# Drivers and Barriers of Smart Cities and Smart Buildings: A Systematic Review

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***Abstract*—Smart cities and smart buildings use technological advancements and Internet of Things (IoT), Big Data and sensors to create a sustainable environment. This study aims to identify and characterize the drivers and barriers of smart city and smart building implementations and the factors that influence and hinder its implementation. In this study, 49 drivers and 48 barriers have been perceived and characterized. The perceived drivers and barriers were further labeled into different categories using the document study method. The 49 drivers were categorized into 10 categories while the 48 barriers were categorized into 8 categories. The drivers and barriers were assigned into strength, weakness, opportunity and threats according to the internal and external factors and roles the categories play. In addition, the study also identifies the role smart cities and smart buildings play in sustainability in creating an eco-friendly environment, enabling sustainable practices and in energy, water and waste management through the use of technological innovations.**

***Keywords—smart city, smart building, drivers, barriers, sustainability.***

## I. INTRODUCTION

The term Smart City (also called a digital city, electronic city) implies the use of information and communication technology (ICT) and other advances of science and technology to improve the daily lives of citizens by increasing operational efficiency, sharing of information among citizens, and a higher quality of governmental services and facilities [1]. Smart cities can have a broad and wide-ranging number of characteristics and requirements such as infrastructures based on the latest smart technologies and implementation of the internet of things (IoT), progressive city plans, proper maintenance and security of private and sensitive data, and implementation of sustainable and green initiatives. Cities namely London, New York, San Francisco, Boston, Dubai, Singapore, Hong Kong are a few examples of smart cities [2].

Smart cities technologies have combinations of IoT, automation, and sensors to develop the lives of the general people, where IoT plays the most prominent and fundamental role in smart cities. The implementation of smart city initiatives and urban development can also contribute to the greening of our environment. In current times the concepts of smart cities, green conservation, and environmental efficiency go hand in hand as it is deeply interconnected and related to each other. Smart cities policy maintain a balance between urban development and sustainability as it helps alleviate the negative side effects and harms of uncontrolled and unplanned technological advancements. Smart cities are service-oriented as it has role in smart healthcare, smart mobility, smart transportation, digital governance, etc.

One of the core requirements and fundamental part of smart cities are smart buildings. Smart buildings are buildings that use advanced technology to efficiently and economically use resources and provide other facilities to the building occupants [3]. Like Smart Cities, the implementation of Smart Buildings also requires the integration and use of the Internet of Things (IoT), sensors, artificial intelligence (AI), building management systems (BMS), augmented reality, etc.

## II. BACKGROUND

The term "Smart City" was introduced around the 1990s focusing on how cities can be labeled as smart and how they can be designed to implement information technologies [4]. Paper [4] explained how a city can be considered as "smart" by working through its definitions, dimension, components, measures of performance, and initiatives were taken. Some of the key components of a smart city are technology, the people, and the institutions. They have concluded that the measurements of a smart city can be multi-faceted, and complicated and its assessment must take into account the mission, vision, and priorities of the city. A smart city needs to include integrated developments in different fields and aspects such as public service, transportation, health care, education, security, etc. [4].

In paper [5] the authors defined smart cities as the place where traditional needs and services are made to be more flexible, efficient, and sustainable. The concept of a smart city involves countless infrastructures like rapid transit systems, waste management systems, water, power, and gas supply systems, healthcare and hospitals, law enforcement, cyber security, digital libraries, and many more [5]. The creation and implementation of smart cities is a natural strategy to reduce energy and water consumption, city waste, and increase sustainability. The core and backbone of smart cities are IoT while Big Data is essential for the large volumes of data generated in a smart city.

The authors of the paper [6] identified five capitals that influence a city's level of intelligence namely economic, human, social, environmental, and institutional. The authors outlined a strategically planned methodology required to create smart cities in a sequential method where the first step would be to diagnose the situation, develop a strategic plan (designing the city model, defining strategic actions, creating a coordinating body, and developing operational plans and policies) and finally taking actions [6]. This paper does not briefly elaborate the challenges for smart cities.

