels of public participation in big data and smart city projects | Cardullo & Kitchin (2019) |
| **Limited trust in data initiatives** | Skepticism from citizens and organizations regarding data use and protection | Cardullo & Kitchin (2019) |
| **Social and cultural attitudes toward technology** | Societal or organizational norms that discourage open data exchange. | Janssen et al. (2012)<br>Cardullo & Kitchin (2019) |
| **Privacy and confidentiality concerns** | Challenges in protecting personal and sensitive information. | European Union Agency for Fundamental Rights (FRA) (2018)<br>Kitchin (2016) |
| **Sanctions** | Concerns about fairness, bias, and discrimination in algorithmic decision making | Katzman (2020). |
| **Lack of market for urban big data supply and demand** | Sanctions significantly hinder Iran's urban big data ecosystem by restricting access to advanced technologies, international investments, and collaborative research. | Davenport (2014)<br>Bibri (2019) |
| **Inadequate benchmarking and performance metrics** | Lack of standardized measures to evaluate the success of big data initiatives | Neirotti et al. (2014)<br>Albino et al. (2015) |
| **Limited scalability of big data solutions** | Challenges in scaling systems as data volume and complexity grow | Shadroo & Rahmani (2018)<br>Keyvanpour & Moradi (2014) |

As mentioned above, expert interviews have identified 17 difficulties out of the complete list as most important ones. The AHP analysis highlighted significant barriers such as the lack of market for urban big data supply and demand, insufficient professional training, and inadequate knowledge about urban big data applications in government services (*Han et al.*, 2019). The analysis also emphasized economic and funding obstacles, alongside government policy gaps and legal issues, as key impediments to progress. Notably, cultural attitudes toward technology and the absence of collaborative knowledge sharing further compounded these challenges. The findings from the AHP analysis outlined a framework for addressing these barriers through targeted policy interventions, enhanced training programs, and fostering an environment conducive to open data sharing and innovation in urban big data initiatives (*Janssen et al.,* 2017).

The most important challenges identified through the AHP model were categorized into four groups based on thematic analysis (*Table 2*). Each category reflects a distinct domain of influence. Financial and economic challenges include issues related to resource allocation and economic policies, while political and governmental challenges focus on governance and legal barriers. Educational challenges highlight the lack of knowledge and training, while social and cultural challenges address societal attitudes and organizational practices. This grouping simplifies the analysis of challenges by grouping them into coherent domains of impact.

**Table 2: Classification of the most important big data challenges in Iran**

| Categories | 17 Challenges |
|---|---|
| Financial and economic challenges (priority level = 0.222) | - Lack of tax incentives<br>- Economic and funding obstacles<br>- Lack of market for urban big data supply and demand<br>- Unsupportive policies for urban big data development |
| Political and governmental challenges (priority level = 0.675) | - Government policies<br>- Sanctions<br>- Legal issues<br>- Lack of international relations in the urban big data context<br>- Lack of a strategic and urban planning plan<br>- Lack of technical context for developing open data<br>- Lack of data digitalization in some data generation resources and failing to aggregate them<br>- Limited resources for data management and infrastructures<br>- Absence of online big data and free sharing |
| Educational challenges (priority level = 0.058) | - Lack of urban big data professional training and mentors<br>- Lack of knowledge about urban big data improvement potentials in government services |
| Social and cultural challenges (priority level = 0.044) | - Social and cultural attitudes toward technology<br>- Low culture of organizations in recognizing and understanding the importance of big data<br>- Low culture of sharing big data knowledge among experts in the field |

The AHP analysis highlighted significant barriers such as the lack of market for urban big data supply and demand, insufficient professional training, and inadequate

knowledge about urban big data applications in government services. Economic and funding obstacles, government policy gaps, and legal issues were also identified as key impediments to progress. Additionally, cultural attitudes toward technology and the absence of collaborative knowledge-sharing further compound these challenges. Such findings underline the importance of a clear framework for addressing these barriers through targeted policy interventions, enhanced training programs, and fostering an environment conducive to open data sharing and innovation in urban big data initiatives (*Velasquez & Hester,* 2013) among others.

According to the expert survey responses the outcomes clearly indicated that political and governmental challenges are by far the most significant barriers to the successful implementation and development of urban big data initiatives in Iran. With a priority level of 0.675, this category far surpasses the other domains in terms of impact. Key issues under this category include government policies, sanctions, and a lack of international relations within the urban big data context. The prominence of this category suggests that addressing governmental policies and enhancing international cooperation are crucial steps toward mitigating these challenges.

The financial and economic domain is the second most significant category, with a priority level of 0.222. This reflects the considerable challenges related to funding, market dynamics, and economic policies that hinder the growth and adoption of big data technologies in urban settings. Issues such as the lack of market for big data supply and demand, as well as economic and funding obstacles, are particularly noteworthy. The moderate priority of this category underscores the importance of economic reforms and financial incentives to support big data initiatives.

Educational challenges form the third most significant group, with a priority level of 0.058. This category includes the need for professional training, mentoring, and increased knowledge about the potential benefits of big data in government services. While less critical than political or economic challenges, the educational aspect is still important for ensuring that the workforce is adequately prepared to manage and utilize big data effectively.

Finally, the social and cultural domain ranks as the least significant category, with a priority level of 0.044. This reflects the challenges related to societal attitudes toward technology and the organizational culture within the country. Although this category has the lowest impact, we believe that addressing social and cultural attitudes remains essential for fostering a supportive environment for big data initiatives in the long term.

## CONCLUSIONS

Our analysis revealed that political and governmental challenges, such as policy gaps, legal barriers, and limited international cooperation, play a dominant role in the obstacles to the development of urban big data in Iran. These issues, prioritized through the AHP model, highlighted the urgent need for reforms to establish a supportive regulatory environment and foster data-driven innovation (*Davarazar & Lotfollahi,* 2020). Alongside these political barriers, financial challenges, including insufficient funding mechanisms and a lack of market incentives, further exacerbate

the barriers to progress. Addressing these economic issues is vital to ensure the sustainability and scalability of big data initiatives (*Selmi et al., 2016*).

According to our analytical outcomes educational and cultural challenges are equally important, such as the lack of professional training programs, insufficient knowledge about big data applications, and resistance to technology adoption. These obstacles underscore the need for capacity-building efforts to bridge skill gaps and promote a culture of collaboration and knowledge-sharing among stakeholders Strengthening education and fostering public-private partnerships could create a foundation for innovation and enhance the integration of big data technologies into urban planning and management (*Davarazar & Lotfollahi,* 2020*)*).

By tackling these interconnected challenges through targeted policy interventions, strategic investments, and capacity-building programs, Iran can pave the way for a more effective and innovative urban big data ecosystem. This approach will address immediate barriers and lay the groundwork for sustainable urban development, empowering cities to leverage big data for smarter decision-making and improved quality of life.

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