Study on the Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia: The Case of Adama City

Yonas Tayu Sintayehu

A Thesis Submitted to Department of Civil Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Construction Engineering and Management

Office of Graduate Studies

Adama Science and Technology University

October, 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "Study on the Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia - The case of Adama City" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Yonas Tayu Sintayehu ______________________ _______________

Name of student Signature Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Study on the Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia - The case of Adama City" prepared under my guidance by **Yonas Tayu Sintayehu** submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Construction Engineering and Management. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Lemma Beressa (PhD) ______________________ ______________

Major Advisor Signature Date

_________________________ ______________________ _______________

Co-advisor Signature Date

APPROVAL PAGE OF THIS M.SC. THESIS

I, the advisor of the thesis entitled "Study on the Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia - The case of Adama City" and developed by Yonas Tayu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Lemma Beressa (PhD)	______________________	______________________
Major Advisor	Signature	Date
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Co-Advisor	Signature	Date

APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the thesis by Yonas Tayu Sintayehu have read and evaluated the thesis entitled "Study on the Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia - The case of Adama City" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and Management.

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AfDB	African Development Bank Group
AI	Artificial intelligence
AR	Augmented Reality
BAS	Building Automation Systems
BEMS	Building Energy Management Systems
BIM BD	Building Information Modeling Big Data
BMS	Building Management Systems
BREEAM	Building Research Establishment Environmental Assessment Method
CSFs	Critical Success Factors
EDGE	Excellence in Design for Greater Efficiencies
EIA	Energy Information Administration
EV	Electric Vehicle
EFA	Exploratory Factor Analysis
GBTs	Green Building Technologies
GHG	Green House Gas
GIS	Geographic Information Systems
GPS	Global Positioning Systems
HVAC	Heating, Ventilation, Air Conditioning
ICT	Information Communications Technology
IOT	Internet of Things
IT	Information Technology
LEED	Leadership in Energy and Environmental Design

LR	Likelihood Ratio
MS	Mean Score
RE	Real Estate
RII	Relative Index
ROI	Return on investment
SBCs	Smart Building Concepts
SBP	Smart Building Project
SBs	Smart Buildings
SBT	Smart Building Technology
SD	Standard Deviation
UNECA	United Nations Economic Commission for Africa
VR	Virtual Reality
5G	Fifth Generation of Wireless Technology

ABSTRACT

The concept of Smart Buildings has emerged as a critical component in the development of smart cities. However, Adama city faces significant challenges in integrating Smart Building Concepts in the development of smart city. This thesis aimed to investigate the application of the Smart Building Concept to support the realization of smart cities, with a focus on Adama City, thereby identify factors that influence the successful adoption of SBCs, investigate the barriers hindering their implementation, and develop a framework for adopting smart building concepts in Adama City to enhance smart city realization. The study employs a mixed-method research approach, combining qualitative data from literature reviews with quantitative data gathered from construction professionals working in Adama City through structured questionnaires. Data were analyzed using thematic analysis, descriptive statistics, principal component factor analysis and Kendall's W Test with tools such as STATA and Excel. The principal component factor analysis identified three key factors driving smart building concept adoption in Adama city: policy framework and technological integration, environmental sustainability and energy management, and public awareness and education. These factors account for approximately 80.48% of the total variance in the dataset, indicating their significant influence on SBC adoption in Adama City. This finding underscores the importance of addressing these critical areas to promote the widespread adoption of SBCs in the region. Inconsistent government policy, inadequate financial mechanisms, high design costs, and poor maintenance culture were identified as significant barriers to Smart Building Concept adoption in Adama City, exhibiting correlation coefficients ranging from 0.65 to 0.85, indicating a strong interrelationship between them. This high degree of association of barriers reinforces their collective role in obstructing the effective implementation of SBCs in the city, emphasizing the need for comprehensive strategies to address these challenges. The proposed framework emphasizes the need for clear policies, financial incentives, capacity building, and pilot projects to foster a supportive environment for SBCs. From the analysis of the study, we can conclude that the adoption of SBCs is primarily driven by key factors, including strong policy frameworks and technological integration, a focus on environmental sustainability and energy management and public awareness and education. These findings offer actionable insights for policymakers, urban planners, and stakeholders involved in smart city initiatives, with relevance to Adama and the broader Ethiopian context. Based on the thesis findings, the recommendations include: strengthening policy frameworks, enhancing technological integration and innovation, increasing public awareness and professional capacity building, and developing financial schemes to support SBC adoption in Adama city and the broader Ethiopian context.

