smart cities

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Review

Smart City Transformation: An Analysis of Dhaka and Its Challenges and Opportunities

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Abstract: Cities worldwide are experiencing rapid urbanization and an increasing population, creating a pressing need for smart infrastructure to enhance citizen services. Dhaka, the capital of Bangladesh, faces similar technological and socio-economic challenges, making it crucial to transform it into a sustainable smart city. This research analyzes the opportunities and challenges of smart cities and Dhaka through SWOT and PESTEL analyses. The study employs a fuzzy rule-based inference system in a MATLAB simulation to calculate the smart city index based on parameters such as governance, transportation, waste management, utility management, healthcare, and industrial automation. The findings reveal that good governance has the highest impact on the smart city index, followed by transportation. The paper proposes a sustainable smart city transportation framework and management technique, outlining future research directions. The proposed framework is expected to impact socio-economic, technological, and environmental aspects positively.

Keywords: smart city transformation; governance; transportation; IoT; smart grid; environmental sustainability; sustainable development

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1. Introduction

Rapid urbanization and population growth are causing various socio-economic, technological, and environmental issues in the cities of developing countries, such as poor governance, traffic congestion, inadequate healthcare, education, and housing facilities, utility management problems, and environmental pollution. Dhaka, the capital of Bangladesh, has been ranked as the third least livable city in the world due to its lack of modern citizen services and basic facilities [1]. The city authorities aim to improve the infrastructure to offer better services to citizens, but this is associated with various stakeholder challenges. These challenges relate to real-time applications such as utility supply, healthcare, transportation, waste management, digitized education, and governance. Addressing these challenges through good governance and innovative technologies is crucial for Dhaka to become a smart city [2]. To develop a smart city, it is crucial to solicit input and feedback from citizens to address local issues and meet their needs [3]. Policies and frameworks should be designed to provide smart city services to citizens in a straightforward and accessible manner. Research on smart cities has shown that inadequate resources, accountability, and infrastructure contribute to poor service delivery in developing countries [4].

With the continual emergence of modern technologies, urban residents around the globe are increasingly interested in integrating smart technology into their city environments. However, implementing technological upgrades and overhauls is a complex and expensive process that requires adequate planning. Information and communication technologies, such as the Internet of Things (IoT), involve sensors, objects, and machines with unique identifiers and are widely used for real-time data transfer between network components. These technologies offer citizens real-time services while maintaining privacy and security with minimal human and machine intervention [5–7]. The significant growth of the global population poses challenges for governance, transportation, utility supplies, and socio-economic and environmental sustainability, particularly in highly populated areas. IoT-based smart cities present a promising solution, although internet access and speed throughout the city are crucial for establishing a smart city framework [8,9]. Incorporating geographic data from IoT devices can enhance governance structures, improve traffic and waste management, standardize healthcare facilities, optimize utility consumption, and reduce environmental pollution in a smart city framework, as suggested in [10].

The effectiveness of IoT infrastructure within a city can be hampered by inadequate and low-speed internet facilities [11]. Case studies on the digitization and smartening of cities in the European region are observed in the literature utilizing IoT devices [12,13]. Therefore, improving internet bandwidth and ensuring proper access are crucial for the success of the IoT framework. A project is underway in Bangladesh, in collaboration with the Dhaka North City Corporation (DNCC) and Local Government Engineering Division (LGED), to improve urban governance, develop GIS-based maps, and deliver smart services to citizens. Additionally, Japan and South Korea will fund several smart city projects in Bangladesh [14]. However, challenges such as transparency and accountability, insufficient infrastructure capacity, internet connectivity and speed, and limited access to online apps and web portals must be addressed [15,16].

Smart city assessment techniques have been developed in research, considering various parameters, including governance, modern technologies, citizens, economy, livability, and environment [17]. Another study has described the main parameters for smart cities as environment, socio-economic factors, technology, legal aspects, and governance [18]. However, various other segments, such as transportation, waste management, utility management, healthcare management, and industrial automation, must also be considered in developing smart cities. Research has been conducted on transforming different cities around the world into smart cities. To the best of the author's knowledge, no study has been conducted on smart city implementation using modern technologies in Dhaka, integrating governance, transportation, healthcare management, utility management systems, waste management technology, and industrial automation technologies. Therefore, this paper's main attempt is to design a transformational model for Dhaka's paradigm and discuss the execution procedure for the transformational model.

The specific contributions of this study include the following:

1. Outline the challenges and methods from the existing literature employed in different cities to foster smart city transformation;
2. Conducted SWOT and PESTEL analyses to determine challenges and opportunities for smart city transformation;
3. Designed a smart city prediction tool using a fuzzy inference system in MATLAB software R2023a;
4. Developed a smart city transformation framework, including different stages using modern technologies;
5. Designed smart city management techniques with proposals for Dhaka, Bangladesh.

This paper is structured into different sections. The first section is a literature review that overviews contemporary literature on smart city transformation in conventional cities. It also includes information about the current state of Dhaka and smart cities around the world. The second section outlines the methodology used in the smart city transformation model. The third section presents a strategic analysis and a fuzzy rule-based model for the

smart city prediction technique. The fourth section describes the conceptual framework for smart city transformation and its impacts. The fifth section proposes guidelines for transforming conventional cities into smart cities. Finally, the conclusion in the seventh section summarizes this study's limitations and future research directions.

2. Literature Review

It is necessary to have a comprehensive and sustainable plan that addresses technological, economic, and environmental aspects during the smart city transformation. However, various obstacles can hinder such a project's cost-effectiveness and timely implementation. Therefore, researchers need to identify the challenges and opportunities of implementing smart city solutions in cities with poor livability standards. An intelligent city utilizes innovative technologies to enhance the quality of services provided to its citizens, improving efficiency, consistency, and security. As urbanization continues to increase, the development of smart cities has become vital. This literature review has three parts: first, it examines the challenges faced by different countries when implementing smart city solutions; second, it presents an existing framework for transforming smart cities; and third, it outlines smart city transformation barriers and solutions in developing countries.

This research reviewed existing literature from Google Scholar by searching for the keyword "Smart City Transformation" from 2010 to 2023. A total of 862 original research articles and 91 review articles were found, with case studies investigating several cities. Only case study papers with a transformation framework were selected for this research.

2.1. Challenges of Smart City Development in Different Countries

The literature review summarizes recent studies investigating the obstacles encountered in the development of smart cities in different countries. Table 1 presents the findings of these studies in a concise and accessible format for easy reference and visualization. Table 1 provides insight into countries' common challenges when implementing smart city solutions.

Table 1. Challenges of smart city development in different countries.

Source	Method	Place	Challenges
A Al Enezi et al. [19]	Reviewing papers for identifying challenges for IoT in smart city development	Kuwait	Mind scaping, investment, security/privacy
N P Rana et al. [20]	Fuzzy analytical hierarchy process method for prioritizing barriers in innovative city development	India	Thirty-one barriers are indicated and classified into six groups, i.e., governance, economic, social, technological, environmental, and legal and ethics
H HKhan et al. [21]	Reviewing research works relevant to innovative city development	Pakistan	Budgetary problems, lack of resources, lack of social awareness and adaptation, technological capacity, lack of smart city framework, lack of sustainable strategies, system incorporation
S Khan et al. [22]	Prioritizing challenges using the weighted aggregated sum/product assessment (WASPS) method	India	ICT infrastructure, population, budget, security and privacy, data sources and features, data quality, people need social polarization, green energy, data, and information sharing.