From paper [7] the author showed an analysis of three of the most important initiatives in Green Technologies and Smart Cities implementation such as Green Buildings, Smart grid-Smart lighting, and Smart mobility. A smart city has

many interconnected parts like smart government, smart environment, smart economy, smart mobility, and smart living. The study and analysis show that many smart cities around the world are mainly focused on energy efficiency in buildings, flexible transportation, digital infrastructure, etc.

The paper [3] aims to define a smart building as a building that integrates intelligence to meet the drivers of buildings progression such as energy and efficiency, longevity, and comfort. The paper concluded that smart buildings are adaptive by the use of intelligence, enterprise, materials design, and control. The smart buildings review paper [8] aims to answer questions related to Smart Buildings such as related benefits, required technologies, limitations, and challenges of smart buildings. A smart building has a few basic features and technologies such as automation, multi-functionality, adaptability, interactivity, and efficiency. A smart building takes into account the climate, grid, user, and proper monitoring. The paper concluded that current legislation and the general public's acceptance are some of the main challenges.

## III. Problem Statement

The implementation of Smart City is very important in Bangladesh and many projects and campaigns have been performed to achieve this goal. Many campaigns and policies have been established emphasizing the importance of smart cities and smart buildings. Introducing smart buildings features such as efficient energy, water consumption, HVAC systems, and using green energy, Dhaka city will slowly become a smart city. The authors of the paper [4] concluded that smart city metrics can be imprecise and confusing and that a smart city evaluation must consider the city's goal, vision, and priorities when establishing smart city projects. In both papers [4] and [5] there has been a broad introduction to many concepts, fields, and divisions in smart cities highlighting the integration of advanced technologies including IoT and Big Data. In paper [6] a model for smart city implementation was proposed. The implementation process mentioned may be too broad to include all the categories of a city and does not inform the drivers and barriers of the implementation process.

A smart city has been defined generically and the implementation framework takes the smart city integration broadly. There exists a lack of knowledge in the implementation of smart cities in a more modular approach and segmented approach. The previous studies shows a lacking in terms of addressing the challenges faced in a different processes such as the initial implementation phase, growth phase and in maintenance phase. The implementation of smart buildings and smart cities can face countless challenges in different stages, which have not been explicitly described in the papers. In the aforementioned papers, there is a lack of knowledge in the implementation of smart cities using required technologies while mentioning the challenges, limitations, and opportunities that may be faced in the process. Additionally, these papers are predominantly focused on urbanization issues instead of elaborately defining the role smart cities and smart buildings play in creating a green and sustainable environment.

### A. Aim

This study explores the drivers and barriers to the implementation of smart buildings.

### B. Objectives

The objectives of this study are as follows:

- To characterize the drivers of smart buildings implementation.
- To identify the barriers and challenges of smart buildings implementation.

## IV. Literature Review

The implementation of Smart cities policies from the perspective of Bangladesh is a very important topic. Paper [9] provides a general understanding of the urbanization of Bangladesh and related challenges faced to embrace them. Major challenges include rapid population growth, scarcity of advanced infrastructure and basic amenities, poverty, violence, pollution, natural and manmade hazards, and instability in government systems. This paper concluded that the decentralization of political-administrative structure and economic growth, supporting the visions and works of organizations working to establish green initiatives in Bangladesh could be the drivers in smart city implementation. This study is limited to only one service.

In the paper [10] the authors performed a systematic review on 22 papers to find the challenges in the implementation of smart buildings and smart cities using IoT and Big Data. The paper found major challenges in data management in regards to privacy and security, the collection and governance of heterogeneous data. Challenges in other areas such as data analysis, planning, and monitoring in smart buildings and smart cities were also briefly discussed. The authors provided solutions and recommendations such as using advanced technologies like Machine Learning, Apache Spark, and using IoT sensor devices.

The authors of the paper [11] briefly discussed the role of 5G in the implementation of smart cities along with the challenges and drivers. According to the paper, 5G network provided many benefits to overcome challenges and limitations like low latency, interference in network connection, signal interference, inconsistent signal. The authors suggested that advanced technologies such as IoT, artificial intelligence, augmented and virtual reality, drones, video and image analysis can play a huge role as drivers in smart cities facility management.