***Keywords**: Smart Building Concepts, Smart City, Adama City, Sustainable Development, Policy Framework, Technological Integration, Energy Efficiency, Public Awareness, Financial Incentives, Capacity Building, Developing Countries, Urban Planning, Environmental Sustainability.*

1. INTRODUCTION

1.1 Background

Ethiopia is experiencing significant urbanization, with cities facing challenges related to infrastructure, energy consumption and environmental sustainability. This rapid urbanization and population growth in cities like Adama, have led to increased challenges in urban management (UN-Habitat., 2020). As the country endeavors to address these issues, the Smart City paradigm emerges as a promising solution. Smart cities are rapidly emerging as a key focus in urban development strategies worldwide, with a growing emphasis on leveraging technology to improve sustainability, efficiency, and quality of life for residents (Caragliu et al., 2009).

In Ethiopia, the concept of smart cities is gaining power as the country seeks to modernize its urban areas and address the challenges posed by rapid urbanization (Tadege, 2018). Adama City, located in the Oromia region, stands out as a prime candidate for transformation into a smart city due to its strategic location and potential for sustainable development (Alemu et al., 2020).

Smart buildings play a pivotal role in the realization of smart cities by integrating advanced technologies to optimize energy consumption, enhance occupant comfort, and promote sustainable practices (Ahmad et al., 2019). By incorporating smart building solutions into urban infrastructure, cities can achieve significant reductions in resource consumption and environmental impact while improving overall livability for residents (Bibri & Krogstie, 2017). The development of smart buildings not only enhances the smart city concept but also promotes positivity to the urban development and national economy, increases the quality of life of the whole population reacting to global challenges: reducing CO_2 emissions, recycling and using resources efficiently and sustainably by being employed through whole life-cycle. i.e., all project development stages (Apanaviciene et al., 2020).

By incorporating smart building technologies, Adama City has the potential to significantly improve energy efficiency, reduce operational costs, and enhance the overall quality of life for its residents. However, the city faces significant challenges in aligning with global trends toward smart city development, particularly in integrating Smart Building Concepts (SBCs). Despite efforts to modernize infrastructure, the construction industry in Ethiopia, and particularly in Adama City, struggles with outdated practices, lack of technological integration, insufficient policy support, and limited public awareness of smart building technologies (Ministry of Urban Development and Construction, 2017). These challenges hinder the city's ability to optimize energy efficiency, environmental sustainability, and urban management, which are crucial for smart city realization. There exists a knowledge gap in understanding the specific contextual factors and challenges associated with integrating smart building concepts into Ethiopia's urban environment, especially in the case of Adama City.

This research aims to address this knowledge gap by exploring the unique challenges and opportunities for integrating smart building concepts within the specific context of Adama City. The thesis seeks to investigate how these technologies can facilitate Adama's journey toward becoming a smart city. By examining the opportunities, challenges, and potential impacts of integrating smart building solutions into the urban fabric of Adama City, this study aspires to provide valuable insights for policymakers, urban planners, and stakeholders engaged in smart city development initiatives in Ethiopia.

The study employed mixed approach i.e both qualitative and quantitative research approach. For research question 1 qualitative data obtained from the literature review is analyzed thematically to identify insights related to current trends of SBCs application. For research questions 2 and 3 quantitative data collected through the questionnaire survey from construction professionals working in Adama City's Construction Authority, Consultants, Contractors and Building owners is analyzed using Statistical Analysis Software (STATA) and Excel. For quantitative data analysis, both descriptive and inferential statistics are employed, including mean score and factor analysis to assess factors influencing the adoption of smart building concepts in Adama City and mean item score and agreement analysis technique to assess barriers of SBCs application in Adama city. For research question 1, purposive (Judgmental) sampling approach is adopted and for research question 2 and 3 random probability sampling technique is adopted. Through exploration of primary data i.e questionnaire survey and assessment of secondary data i.e literature review, this thesis developed a framework for the successful implementation of smart building concepts in Adama City.

1.2 Problem Statement

The challenge lies in understanding how the Smart Building concept can be effectively applied to contribute to the broader goals of Smart City development in Adama and further in Ethiopia.