Table 1. *Cont.*

Source	Method	Place	Challenges
N Sidek et al. [23]	IoT implementation in services using a review of contemporary research and determined challenges	Malaysia	Individual readiness, system/information/service quality, and government regulatory policies
L Oyedele et al. [24]	Using a systematic review of research author analyzed the feasibility of the implementation of a smart city	Nigeria	Corruption, lack of human and material resources, regulatory policies, harmony between stakeholders
K Hoang VietBach et al. [25]	Analyze the smart city development phase using the SWOT tool	Dalat City, Vietnam	Understanding current and future challenges, project complexities, technical challenges and institutional capacity, physical infrastructures, and network connectivity
L Pazmiñoet al. [26]	Developed a framework for IoT deployment in Ecuador	Ecuador	Industry, infrastructure and technology, security and privacy, legal aspects, education, and society
ME Akiner et al. [27]	Analysis of challenges of smart city transformation using Urban Information system and Geographical information system	Turkey	Challenges are in energy, environment, water, transportation, urban services, security, and healthcare facilities
G Meiwanda et al. [28]	Presented an in-depth analysis of the barriers to smart city development	Pekanbaru city, Indonesia	Governance speed, agility, adaptability, and social and public services
Y Li et al. [29]	Challenges and suggestions for smart city development using IoT	China	Challenges in four aspects-applications, technology, standards, and security issues
De Melo Cartaxo et al. [30]	Case studies for digitization and smartening of two cities in the European High North region	Norway and Finland	It recommends combining development, sustainability, and human well-being for smart city transformation
Haarstad, Håvard et al. [31]	Examines the role of sustainable development in smart city construction	Stavanger, Norway	It discussed innovation, technology, economic entrepreneurialism, and sustainability towards smart city development, where the inclusion of good governance is pivotal.

2.2. Literature Studies on Existing Smart City Transformation Framework

This section provides an overview of the current literature on transforming cities into smart cities using innovative technologies. Ibrahim et al. [32] proposed a theoretical logic model for transforming cities into sustainable smart cities. Meanwhile, Kumar et al. [33] presented a framework consisting of planning, physical setup, ICT infrastructure setup, and deploying smart solutions. Kuru et al. [34] designed a transformation framework called TCitySmartF with four dimensions: engagement with stakeholders, development of smart city infrastructure, integration into smart city domains, and integration with national and international environments. The framework aims to incorporate distributed services and assets, deliver effective, user-friendly solutions and real-time aid services, enhance sustainability, and promote economic expansion and competitiveness.

In a study, a benchmark model is developed considering a novel Relative Area Index (RAI) based on traffic assignment theory that is proposed to measure multi-scale urban road networks. It fosters the robustness of transforming conventional cities into smart cities in relation to the transport sector [35]. Another study investigates the role of low-carbon

technology (LCT) in sustainable urban development, focusing on three main aspects such as energy conservation, emission reduction, and carbon capture, storage, and utilization technologies [36]. A review of the expansion and adoption of digital twins in smart city transformation concludes that they improve operational efficiency and governance levels and highlights the need for accelerating their adoption [37].

A study proposes a data-driven approach to smart city deployment that considers technological and stakeholder perspectives, focusing on data privacy and security [38]. Another study examines the factors that affect the transformation of conventional cities into smart cities in Australian cities, including population density, unemployment level, and labor productivity [39]. The study provides insights for urban policymakers, managers, and planners to make informed decisions regarding smart city policies and planning. Finally, a study proposes an Enterprise Architecture Framework (EAF) to address the challenge of integrating pervasive systems in smart cities that involve multiple stakeholders and actors [40].

Hamalainen et al. [41] proposed a framework of four dimensions—strategy, technology, government, and stakeholders—to strengthen governance and sustainability in smart city initiatives. The framework was applied to Helsinki City, Finland, to maintain operations and implement smart city projects. Mishra et al. [42] presented a novel architecture incorporating IoT, AI, and cloud computing in smart cities to benefit the ecological system. A conceptual framework [21] was proposed to identify challenges for smart city development, including budgetary problems, lack of resources, social awareness and adaptation, technological capacity, a lack of a smart city framework, a lack of sustainable strategies, and system incorporation. The challenges facing smart city networks are discussed in this research, and ways to overcome these challenges are suggested. Cohen's smart city wheel framework defines a smart city, which includes smart governance, economy, environment, mobility, people, and living facilities [43]. Privacy and security, data quality, scalability, complexity, and a lack of IoT-based governance are critical factors hindering IoT implementation in smart city projects [44]. A comprehensive IoT implementation model is needed to consider these factors.

The concept of smart city transformation is mainly performed in developed countries where governance, investment, infrastructure, and social awareness are high enough compared to developing countries. Hence, developed countries faced fewer difficulties in smart city transformation than developing countries.

2.3. Barriers and Solutions for Smart City Transformation in Developing Countries

The smart city transformation in developing countries is more challenging compared to developed countries. The reason behind these challenges is poor governance, inadequate infrastructure, funding, skilled personnel, a lack of stakeholder engagement, data security, and privacy, as described in a study [45]. This study concludes that transparent governance and a strict regulatory framework can foster smart city transformation in developing countries. Another study in a developing country, Vietnam, conducted a survey and indicated that online government services could limit corruption during city service development [46]. This study reveals that promoting ICT infrastructures, strategic decisions, operational management, and good governance can help accelerate city transformation.

A study conducted on the urban transportation system in Lusail City, Qatar, proposes implementing a smart road network, light rail transit, two-wheeler and pedestrian networks, parking facilities, water taxis, and electric vehicle (EV) charging stations. These interventions aim to transform the urban transportation system and make Lusail City a smart city [47]. This paper mentioned numerous benefits to the travelers of this city, although maintaining the operation of these interconnected networks will be more challenging. Research in the context of Nigeria concludes with a fuzzy-synthetic analysis that identifies barriers to smart city development in several aspects, such as governance, economic, social, technological, environmental, and legal issues [48]. However, prioritization of the problems is needed for implementation purposes.

An analysis was conducted in the context of India to determine the strength and priority of aspects of smart city transformation [49]. This study identified 31 sustainable smart city enablers and used a clustering approach to assess the aspects' significance. In that analysis, the strategic and policy-oriented enablers score the highest importance, followed by ICT infrastructure development, energy and environment, transportation, and social contexts. The smartness of the cities is assessed using fuzzy synthetic analysis in a study conducted in Kumasi city, Ghana, including six dimensions: economy, living, governance, environment, mobility, and people. Based on the index obtained from fuzzy synthetic evaluation, the cities' readiness is measured in this study, which considers a survey of the city's citizens [50]. Research conducted on the smart city framework for developing countries depicts a model for the sustainable development of cities that prioritizes national and local sustainability policies, infrastructure, investment, services, data availability, and citizen participation [51].

Previous research has primarily focused on developing frameworks based on a few dimensions of cities [52,53], and there is a lack of monitoring and controlling issues for the sustainable operation of smart city networks. The research proposes a fuzzy rule-based smart city prediction technique and a smart city management system to address these issues, covering all dimensions of a smart city and using modern ICT technologies for monitoring and controlling operations cost-effectively.

3. Methodology

Dhaka, Bangladesh, is facing numerous challenges related to urbanization, including traffic congestion, air pollution, insufficient public services, and inadequate infrastructure, among others. With a population of over 20 million, Dhaka is also the fastest-growing city globally, exacerbating the challenges further. To address these challenges, the government is exploring ways to leverage technology and innovation to transform Dhaka into a smart city. The transformation can help make the city more sustainable, efficient, and livable for its inhabitants.