Paper [12] briefly explores the governance structure and initiatives in implementing smart cities from the perspective of a Dutch city. The paper identified the enabling and inhibiting elements of smart city implementation in the initiation stage and growth stage. The paper concluded that transformational leadership, goal setting, collaboration, performance measures, etc. can be drivers while the absence of leadership, communication, trust, expectation management, etc. can be barriers in smart city initiatives. The paper focuses mainly on the governance area in smart city implementation based on a single case study.

From paper [13] it can be seen that the authors highlighted multiple challenges in smart building implementation and data analysis. Challenges and barriers such as task specialization, expertise, and advice from skilled personnel, usability, flexibility, and motivations were mentioned in this paper. The authors of this paper suggested collaborative data analysis between smart buildings as it will give rise to many advantages and opportunities such as

reducing energy consumption, reducing cost, and obtaining efficiency in data collection and analysis. The paper focuses on the data collection and analysis of smart buildings.

In paper [14] the recent advances and challenges of IoT in the implementation and maintenance of smart cities were briefly discussed. The paper mentioned that IoT applications can be seen in every category in smart cities and but technological advancements and smart city initiatives still face many research challenges. The most prominent challenge of advanced technologies would be privacy, security, and trust. Many challenges can be faced due to interoperability, requiring high power, expense, connectivity, risk assessment, etc.

### A. *Research Questions*

The research questions of this study are as follows:

1. How to identify the factors that will influence the implementation of smart cities and smart buildings?
2. Which factors will hinder the implementation of smart cities and smart buildings?
3. What role do smart cities and smart buildings play in sustainability?

## V. METHODOLOGY

The research method selected for conducting this study is the document study method. Smart city and the smart building is an established and much-researched topic with countless journals, books, and conference publications. The research method of document study has been selected because of easy access to data, cost-effectiveness, and permanence of data [15]. For this study, forty academic journals and conference papers published in reputable conferences refereed by experts in this field have been selected for document study. The method of document study has high credibility and authoritativeness as the selected documents have authenticity and reliability of the information.

Other than document study there are other research methods such as surveys and questionnaires, interviews, and observation. For this study, the document study method is most suitable as there can be bias for surveys as it mostly depends on the questions the researcher gives preference to. There is also little opportunity to check the correctness through questionnaires. The methods of interviewing and observation have been rejected as those methods are time-consuming, oversimplify the data, and miss contextual information.

From the Literature Review section, it can be seen that the authors of paper [11] used the mixed method to conduct their study to build a complete roadmap for implementation of smart cities while paper [12] selected the interview method by interviewing government officials to determine the elements required for smart city implementation in the focused city. The authors of papers [9], [10], [13], and [14] used the document study method for their studies to determine the challenges and opportunities of smart cities and smart buildings initiatives. Based on the research methods of the recent studies it can be concluded that document study is the most suitable for this study.

### A. *Methodology of Data Collection*

For document study, the research papers and journals were collected using the Mendeley library to find eligible documents from reputed online databases [16]. For conducting the systematic literature review, topics and keywords such as smart buildings and smart cities were focused on. The selected papers were published between the years 2017 to 2021 and written in English. The study focuses on the drivers-barriers, challenges, limitations, opportunities, etc. discussed in the selected papers. The selected papers were also used to find the role of sustainability of smart buildings and smart cities in establishing a green and eco-friendly environment.

### B. *Methodology of Data Analysis*

The collected data received from the selected papers were qualitative. The data were assigned into categories based on their functions and roles. The data was further analyzed to determine the drivers and barriers along with the strengths, weaknesses, opportunities, and threats for each data. The targets and goals were categorized to determine the part smart cities and smart buildings play in sustainability.

### C. *Research Ethics*

The documents and papers used to conduct this study were collected from reliable and creditable sources. As the study was conducted based on already published works on reputable platforms, this study ensures research ethics.

## VI. SUMMARY OF FINDINGS

In this study, the barriers and drivers are identified and characterized. The data were further categorized into smaller sections.