Ethiopia has launched 'smart city' efforts and based on this Adama city administration is on implementing smart city projects. Smart cities, the operational efficiency of which is heavily dependent on buildings, are the most prominent trend in creating a cohesive environment of the future (Sodhro et al., 2019). In order to have smart cities, it's important to understand the most fundamental part of them that is smart buildings. The development of smart buildings not only enhances the smart city concept but also promotes positivity to the urban development and national economy, increases the quality of life of the whole population reacting to global challenges: reducing CO_2 emissions, recycling and using resources efficiently and sustainably by being employed through whole life-cycles (Apanaviciene et al., 2020). Adama City is experiencing rapid urbanization and population growth, leading to increased demand for housing and infrastructure. By incorporating smart building technologies, city planners can create more efficient and sustainable urban environments that meet the needs of a growing population (Tsehay et al., 2020).

Rapid urbanization and population growth in Adama City, Ethiopia, have increased the demand for efficient, sustainable urban infrastructure. However, the city faces significant challenges in aligning with global trends toward smart city development, particularly in integrating Smart Building Concepts (SBCs). Despite efforts to modernize infrastructure, the construction industry in Ethiopia, and particularly in Adama City, struggles with outdated practices, lack of technological integration, insufficient policy support, and limited public awareness of smart building technologies. These challenges hinder the city’s ability to optimize energy efficiency, environmental sustainability, and urban management, which are crucial for smart city realization.

Given the growing need for sustainable urban development, there is an urgent need to investigate the factors that drive or impede the adoption of SBCs in Adama City. The absence of a structured framework that addresses local challenges, coupled with the limited implementation of SBCs, highlights the necessity to develop a comprehensive strategy that can facilitate the successful application of smart buildings in enhancing Adama’s transition toward a smart city.

This study aims to fill this gap by identifying current trends, key drivers, barriers, and proposing a tailored framework for SBC implementation that considers the unique socio-economic, regulatory, and environmental conditions in Adama City.

1.3 Objective

1.3.1 General Objective

The general objective of the research is to explore the application of smart building concept to enhance smart city realization in Ethiopia, particularly in the context of Adama City.

1.3.2 Specific Objectives

The specific objectives of the Research include:

1. To identify the current trends and practices of smart building concept implementation, with a focus on enhancing smart city realization.
2. To assess the factors enhancing the implementation of smart building concepts in the context of smart city development.
3. To investigate the barriers hindering the application of smart building concepts.
4. To develop a framework to guide the successful implementation of smart building concepts, taking into account the unique characteristics and challenges of the city as a case study in Ethiopia.

1.4 Research Questions

This research aimed to address the following questions:

1. What are the current trends and practices in implementing smart building concepts, and how do they contribute to the realization of smart cities?

2. Which factors can enhance the successful implementation of smart building concepts within smart city development?

3. What are the barriers hindering the application of smart building concepts?

4. How can a framework be developed to guide the successful implementation of smart building concepts in Adama City, considering the unique characteristics and challenges of the city as a case study in Ethiopia?

1.5 Significance of the Study

The significance of this study is substantial, given the emerging importance of smart building concepts in realizing smart cities, especially in rapidly urbanizing cities like Adama. The study will contribute in several ways:

Advancement of Knowledge in Smart Building and Smart City Research: This research will add to the limited body of knowledge on smart building concepts within the Ethiopian context, specifically Adama City, providing valuable insights into current trends, practices, drivers, and barriers. This will benefit future researchers by offering a foundation to build upon and helping to bridge the knowledge gap in smart city and smart building studies in Ethiopia.

Identification of Key Factors Influencing Implementation: By identifying the key drivers and barriers to smart building adoption, the study will highlight factors that can either facilitate or hinder the development of smart buildings within a smart city framework. This information will be useful for policymakers, urban planners, and stakeholders who are looking to foster environments conducive to sustainable urban development through smart buildings.

Practical Framework for Local Implementation: The development of a framework tailored to Adama City will offer a practical guide for implementing smart building concepts in similar urban settings across Ethiopia.

In summary, this research will provide actionable insights and a localized framework that are crucial for the adoption of smart building concepts to foster sustainable, technologically advanced cities in Ethiopia.