The research methodology shown in Figure 1 involves using SWOT and PESTEL analyses to identify challenges and opportunities for smart city transformation. A fuzzy inference system in MATLAB software creates a smart city prediction tool that considers governance, transportation, healthcare, utilities, waste management, and industrial automation. A smart city transformation framework is developed using modern technologies, and smart city management techniques are proposed for Dhaka, currently ranked as the third least livable city in the world.

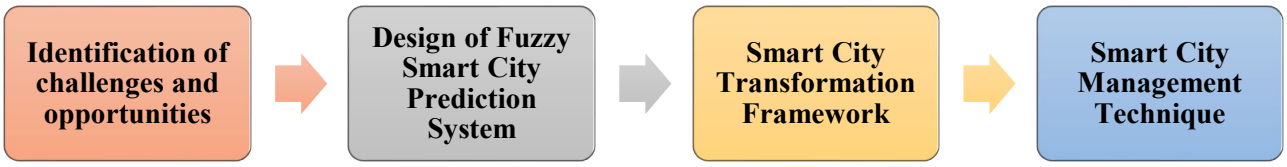


Figure 1. Methodology.

Current Status of Dhaka, Bangladesh, and Smart Cities in the World

Smart cities have become a priority in global development, with innovative facilities attracting investment and recognition. The Smart City Index 2019, created by the Intelligent World IMD City Observatory and the Singapore University of Technology and Design, ranks 102 cities worldwide [54]. Based on the index, the top ten most innovative cities are Singapore, Zurich, Oslo, Geneva, Copenhagen, Auckland, Taipei City, Helsinki, Bilbao, and Dusseldorf. Singapore is ranked as the top smart city due to its advanced safety and monitoring systems for air pollution and traffic. Auckland, Taipei City, Helsinki, Bilbao, and Dusseldorf are among the top 10 smart cities worldwide, per the IMD Smart City Index 2019. Auckland ranks 6th due to its integrated transport system and excellent digital governance, while Taipei City ranks 7th for its advanced digital infrastructure and efficient public

services. Helsinki is placed 8th for its focus on innovation and sustainability, and Bilbao ranks 9th due to its extensive use of renewable energy sources and urban regeneration projects. Finally, Dusseldorf is ranked 10th due to its efficient waste management system and emphasis on energy-efficient buildings.

Many other cities are increasing due to their innovations toward a smart city. Firstly, Bilbao is perfect for transparency and a sound governance system. London is an innovative city due to Wi-Fi connectivity with renewable energy integration. In the field of sustainable development, the city of San Francisco is famous for innovation and is a zero-waste city with an 85 percent recycling capacity. However, the concept of an intelligent city may vary based on significant aspects, such as governance, mobility, health, security, and environment. The smart city will be covered effectively by all these aspects. In the case of Southeast Asia, the cities are called rising smart towns, except for Singapore, because they are already at the top of the world. The other cities are Mandalay (Myanmar), Phuket (Thailand), Danang (Vietnam), Bangkok (Thailand), Seoul (South Korea), New Clark City (Philippines), Jakarta (Indonesia), and Hanoi (Vietnam) [54].

Dhaka is the world's most densely populated area, where one-third of the urban population lives. Additionally, it is a commercial and administrative city in Bangladesh. Compared to other cities in the world, Dhaka is the third least livable city according to the 2019 Annual Global Livability Index, EIU report. It is mentioned that Dhaka's instability scored 55 points: 29.2 in healthcare, 41.7 in the education system, 40.5 in culture and environment, and 26.8 in infrastructure. In Figure 2, it is seen that the crowded city area with traffic jams in Dhaka is placed as the 3rd most miniature livable city in the world.

Figure 2. Traffic congestion in Dhaka, Bangladesh.

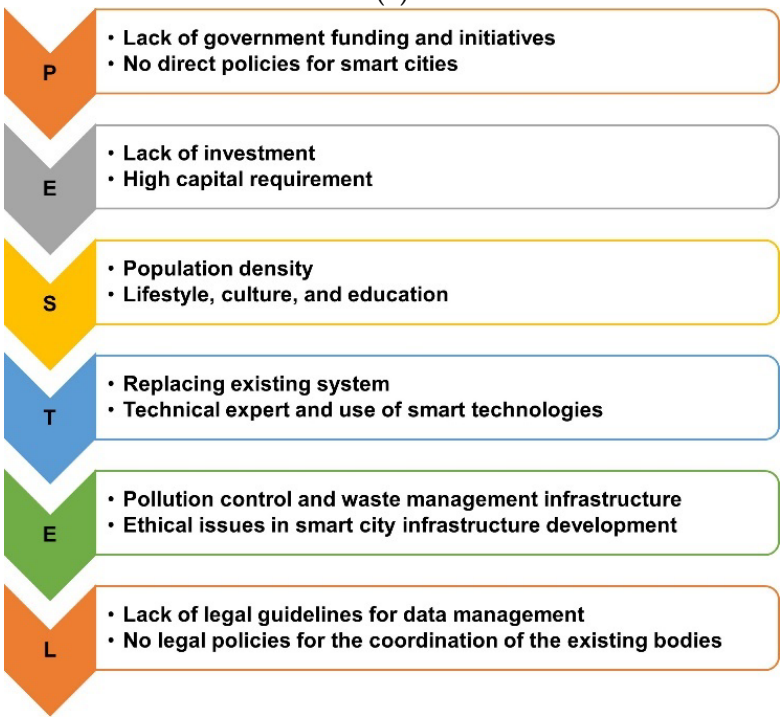
4. Strategic Analysis for the existing Smart Cities

In this section, strategic analysis and SWOT analysis are performed for the existing intelligent cities in the world from other contemporary research, whereas the PESTEL analysis of the challenges of Dhaka, Bangladesh, for transforming into a smart city is presented.

These strategic analyses identify challenges and opportunities for smart city transformation. SWOT and PESTEL analyses are popular tools for project managers to make informed decisions. SWOT stands for Strengths, Weaknesses, Opportunities, and Threats, whereas PESTEL stands for Political, Economic, Social, Technical, Environmental, and Legal. SWOT analysis has two essential parts: internal (Strengths and Weaknesses) and external (Opportunities and Threats), demonstrating the existing challenges and opportunities for smart cities. Furthermore, PESTEL analysis shows the challenges encountered in conventional Dhaka, Bangladesh. Based on the literature observed on the aspects of Dhaka, the SWOT and PESTEL analyses are determined [55–58]. Figure 3a shows the SWOT analysis, whereas Figure 3b presents the PESTEL analysis for determining challenges and opportunities in smart city transformation.

	Strengths (S)	Weakness (W)
Internal Factors	• Innovative and smart technology • Real-time monitoring • Processing time and cost reduction • Enhanced efficiency and easy use	• Data privacy and security • Complex system design • No built-in infrastructure • Implementation duration
	Opportunities (O)	**Threats (T)**
External Factors	• Good governance System • Prompt healthcare and education services • Traffic management and road safety • Effective utility management • Increasing productivity • Environment friendly	• Data vulnerability • High Investment required • Technology adoption problem • Trained personnel for management

(**a**)



(**b**)

Figure 3. (**a**): SWOT analysis for existing smart cities. (**b**): PESTEL analysis for Dhaka, Bangladesh.