### A. *Barriers*

By analyzing all the papers, a total of 48 barriers were seen. For ease of understanding the 48 barriers were categorized into 8 different categories which are Data, Security Issues, Poor Planning, Technological Issues, Social Problems, Environmental Problems, Cost, and Lack of Expertise. All those categories determine the barriers for smart building and smart cities implementation. The barriers were assigned into two other categories Weakness (the internal barriers) and Threats (the external barriers). Table I shows a detailed list of the categorized barriers along with the papers where the data was seen.

TABLE I. PERCEIVED BARRIERS OF SMART BUILDINGS AND SMART CITIES IMPLEMENTATION

| Categories | Barriers | Weakness/Threats | Paper |
|---|---|---|---|
| Data | Data Collection and Storage Issues | Weakness | [10], [17], [18], [19] |
| | Data Governance | Weakness | [10] |
| | Data Integration and Anonymity | Weakness | [10], [18], [14], [20] |
| | Data Analysis | Weakness | [10], [21], [22] |
| | Data Acquisition | Weakness | [18], [19], [23] |
| | Data Cleaning and Processing Issues | Weakness | [18], [19], [24], [25] |
| Security Issues | (Vulnerable) Security | Threat | [10], [18], [19], [14], [20], [24], [26], [27], [28], [29], [30], [31] |
| | Privacy (of Users) | Threat | [10], [19], [14], [22], [25], [31], [11] |
| | Hacking and Tampering | Threat | [25], [29], [30], [32], [5] |
| | Privacy Breach and Device Hijacking | Threat | [25], [32] |
| | Data Security | Threat | [22], [25], [11] |
| | Monitoring and Access | Weakness | [10],[13] |
| Poor Planning | Poor Planning and Strategy | Weakness | [10], [21], [28], [33], [34], [6] |
| | Lack of Leadership and Management | Weakness | [12] |
| | The task of developing indicators | Weakness | [26] |
| | Design and Measurement Errors | Weakness | [25], [33], [35] |
| | Standardization and Maintenance | Weakness | [32], [33],[36],[8] |
| | Topological Restrictions | Weakness | [28], [11] |
| | Heavy Industrialization | Weakness | [36] |
| Technological Problems | Complex Technology Systems | Weakness | [33],[37] |
| | Operational Uncertainty and Model Error | Weakness | [38] |
| | Manufacturing Variability | Weakness | [38] |
| | Lack of testing technology and simulation tools | Weakness | [20], [24], [11],[39] |
| | Network Connectivity and Coverage | Weakness | [24], [28], [29] |
| | Sensor Management | Weakness | [24], [30] |
| | Device Control and Mobility | Weakness | [29], [32] |
| | Power and Equipment Failure | Weakness | [29], [5] |
| Social Issues | Transportation Issues and Traffic Congestion | Threat | [20], [25], [26] |
| | Insecurity and Unemployment | Threat | [25] |
| | Economic Disparity and Instability | Threat | [25],[39], [40] |
| | Vandalism | Threat | [29], [30], [33] |
| | Uncooperative Attitude | Threat | [33] |
| | Lack of Awareness | Threat | [34] |
| | Lack of Policies | Threat | [34], [8] |
| | Motivation and Trust | Threat | [14], [13] |
| | Rapid Population Growth | Weakness | [23], [36], [40], [37], [7] |
| Environmental Problems | Environmental Degradation | Threat | [17], [25], [39] |
| | Climate Change and Natural Disaster | Threat | [5], [40], [7], [41] |
| Cost | Cost | Weakness | [19], [23], [5], [33], [34], [7], [42], [43], [7], [31] |
| | Operational Expenditures | Weakness | [32], [5] |
| | Low Budget and Unavailable Funds | Weakness | [33] |
| | Sunk costs | Weakness | [17], [21] |
| | Labor and Deployment Cost | Weakness | [28], [38] |
| | Lack of Economic Development | Threat | [26] |
| Lack of Expertise | Inadequate Training | Weakness | [17], [11], [33] |
| | Limited Knowledge | Weakness | [38] |
| | Lack of Adaptability | Weakness | [19], [22], [11] |

### *B. Drivers*

By analyzing all the papers, a total of 49 drivers were seen. For ease of understanding the 48 barriers were categorized into 10 different categories such as Technological Innovation, Strategy, Cooperation and Collaboration, Secure Systems, Economic Development/Profits, Interoperability, Sustainability, Benefits, Positive Social Impacts, and Efficiency. All those categories determine the barriers for smart building and smart cities implementation. The barriers were assigned into two other categories Weakness (the internal barriers) and Threats (the external barriers). Table I shows a detailed list of the categorized barriers along with the papers where the data was seen.