1.6 Scope of the Study

Adama City is the economic hub and among the cities which started adopting smart city initiative in Ethiopia. However, smart building concept is novel to Ethiopian construction industry, Adama city. The study examined the concept of smart buildings application and their potential impact on smart city development.

The study focused on Adama City in Ethiopia as a case study to explore the application of smart building concepts in enhancing smart city realization. The research is limited to this specific geographical area to provide in-depth insights into the context of urban development in Ethiopia.

The research involved engaging with key professionals participating in urban development and infrastructure projects in Adama City, including Architects, Engineers (Civil, Mechanical, and Electrical), and Quantity Surveyors practicing in Adama city's Construction Authority, Consultant, Contractor and Building owners offices as they are the primary participants who have substantial involvement and responsibilities in smart building concepts. Their perspectives and experiences will be essential for understanding the challenges and opportunities in implementing smart building concepts.

2. LITERATURE REVIEW

2.1 Introduction

The concept of Smart Buildings has emerged as a critical component in the development of smart cities, aiming to optimize energy efficiency, enhance occupant comfort, and improve overall building performance (Albino, V., Berardi, U., & Dangelico, R. M., 2015). In the context of developing countries, the application of Smart Building concepts plays a pivotal role in realizing the vision of smart cities by leveraging technology and innovation to create sustainable urban environments (Kumar, T., & Dahiya, B., 2017).

Ethiopia has launched 'smart city' efforts encompassing the four pillars of comprehensive development – institutional, physical, social and economic infrastructure. For example, Adama city is dedicated to build a smart city by agreeing with Ehio Telecom to install ICT and agreed with Engineering Corporation of Oromia (ECO) to build the Adama Smart City project which demonstrates the city’s commitment to transform into a technologically advanced hub. The ten components of the Adama smart city initiative include smart governance, smart people, smart Public relation research and knowledge management, smart tourism and culture, smart social service, smart mobility, smart environment & organic production, smart urban design and land use management, smart security and digital Adama (Ethiopian Press Agency).

This literature review aims to synthesize existing research findings to address the specific objectives of the research thesis and gather data to identify current trends and practices of SBCs, identify key drivers of SBCs, investigate barriers to adoption of SBCs, and to develop a framework for the successful implementation of smart building concepts in Adama City in the context of smart city realization. The review also identify the concept of smart city and smart building.

2.2 Concept of Smart City

Many papers and reports referring to the smart city begin with an acknowledgement that the driver of change is population growth, urbanization and an opportunity to capitalize on the economic return possible through tech-based growth (Cosgrave, E., 2018). The concept of a smart city is the brightest contemporary trend integrating the ideas of smart mobility, smart economy, smart people, smart government, smart environment and smart living. The concept of a smart city encompasses various infrastructure domains such as energy, mobility, water, security and waste management, where digital technologies and data driven solutions play a crucial role (Duque, J, 2023). According to Al Mansoori, S., 2021 several factors have been put forward to help explaining the concept of smart cities: (a) management and organization, (b) technology and innovation, (c) governance, (d) policy context, (e) people and communities, (f) economy, (g) built-in infrastructure, and (h) natural environment. Alizadeh has defined smart cities as "urban settlements that capitalize on telecommunication technologies to enhance liveability, workability and sustainability." This definition highlights the importance of telecommunication infrastructure in creating smart cities (Alizadeh, T, 2017). Although smart cities are structurally "bound" and supported by an integrated system of ICTs, the use of technologies alone does not automatically make cities "smart." Buildings are the ideal starting points from which a smart city can grow. In order to have smart cities, it's important to understand the most fundamental part of them that is smart buildings. Smart buildings integrate technology and Internet of things (IoT) to provide solutions to common building management challenges through all the systems are connected – energy, lighting, and water, lighting, emergency and security services. Digitalization provides the necessary infrastructure and connectivity for smart buildings to interact with the broader smart city ecosystem, enabling data exchange, interoperability and resource optimization across various domains (Apanaviciene et al., 2023).

2.3 Concept of Smart Building

The smart building concept has evolved since its introduction by the Intelligent Building Institute of the United States in 1989 (Ejidike, C.C., 2022). Initially focused on integrating building automation systems for managing HVAC (heating, ventilation, and air conditioning), the concept has expanded to include advanced technologies that enhance energy efficiency, comfort, and overall performance of buildings (Olanipekun, 2017 and Bao et al., 2020). This shift laid the groundwork for today's smart buildings, which use IoT, automation, and intelligent systems to adapt to user needs and environmental conditions (Froufe et al., 2020 and Attoue, Shahrour, and Younes, 2018).