4.1. Fuzzy-Based Smart City Prediction Technique

Based on the identified barriers in the SWOT and PESTEL analyses, essential parameters such as governance, transportation, healthcare facilities, utility management systems, waste management systems, and industrial automation were selected for the smart city transformation. A fuzzy rule-based smart city prediction framework was shown in Figure 4, where these parameters were considered input variables and the smart city was the output variable. The input variables are "governance", "transportation", "utility management", "waste management", "healthcare facility", and "industrial automation." The centroid-based defuzzification method was used in the fuzzy inference system. The input and output variables for the fuzzy inference system are presented in Figure 5.

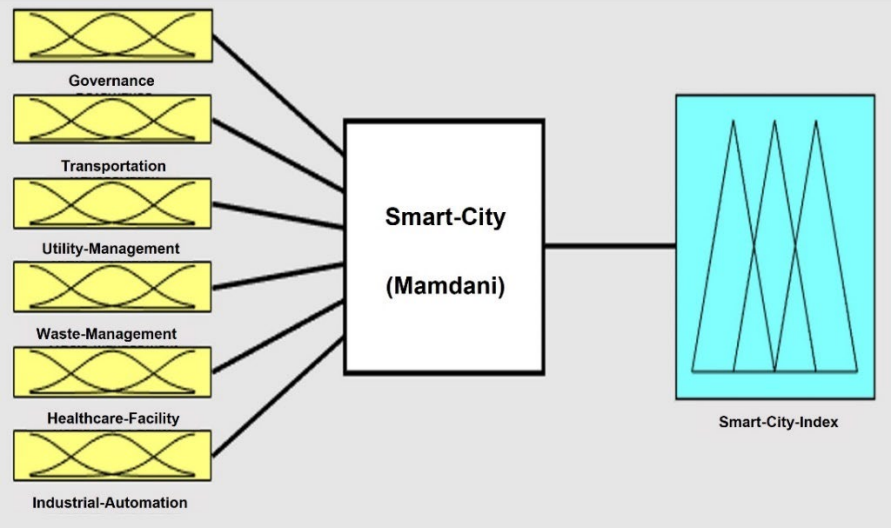


Figure 4. Fuzzy rule-based smart city prediction tool considering six input parameters.

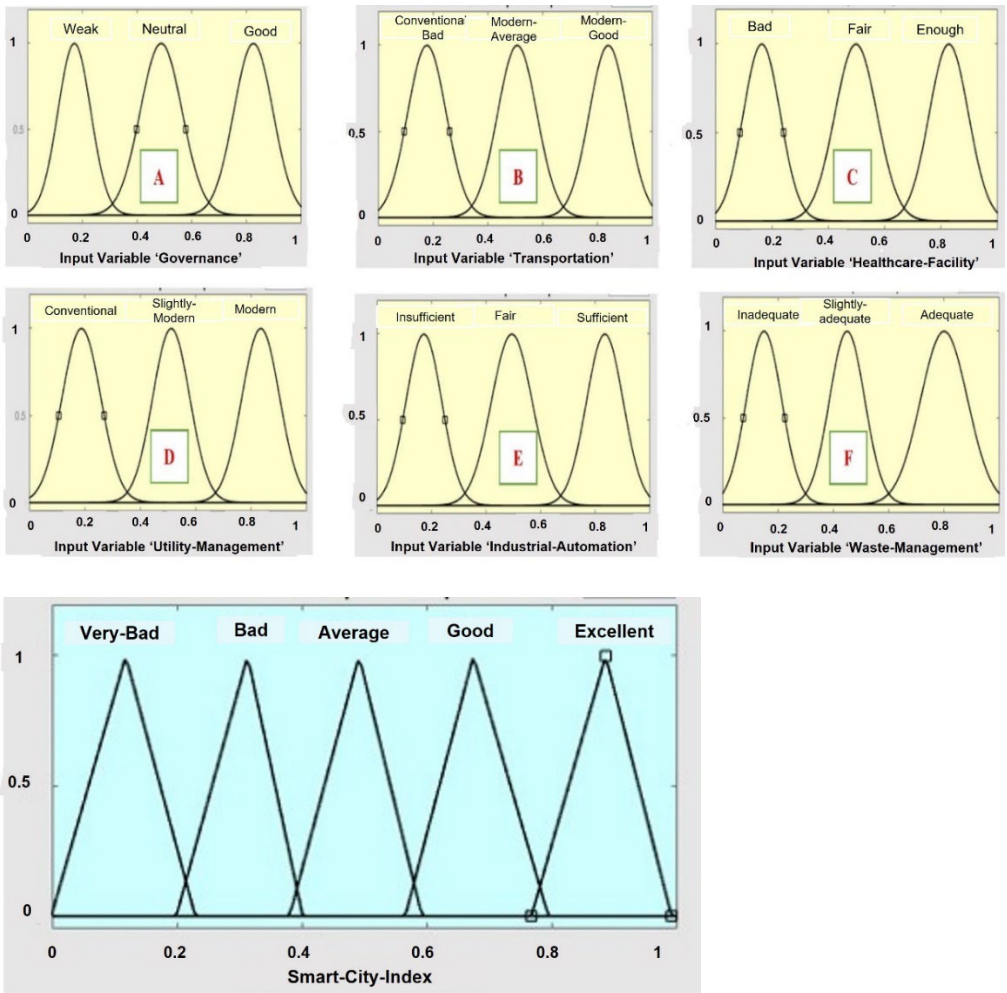


Figure 5. Fuzzy input and output variables with membership functions.

Input and Output Variables

Three Gaussian membership functions are used in all input variables, and five triangular membership functions are used in the output variable. All the input and output variables vary from 0 to 1.

Thirty fuzzy "if-then" rules are included in this system, as shown in Figure 6, where the output variable varies depending on the combinations of input variables.

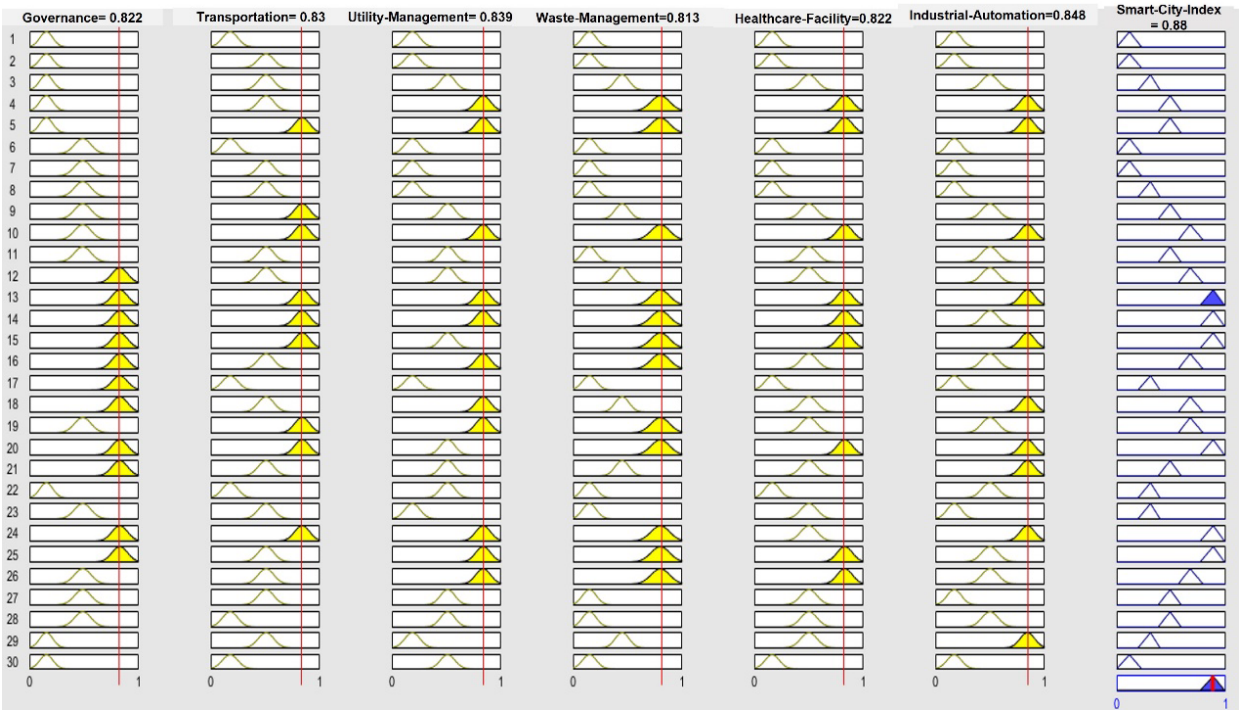


Figure 6. Fuzzy rule viewer.