TABLE II. PERCEIVED DRIVERS OF SMART BUILDINGS AND SMART CITIES

| Categories | Drivers | Strength/Opportunities | Paper |
|---|---|---|---|
| Technological Innovation | Artificial Intelligence | Strength | [10] |
| | Research and Development | Strength | [25], [6], [21] |
| | Technological Innovation | Strength | [25], [6], [20], [38], [43], [18], [41], [7] |
| | Virtualization | Opportunity | [32] |
| | Data Processing | Strength | [13] |
| | Big Data Analytics | Strength | [38], [13] |
| | Sharing Hardware Resource | Strength | [38] |
| | Design Analysis | Strength | [21] |

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|---|---|---|---|
| | High Bandwidth and Low Latency | Strength | [11], [39], [37] |
| | Network Slicing | Strength | [11] |
| | Real-time Measurements | Strength | [18] |
| | Contextual Information | Strength | [18] |
| | Resilient | Strength | [40] |
| Strategy | Leadership | Strength | [40], [12] |
| | Strategy and Goal Setting | Strength | [6], [12] |
| | Good Business Practice | Opportunity | [6], [32], [7], [27] |
| | Detailed Risk Assessment | Strength | [14] |
| | Urban Design | Opportunity | [39] |
| Cooperation and Collaboration | Cooperation and awareness | Strength | [20], [37], [12], [7],[19] |
| | Societal Concerns and Integration | Opportunity | [25], [40] |
| | Government Regulations | Opportunity | [25], [32], [7] |
| Secure Systems | Data Safety and Management | Strength | [25], [6], [37] |
| | Efficient Security Solutions | Strength | [14], [44], [29], [22], [27] |
| | Accuracy of Information | Strength | [36] |
| Economic Development/ Profits | Reduce Energy Cost | Strength | [32], [13], [44], [45] |
| | Cost-Effectiveness and Reductions | Strength | [32], [40], [27], [29], [5] |
| | Improve Return Of Investment | Strength | [43], [44] |
| | Sustainable Economic Growth | Opportunity | [41], [40], [46] |
| Interoperability | Interoperability | Strength | [20], [43], [32], [14], [44], [19] |
| Sustainability | Energy: | | |
| | Reduce Energy Consumption | Strength | [21], [38], [43], [41], [37], [40], [7], [14], [29], [33], [28], [5], [27], [35], [13] |
| | Minimize Peak Usage | Strength | [27] |
| | Energy Management | Strength | [32], [27], [44], [24], [45] |
| | Environment: | | |
| | Ensure Sustainable Environment | Opportunity | [20], [41], [33] |
| | Reduces CO2 emission and carbon footprints | Opportunity | [38], [37], [40], [29], [33] |
| | Sustainable Practices | Opportunity | [25], [21], [43], [18], [41], [11], [37], [40], [7], [14], [36] |
| | Water: | | |
| | Reduce Water Consumption | Opportunity | [6], [32], [14], [5], [46], [33], [47] |
| | Waste: | | |
| | Waste Management | Opportunity | [6], [32], [14], [5], [46], [33], [47], [25], [37] |
| Benefits | Improve Health Conditions | Opportunity | [25], [43], [29], [22], [5], [33] |
| | Space Optimization | Strength | [29], [33] |
| | Increased Flexibility | Strength | [38], [43], [7], [14], [5] |
| | Smart Infrastructure | Opportunity | [38], [39], [38] |
| | Promoting Entrepreneurship | Opportunity | [37], [44] |
| Positive Social Impacts | Good environmental education | Opportunity | [6] |
| | Improved competitiveness | Strength | [41], [11], [5] |
| | Public Security and Safety | Strength | [43], [32], [13], [40], [27], [44], [5] |
| | Livability and Workability | Strength | [33] |
| | Social Inclusion | Strength | [26] |
| Efficiency | Efficiency | Strength | [25], [20], [43], [40], [44], [5] |
| | Scheduling of power consumption | Strength | [24] |