Various studies on the smart building concept in the construction industry have used various expressions to practice the smart building concept. Indrawati et al., 2017 defined the smart building concept as the collaboration of building automation systems, integration systems and telecommunication systems for the smart building's efficiency, functionality, optimization, comfort and economic stability. Ejidike described Smart building as structures that include technologies such as digital infrastructure, energy efficiency measures, intelligent building management systems, wireless technologies, remote monitoring, information and communications networks, adaptive energy systems, networked appliances, data gathering devices, assistive technologies and automated systems (Ejidike et al., 2023). According to Gbadamosi et al, 2019, a smart building differs from a conventional traditional building in design, construction management and maintenance of the building life cycle, which involves using technologies. The advancement of ICT has led the expansion of the smart buildings market and the change in the smart building concept.

The concept of a smart building has gained significant attention in the context of creating sustainable, energy-efficient and intelligent built environments. According to TrueOccupancy, 2019, Smart buildings integrate technology and the Internet of things (IoT) to provide solutions to the age-old issues of overspend and inefficiency in building construction and use, including: reduce energy consumption, provide building efficiency, predictive maintenance, increase productivity and better use of resources. One of the applications of the IoT in urban contexts is the utilization of ICT to enhance the quality of life for occupants in smart building environments (Apanaviciene et al., 2023). Smart buildings provide solutions, improve efficiency, and reduce consumption and energy costs. Again the use of sensors built into infrastructure and data collected in smart buildings allows for a significant improvement in the management of buildings (Takasolutions, 2018). Smart buildings within a smart grid may not only participate to load shifting, increase energy efficiency or decrease in electricity consumption, but can also contribute significantly to the reduction of CO_2 emissions (Wang and Moriarty, 2018).

According to Apanaviciene et al., 2023, Smart buildings possess several key features that set them apart from traditional buildings. Firstly, they incorporate automated systems for environmental control, including heating, ventilation, air conditioning (HVAC), lighting and shading. These systems use real-time data from sensors to adjust settings based on occupancy, weather conditions and energy consumption patterns, leading to energy efficiency and enhanced occupant comfort. Secondly, smart buildings employ advanced building management systems (BMS) that integrate various subsystems and devices into a centralized platform. This allows for centralized monitoring, control and analysis of building operations, leading to improved operational efficiency, predictive maintenance and proactive decision making. Moreover, smart buildings leverage data analytics and machine learning algorithms to derive insights from collected data. By analyzing patterns, trends, and anomalies, these buildings can optimize resource utilization, identify energy-saving opportunities, and anticipate maintenance needs (Apanaviciene et al., 2023).

The concept of a smart building is being developed at all stages of the building life cycle, focusing on the design, construction and operational phases. In many cases, a smart building combines the characteristics of a sustainable building and a green building. At the design stage, when the building's digital model is developed, the energy efficiency of the future building is simulated and analyzed, considering the location and orientation, urban infrastructure and other environmental conditions using the latest and most effective technological solutions of building materials and products, building services and construction processes based on ICT (Apanaviciene et al., 2020).

The objective of smart buildings is to achieve a state of self-management, learning, prediction and adaptation without requiring any intervention or awareness from their occupants. Sensors and monitors can expeditiously and autonomously modify ambient temperatures, illumination, shading, energy efficiency and water usage (Apanaviciene et al., 2023). Smart buildings embody advanced technologies and systems that optimize resource utilization, improve occupant comfort and enable efficient operation and management (Hilali, E.; Azougagh, 2022). Smart buildings can also be expressed as intelligent and self-sustainable buildings by exploiting sensors, technologies and innovative materials to achieve energy management and occupant comfort (Ejidike C, Mewomo M, 2022). Globally, the interest in smart building technology has progressively increased over the years (Crespi M, 2020).

2.4 Smart Building Concept in the Context of Smart City Development

Smart buildings are central to smart city development due to their integration of IoT, AI, and BIM for real-time monitoring and automation of energy systems. These technologies help optimize resource use and enhance sustainability goals. Research by Allam et al., 2019 highlights this synergy between smart buildings and urban innovation.