Input variable "Governance" has categorized as three membership functions named "Weak", "Neutral", and "Good", whereas "Transportation" has three membership functions named "Conventional_Bad", "Modern_Average", and "Modern_Good". "Utility_management" has three categories of membership functions named "conventional", "slightly_modern", and "modern", while "Waste_Management" has three membership functions named "Inadequate", "Slightly_Adequate", and "Adequate". "Healthcare_Facility" refers to three membership functions named "Bad", "Fair", and "Enough".

In a fuzzy logic system, input variables are described by membership functions that define how each input value is related to different degrees of membership in a set or category. In this case, each input variable has three membership functions describing different conditions or states the variable can take on. On the other hand, the output variable represents the degree of smart city development, and it is described by five membership functions that indicate how the input variables influence the output. The smart city index ranges from 0 to 1, where 0 represents a conventional city and 1 illustrates a fully developed smart city.

Figure 7 displays the surface views of the output variable in relation to the input variables. This means that the figure illustrates how the output value changes as the input variables change. The graph shows the combinations of input values and their corresponding output values.

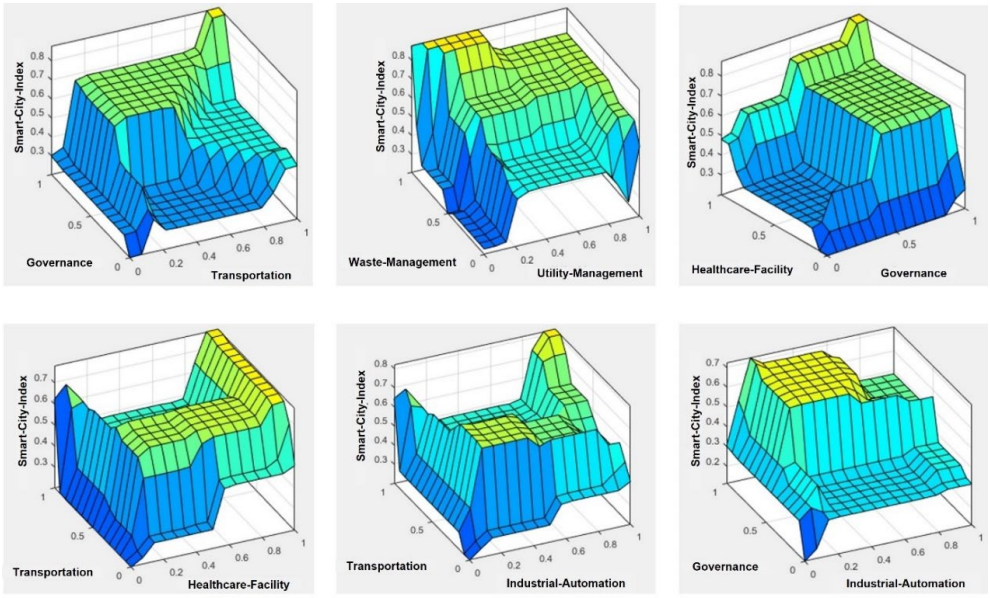


Figure 7. Surface view plot of smart city prediction scheme considering six key parameters.

Overall, this fuzzy logic system provides a way to model and analyze the development of smart cities using multiple input variables and a single output variable. By using membership functions to represent the relationships between inputs and outputs, the system can capture complex and uncertain relationships between variables and provide valuable insights into the development of smart cities.

4.2. Proposed Framework for Transforming Dhaka into a Smart City

This article proposes a framework for achieving sustainable transformation in Dhaka. This framework comprises five distinct phases that must be followed in order: identification and prioritization, planning, physical setup, development of IoT infrastructures, and monitoring and controlling. Each stage has a specific set of actions and goals that must be achieved to transform Dhaka into a smart city. These details are illustrated in Figure 8, which visually represents the framework and its various components.

(i) Identification and Prioritization Phase

In this phase, the challenges and barriers to implementing IoT for smart city transformation are identified using recent relevant research. After that, the SWOT and PESTEL analyses are executed to identify the city system's strengths, challenges, and opportunities.

(ii) Planning Phase

In the planning phase, policymakers must prioritize development efforts based on identified problems, redesign government policies for sustainable development, gather information from citizens, estimate the budget, and conceptualize solutions for identified barriers.

(iii) Physical Setup Phase

In the implementation phase, the policy developed in the planning phase is implemented to improve the city's performance. Before incorporating intelligent technologies into the city's network, basic facilities relevant to the transformation must be implemented. The processes required for this step include decentralization, the provision of adequate housing facilities, the development of roads and transportation systems, smart utility management, the implementation of environmental protection and control measures, waste management and recycling, and the formulation of strict legal policies. These steps are crucial to ensuring that the city's infrastructure is in place before introducing smart technologies.

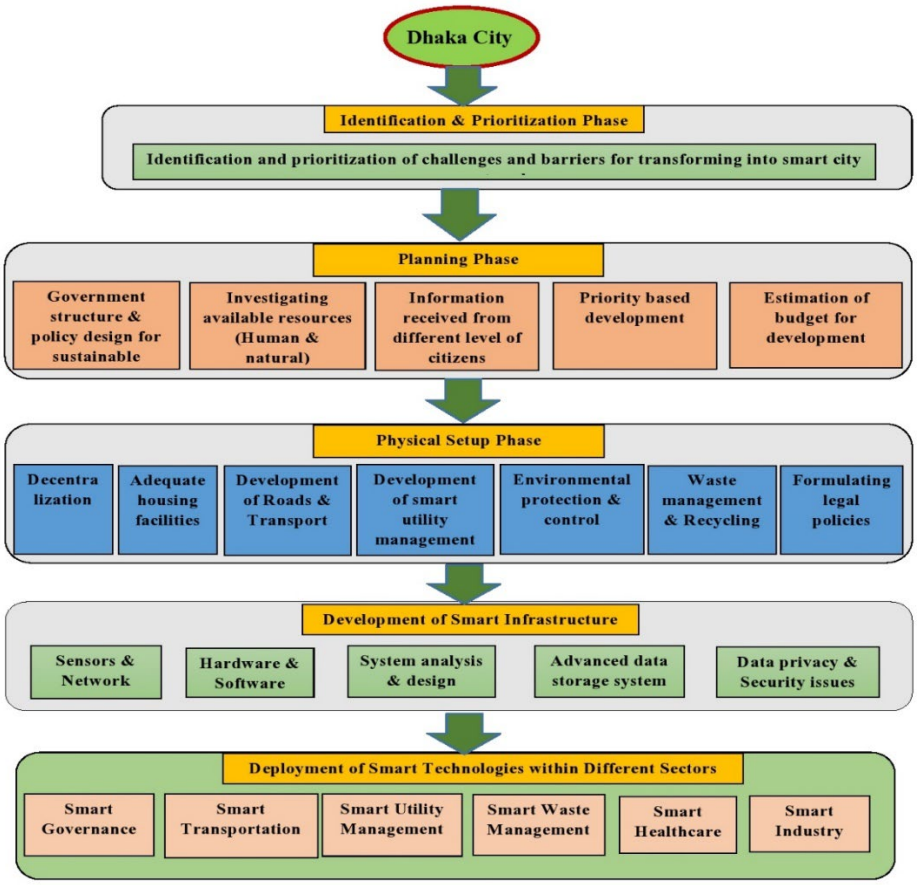


Figure 8. Smart city transformation framework for Dhaka.