### *C. Sustainability*

Sustainability is considered a primary goal for smart buildings and smart cities. From the collected data it has been seen that reduction of energy consumption, energy management, ensuring a sustainable environment, reducing carbon and greenhouse emissions, reducing carbon footprints, water management, waste management, etc. are some of the most important drivers and targets for smart buildings and smart cities. The implementation of smart buildings and smart cities result in ensuring a sustainable environment through the use of renewable and clean energy sources and new technological innovations. Sustainability can as seen as one of the influencing drivers for smart buildings and smart cities implementation.

## VII. DISCUSSION

In this study, 48 barriers and 49 drivers were identified from 40 published papers which were further categorized into general categories and according to the strength (the internal factors and drivers that influences smart buildings and smart cities), weaknesses (the internal factors that act as barriers and limit smart buildings and smart cities), opportunities (the external drivers that create scopes for implementation of smart buildings and smart cities), and threats (the external barriers that hinder and obstruct smart buildings and smart cities implementations). From the categories, it can be seen that the drivers and barriers of smart buildings and smart cities belong to different types of factors and categories.

### *A. Significance of Results*

By analyzing more papers from recent years this study determined more drivers and barriers compared to previous studies. To identify the factors that will hinder the implementation of smart buildings and smart cities, it is required to see the current technologies. Issues regarding the collection, storage, and processing of data, technologies without proper security measures, poor planning, lack of expertise and skilled personnel, technological issues, and social problems hinder the implementation of smart buildings and smart cities. While on the other hand, factors such as new technological innovations, strategic and long-term planning, positive social impacts, sustainable and

efficient methods influence the implementation of smart buildings and smart cities and play an impactful role as drivers.

Technological issues, poor planning, and lack of expertise can act as weaknesses while social issues can act as threats. Drivers like technological innovations, long-term strategies, and services can act as strengths while government regulations and policies, implementing good business opportunities, and environmental education can be opportunities for smart cities and smart buildings implementation.

Furthermore, it has been seen that smart cities and smart buildings play a major role in sustainability by reducing energy and water consumption, reducing carbon emissions. Through the use of the Internet of Things (IoT) and Sensor, other functions such as water management, waste management, resource and asset management, by promoting green energy the buildings and cities can become smart and sustainable.

### *B. Limitations and Future Works*

The findings of this study can be used to determine the drivers and barriers of smart buildings and smart cities. The future work of this study would include the determination of priorities and importance of each drivers and barriers. Surveys and questionnaires can be conducted in order to determine the significance of each perceived factors. This study can be used as a guide to focus on during the implementation of smart buildings and smart cities. There are also possibilities of different drivers and barriers in the growth stage and maintenance stage which does not fall under the scope of this study. The results are limited to only one of the infrastructure of smart cities. The other infrastructures could should different drivers and barriers in a service-oriented nature and creates scope for future research works and studies.

## VIII. CONCLUSION

This study focused and limited to one of the infrastructures of smart cities which is smart buildings. There are other infrastructures such as smart governance, smart mobility, smart healthcare service, etc. which do not fall in the scope of this study.

The drivers and barriers that support and limit the application of smart buildings employing IoT and other technologies have been highlighted in this study. In this study, 48 barriers and 49 drivers were found and categorized based on the collected papers. By categorizing the factors that enable and inhibit smart city and smart building implementation it is seen how it results in a more sustainable environment in the long run. This study will help the further the implementation of smart buildings to transform a city into a smart city and also give deep insights on which area to focus during the implementation and growth phase. Hence, smart cities can have a wide range of traits and prerequisites, such as infrastructure built with cutting-edge smart technology and internet of things deployment that play a fundamental role in sustainability and implementing environment friendly technologies.

Smart buildings and smart cities play a fundamental role in sustainability and the implementation of smart cities technologies and services has become essential for creating an eco-friendly environment using clean and green energy.


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