Studies like those by Albino, Berardi, and Dangelico, 2015 underscore the importance of energy efficiency in smart buildings, which contribute to smart cities by reducing carbon emissions and improving energy use through intelligent systemsence and Sustainability. Smart cities aim to enhance urban resilience, and smart buildings play a key role by optimizing energy management systems and integrating renewable energy sources. Research by Ahvenniemi et al., 2017 illustrates the relationship between urban resilience and smart technologies used in buildings.

Research conducted by Neirotti et al., 2014explains how smart buildings enhance smart city functions by providing better connectivity and digital infrastructure, improving public services and governance.

2.4.1 The Role of Smart Buildings in Smart Cities

Smart buildings are increasingly recognized as integral components of the smart city ecosystem, contributing significantly to sustainable urban development. Liu et al., 2019 emphasized that these buildings are a key part of green energy management systems, facilitating energy optimization through intelligent edge computing. By integrating IoT technologies, smart buildings can enhance energy efficiency, which is critical for the sustainability goals of smart cities (Verma et al., 2019).

Furthermore, the architectural design of smart cities incorporates smart buildings to improve urban infrastructure and services, thereby elevating living standards and resource management (Haque et al., 2021; Wenge et al., 2014). This integration not only enhances operational efficiency but also ensures that urban environments can adapt to the growing demands of urbanization.

Ahiabor, 2019, in his study, suggests that the smart building concept needs better understanding by the professionals in the adoption of smart building technologies and creates clear opportunities for development by the real estate agent and developer.

2.4.2 Sustainable Urban Development and Smart Buildings

The concept of sustainability is deeply embedded in both smart cities and smart buildings. Yigitcanlar, 2015 noted that smart urban technologies, particularly smart buildings, are essential for promoting sustainable development. These buildings utilize advanced technologies to optimize resource use and reduce environmental impact, aligning with the sustainability objectives outlined in smart city frameworks (Angelidou et al., 2017).

Moreover, smart buildings facilitate the integration of various technologies, contributing to improved urban living and resource management (Villegas-Ch. et al., 2019). They encompass a range of functionalities, from energy management to security systems, which are pivotal for developing resilient urban centers capable of meeting contemporary challenges (Rathore et al., 2017).

2.4.3 Intersection of IoT and Smart Buildings

The integration of IoT infrastructure in smart buildings significantly enhances their operational capabilities. Minoli et al., 2017 identified that IoT-enabled smart buildings support various aspects of building management systems, focusing on energy optimization and user comfort. Verma et al., 2019 further elaborated that IoT technologies enable real-time monitoring and control of building systems, which is crucial for maintaining efficiency and sustainability.

The deployment of IoT edge and fog computing technologies in smart buildings has been shown to improve service delivery and operational efficiency (Ferrandez-Pastor et al., 2018). These technologies support the development of smart building services that are essential for the comprehensive functionality of smart cities.

Research Gap

Ahiabor, 2019 suggests that the smart building concept needs better understanding by the professionals in the adoption of smart building technologies and creates clear opportunities for development by the real estate agent and developer. Research into the construction industry in developing countries indicates that the adoption of smart building concepts, attributed to a low level of awareness and knowledge of SBCs among construction professionals, is still low (Ghansah, Owusu-Manu, and Ayarkwa, 2019).

Therefore, there is a need for study on the adoption of smart building concepts to enhance smart city realization in Adama.

2.5 Current Trends and Practices of Smart Building Concept Implementation

The idea of a "smart building" is becoming very popular in developing countries, as these countries try to become more energy efficient, more sustainable, and in general, have better performing buildings. The smart city concept has been increasingly recognized as a potential solution for addressing the challenges faced by developing countries, particularly in terms of population pressures and infrastructure demands. However, Tan and Taeihagh, 2020 highlight that the successful realization of technology-enabled smart cities in developing countries requires concurrent socioeconomic, human, legal, and regulatory reforms. The review emphasizes the importance of fulfilling basic infrastructure needs, raising revenue, developing clear regulatory frameworks, and ensuring digital inclusivity and environmental sustainability. It also emphasizes the need for a supportive ecosystem that encourages citizen participation, nurtures start-ups, and promotes public-private partnerships. Further, the evaluation of smart building integration into smart cities is explored by Lee and Chiu, 2020, who identified key features that smart buildings should fulfill to be compatible with the smart city context. The research included analysis of scientific literature and international projects, which revealed that smart buildings have the potential to become smarter by utilizing smart cities capabilities in the areas of smart energy, smart mobility, smart life, and smart environment. This suggests that smart building concepts can be effectively integrated into the broader framework of smart cities to enhance their realization.