(iv) Development and Deployment of IoT Infrastructure Phase

In this phase, the requirements for developing IoT infrastructure are fulfilled. It incorporates sensors, hardware, software components, system analysis and design, data storage facilities, and data protection systems. These components are essential for enabling smart technologies to function effectively in the city. By implementing IoT infrastructure, the city can collect and analyze real-time data to optimize resource usage, enhance services, and improve the quality of life for its citizens.

(v) Continuous Monitoring and Controlling Phase

For sustainable and intelligent solutions to the problems associated with the city area, the IoT infrastructure should be kept under direct control and monitoring by the city authorities. Initially, the project can be more vulnerable due to the lack of proper expertise and knowledge to handle these devices. Moreover, the lack of consciousness and the ignoring of rules and policies may threaten the sustainable development of IoT in Dhaka. To ensure the quality and sustainability of the implemented project, regular maintenance of the project needs monitoring and control. Therefore, continuous monitoring and handling of the activities would be essential for transforming a city into a smart city.

5. Proposed Smart City Framework

The concept of a smart city revolves around leveraging advanced technologies and data analytics to improve the overall quality of life for its citizens. By deploying sensors, networks, and advanced analytics tools, cities can collect and process large amounts of data from various sources, including transportation systems, energy networks, public safety systems, and more.

5.1. Impact of the Framework

A smart city strengthens governance, improves transport and healthcare systems, saves energy, is concerned about environmental sustainability, incorporates updated policies, and maximizes societal adoption of modern technologies. In this section, the impacts are explained.

5.1.1. Impact on Governance

Developed countries have embraced smart governance and sustainable development by leveraging modern technologies to establish advanced infrastructure. Developing countries such as Bangladesh have also started adopting digital technologies, resulting in positive outcomes and benefits for citizens. Implementing web portals, online platforms, and mobile apps has directly empowered citizens, and the "access to information act" has helped ordinary citizens learn about their rights. In addition, the "access to information act (A2I)" in different government organizations in Bangladesh empowered ordinary citizens to know about their rights [59]. At present, citizens are confronting situations about a local government plan due to the embezzlement of the budget that leads to sluggish performance, and the consequence ends up with an extended duration [60,61]. The implementation of an intelligent city using modern technologies would result in significant changes in the governance system of the city. The modification primarily accentuates some outcomes, which are outlined as (a) the transparency of the governance system needs to improve, (b) the enhanced accountability of the in-charge personnel is required, (c) corruption will be reduced, and (d) lastly, the execution time will be alleviated.

5.1.2. Impact on Transport

The primary modes of transportation in Dhaka are motorcycles, rickshaws, public buses, Lagunas, private cars, CNG, minibusses, and taxis. The number of personal vehicles is increasing daily, which is predicted using linear extrapolation that in 2025 and 2030, there will be around 213,268 and 272,107 cars, respectively. This extrapolation shows that the demand for private vehicles increased, which is a primary challenge for the city authorities, although during 2020–2021, it slightly decreased due to the COVID-19 situation.

Figure 9 demonstrates statistics of registered private cars in Dhaka based on the report [62]. Daily public transport such as buses, autos, and CNG shares 1,691,729 trips (70.22%) and private vehicles such as taxis and motorcycles share 310,658 visits (12.89%) except for walking and cycling modes [63]. Due to the traffic congestion in Dhaka, 2.9 percent of gross domestic production (GDP) is reduced, whereas 6 to 10 percent of GDP is lost in the country's other cities [64]. Research on the respondents in five groups estimated that traffic congestion costs USD 1010.76 per year per commuter, whereas the per-capita income is around USD 1211.70 [65]. It loses revenue, resulting in significant challenges to living standards and leading to the development of smart cities.

A news report discloses that the average traffic speed in Dhaka is 6.4 km per hour (kph), which will be 4.7 kph by 2035 with current vehicle growth. It also claims that the strategic transport plan could improve the average traffic speed by about 13.7 kph [66]. The times required to travel from Uttara, Dhaka, to different places in the city between 7 am and 10 am are indicated by green bars. The yellow bars represent the estimated time required to complete the journey at the smart city transportation speed of 13.7 kph. Figure 10 compares travel times for the distance between Uttara and different places in Dhaka.

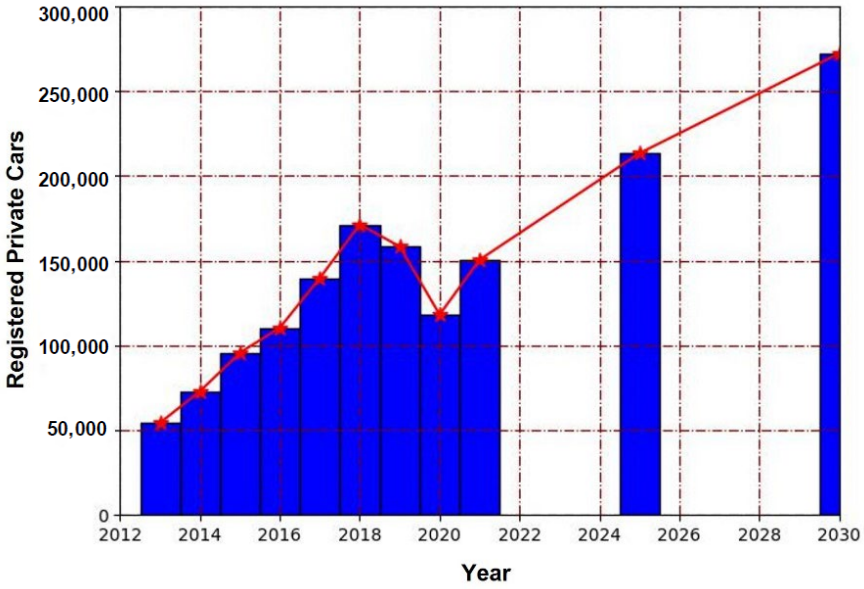


Figure 9. Statistics of registered private cars in Dhaka.

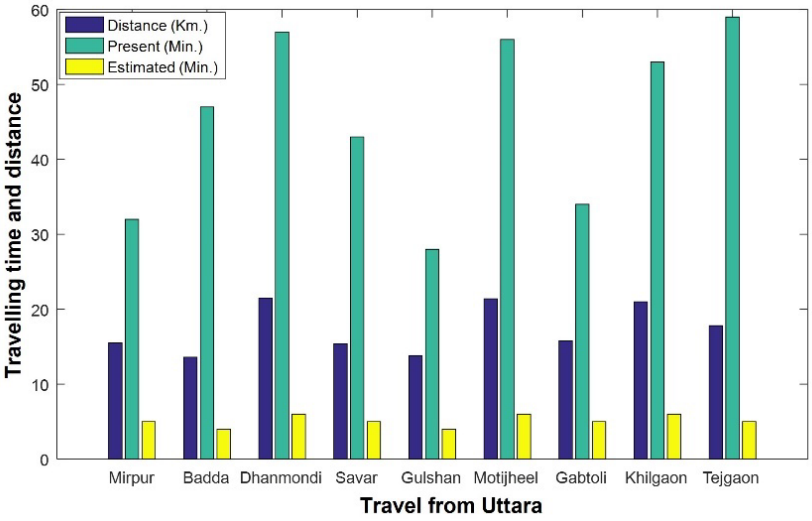


Figure 10. Comparison of traveling time for the distance between Uttara to different places in Dhaka.

5.1.3. Impact on Utility Management System

The utility management system of Dhaka consists of three managing sectors: water, gas, and electricity. "Dhaka Water Supply and Sewerage Authority (DWASA)" published the demand and supply of water in terms of million liters per day in an annual report for 2018–19 [67]. The data interpreted in the graph is the prediction by the linear regression method based on the data published in the annual report. An article claims the system loss of DWASA is 38.78 percent and describes how the transparency of the billing system could bring the system loss down [68]. A study forecasted that in 2050, more than 12.37 million people may be deprived of quality water supply in Dhaka if proper solution steps are not taken [69]. Figure 11 depicts predicted water demand with and without system loss in the upcoming years.

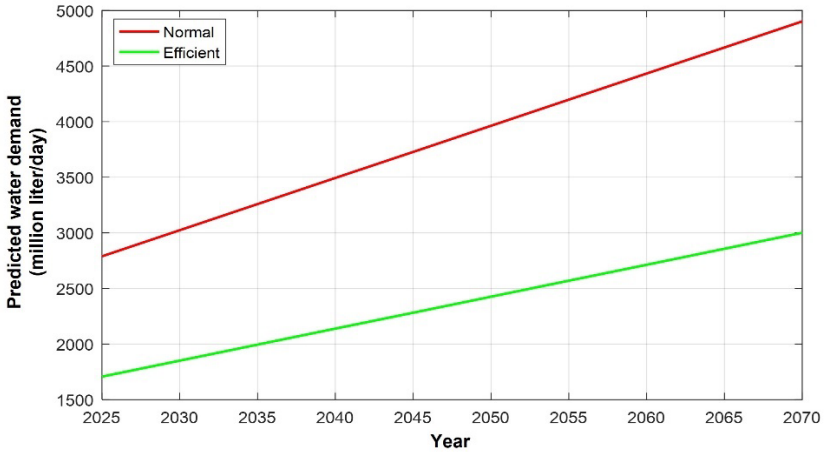


Figure 11. Predicted demand for water per day with and without system loss.

Another report explained that Titas Gas Transmission and Distribution Company Limited faced a system loss of 3 to 12 percent in 2019 due to the absence of meters [70]. It also claimed the transparency of the billing process is an issue. Dhaka Electric Supply Company Limited is one of the distribution companies that the dwellers of Dhaka consume electricity from for their daily needs. The annual report published in 2020 says the system loss of this company is now 6.23 percent [71].

Figure 12 shows the expected electricity demand for the upcoming years in Dhaka. In Dhaka, two power distribution companies, Dhaka Power Distribution Company Ltd. and Dhaka Electric Supply Company Limited, are continuing projects for the automated and underground distribution systems. In addition, renewable solar panel installation guidelines for all residential and commercial buildings in Dhaka have a tremendous environmental impact on reducing GHG emissions.

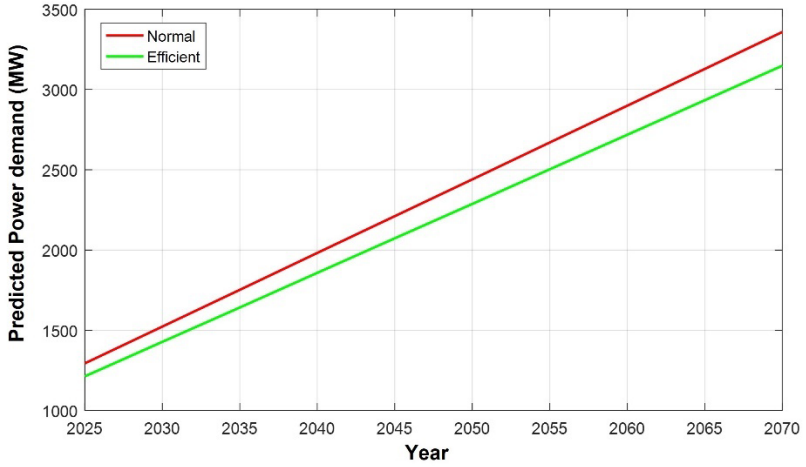


Figure 12. Predicted power demand of Dhaka with and without system loss.

5.2. Proposal for IoT-Based Smart City Management Technique

Transitioning from a conventional city to a smart city requires an efficient management plan to ensure the proper functioning of smart technologies and infrastructures. The management scheme must integrate infrastructure, data, and smart solution services to provide citizens with better facilities and services. The first step that city authorities must undertake is selecting sectors that require improvement. Subsequently, each industry must ensure effective data management practices, including data collection, processing, decision-making, and output services. Adequate government funding and technological infrastructure are essential for successfully implementing these tasks. However, during

the data processing phase, the security and privacy of data must be a priority. To illustrate the proposed smart city management technique for the developed smart city, a graphical representation is presented in Figure 13.

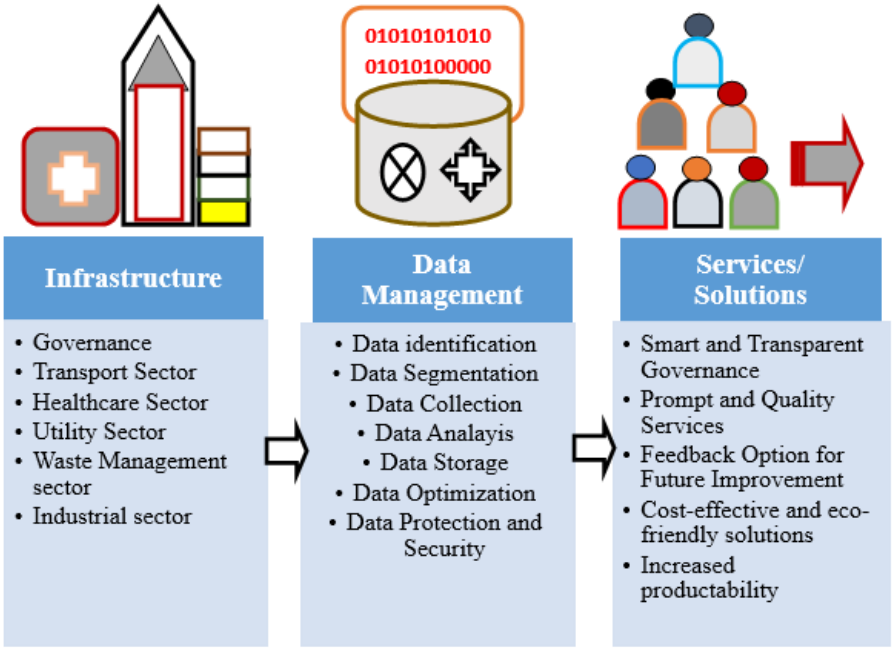


Figure 13. Proposed smart city management technique.

5.3. Policies for Sustainable Smart City Development in Dhaka

The low liveability index depicts Dhaka as more vulnerable due to the lack of facilities for fundamental rights, traffic conditions, pollution, criminal offenses, etc. Therefore, the government realized it needed to hire innovative solutions to achieve smart city facilities. This section describes the several challenges that must be overcome to make Dhaka a smart city.

- Decentralization of the administrative offices, industries, and education institutions: Dhaka, with a population density of 44,500 per square kilometer and a total population of 20.20 million, faces numerous challenges due to its rapid growth [72]. Over 80 percent of administrative offices, industries, and educational institutions are in Dhaka, making it even more vulnerable. The first step should be decentralization to reduce the population burden and transform it into a smart city. Decentralization has been shown to improve the overall efficiency of systems and promote sustainability, as indicated in several research papers [73]. Additionally, decentralization coupled with the use of ICT can make a city more livable by providing intelligent solutions for every need [74]. Therefore, Dhaka's authority needs to explore alternatives to replace the institutions at the district level and monitor all branch activities using innovative technologies;
- Transformation of the transport sector into a smart one: The rapid growth of population and private vehicles has resulted in traffic congestion and air pollution in Dhaka. Only 5% of the population uses personal cars, occupying 29% of the city's space, reducing working hours, and causing traffic jams [75]. Inadequate traffic control, policy oversight, corruption, and a lack of road safety add to the problem. Integrating renewable resources such as solar and biomass can help reduce air pollution, and electric vehicles can be a promising solution for reducing carbon emissions [76]. Stand-alone solar and hybrid solar-biogas-based charging stations can be established in different parts of the city to enable proper charging [77,78]. IoT-based smart devices and artificial intelligence can also be utilized to reduce traffic congestion cost-effectively [79].

Online monitoring of traffic systems can help improve road safety and transform Dhaka into a sustainable and smart city;

- IoT incorporation in industries: Integrating IoT devices into the manufacturing, textile, and tourism industries can significantly enhance efficiency and contribute to economic growth [80]. Bangladesh's ready-made garment (RMG) industry has achieved global recognition, but monitoring activities, production, profits, human resources, and pollution is not regularly conducted. Proper control and management of waste disposal are also necessary to address environmental concerns [81]. However, many industries in Bangladesh continue to operate with conventional technologies, which decreases productivity and increases costs and time. Integrating innovative technologies may also lead to a temporary loss of production during implementation. Therefore, policymakers must conduct a feasibility study and strategic analysis before implementing these technologies to ensure a smooth transition and maximize benefits;
- IoT in waste management: In Dhaka, every day, 4200 tons of waste, i.e., municipal solid waste and healthcare industry waste, are generated, which leads to environmental pollution [82]. The waste-to-energy (WTE) project can be a good option for recovering energy and recycling it into new products. Research in South Africa said that the WTE project manages solid wastes and reduces environmental pollution [83]. IoT-based waste management promotes real-time monitoring of garbage levels, selecting waste transport routes, and segmenting waste, improving the quality of city life. Therefore, utilizing IoT-based smart waste management techniques can be an excellent way to make a liveable city;
- IoT in environmental protection and monitoring: The rapid proliferation of population, urbanization, and the transportation sector are responsible for overall pollution in a city. The increasing pollution is raising the chance of health risks for the citizens. However, it must monitor the environment strictly to reduce health risks due to a polluted environment. Closely monitoring waste disposal and enforcing strict laws may help in controlling pollution. Therefore, collecting and analyzing data based on artificial intelligence will be a new research field and promote environmental sustainability [84];
- Strengthening governance system: A robust governance system is a powerful tool for making a city smart. However, in Dhaka, corruption, illegal use of the law, increased criminal offense, unethical work, and substantial human interaction weaken the governance system [85]. Robust internet connectivity with available sensor networks can improve performance within a smart city. Therefore, infrastructure and trained professionals are necessary to maintain innovative integrated systems using investment from the government or city authorities.

5.4. Implications

The implications for research in smart city transformation are significant. Firstly, this study highlights the need for a multidisciplinary approach incorporating various factors, including governance, transportation, waste management, healthcare, and industrial automation, in predicting and implementing smart city transformation. SWOT analysis is performed from different intelligent city literature perspectives from several countries. Additionally, data privacy and security, complex architectural design, high capital requirements, technology adoption problems, and expert personnel for the management are considered significant challenges. In contrast, PESTEL analysis reveals the challenges of Dhaka's transformation.

Further research could delve deeper into each area's specific challenges and opportunities to identify effective solutions. Secondly, this study emphasizes the importance of citizen engagement in smart city transformation. Future research could investigate the most effective ways to involve citizens in planning and implementing smart city projects.

This study uses a fuzzy rule-based model for smart city prediction, which could be further developed and improved. A fuzzy-based prediction technique has been designed

to rank smart cities based on six input parameters. The method employs thirty "if-then" rules to obtain the smart city index in the MATLAB environment. Governance is the most crucial parameter among the six input factors, followed by "Transportation" and "Utility_Management". The results show that poor governance can significantly affect the smart city index even if all other indicators are excellent. The smart city transformation framework comprises five phases: identification, planning, physical setup, development of smart infrastructure, and deployment of smart technologies in various sectors. The identification and planning phases require expert analysis, contemporary research, and observations from existing smart cities to develop policies and budget requirements. Good governance is necessary to maintain a budget and implement smart technologies successfully. Future research could explore using other data analytics techniques, such as machine learning and artificial intelligence, to improve the accuracy and efficiency of smart city prediction and decision-making. Fourthly, this study discusses the impact of modern technologies on smart city transformation, and future research could examine the social, economic, and environmental effects of these technologies in more detail.

Overall, this study provides valuable insights into the challenges and opportunities of smart city transformation and opens up several avenues for further research in this area.

6. Conclusions

Using smart technologies in urban areas can offer several advantages, such as enhanced governance, more efficient utility management, and increased productivity. Nonetheless, considerable hurdles must be addressed, such as data privacy/security concerns, technology integration, and a shortage of skilled personnel. To overcome these challenges, strategic analysis tools such as SWOT and PESTEL can be used to identify key obstacles and opportunities for innovation. The fuzzy rule viewer can then provide a clear view of the city's current transformation and progress as a smart city. Solutions based on smart infrastructures, data management, and smart solutions/services can be proposed to address these challenges.

To transform Dhaka into a smart city, important factors include offering online services to citizens, implementing real-time monitoring for traffic and healthcare systems, digitizing education systems, and promoting a knowledge-based society. Investing in smart technologies and promoting smart utility management are also important. It is important to recognize that the challenges of smart city development can vary across different countries and regions and that the solutions proposed in this research may not be fully applicable in all contexts. It is also important to consider the physical infrastructure required for a smart city network and issues related to funding, time, data security/privacy, and network connectivity.

In future research, it may be useful to conduct feasibility analyses of IoT-based smart cities in specific contexts, considering socio-economic, technological, and environmental factors. This could help to identify the most effective strategies for smart city development in different regions and to address the challenges and opportunities specific to each context.

Overall, while this research provides valuable insights into the challenges and solutions for smart city development, many areas still require further research and exploration. By continuing to study and develop smart city technologies and strategies, we can work towards creating more efficient, sustainable, and livable urban environments for citizens worldwide.

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