Current Trends in Smart Building Implementation

Energy Efficiency and Sustainability: A significant focus in recent SBC implementations is on energy-efficient solutions. As urban areas experience increased energy demands, SBCs use AI and predictive algorithms to minimize energy usage and optimize consumption patterns, as noted by Peng et al., 2021. The integration of renewable energy sources, such as solar panels, into smart buildings is a notable trend.

Integration of IoT and Real-Time Data Analytics: IoT sensors and devices are increasingly used to collect data in real-time. This data is analyzed to create responsive environments, improving operational efficiency and allowing remote monitoring capabilities. A study by Zheng et al., 2019 highlights that IoT has become indispensable in SBCs, enabling predictive maintenance and cost-saving measures.

User-Centric Design and Enhanced Occupant Experience: SBCs aim to create an environment that adapts to occupants' needs through personalized settings for lighting, temperature, and security. This trend is driven by the growing emphasis on user satisfaction and productivity within smart buildings.

Focus on Security and Privacy: As buildings become more connected, the importance of cybersecurity has risen. Recent studies emphasize incorporating robust cybersecurity protocols to protect sensitive data and prevent breaches in automated systems (Chen & Chou, 2022).

Common Practices in SBC Implementation

Building Information Modeling (BIM): BIM has become a cornerstone of SBC, allowing for detailed digital representations and simulations of building performance. BIM aids in planning, designing, and managing building information throughout its lifecycle, as highlighted by Li et al. (2021).

Predictive Maintenance and Automation: Predictive maintenance systems utilize IoT data to anticipate failures and optimize maintenance schedules, reducing costs and downtime. In practice, automated HVAC systems, smart lighting, and occupancy sensors are common features in SBCs, as described by Abbas et al. (2020).

Sustainable Materials and Green Building Standards: Many SBC projects now adhere to standards like LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) to promote sustainability. This practice aligns SBCs with broader environmental goals and policies, particularly in urban areas with stringent sustainability regulations.

2.5.1 Current Trends in Smart Building Implementation in East African Countries

Smart buildings integrate advanced technologies such as the Internet of Things (IoT), automation, and energy-efficient systems to enhance operational efficiency and user comfort. In East Africa, the adoption of these technologies is still in its emerging stages, predominantly driven by urbanization and the need for infrastructure development. Recent studies indicate that the implementation of smart technologies is crucial for addressing energy demands, particularly in urban areas where population density is increasing (Ding et al., 2019). Although SBC adoption is slower in East Africa than in developed regions, interest is growing among government bodies, private investors, and international organizations (UN-Habitat, 2020).

The deployment of IoT and fog computing technologies in smart building services has been highlighted as a significant trend. Such technologies facilitate real-time data collection and analysis, enabling better energy management and reducing operational costs (Ferrandez-Pastor et al., 2018). Additionally, the design and implementation of smart disaster management systems emphasize the necessity of integrating technology for urban resilience, particularly in disaster-prone regions (Park et al., 2018).

At a broader continental level, the **Transform Africa Summit** highlighted the adoption of ICT as a crucial component of socio-economic development across Africa. The summit produced **smart city blueprints** encouraging African countries to incorporate data-driven and technology-focused approaches to urban development, emphasizing the importance of smart city frameworks to guide urban expansion (Smart city initiatives in Africa | Brookings).

Trends in Smart Building Implementation

Energy Efficiency and Renewable Energy Integration: One of the main drivers of SBCs in East Africa is energy efficiency, as the region faces frequent power shortages and high electricity costs. In countries like Kenya, Uganda, and Tanzania, there is an increasing trend toward integrating solar energy, efficient lighting, and passive design strategies into building projects. This trend is evident in Nairobi and Kampala, where smart buildings aim to reduce energy dependence through renewable sources and automated systems (Mwangi & Kimani, 2021).

Focus on Sustainability and Green Building Standards: Sustainable building practices are becoming more prominent in East Africa, driven by government policies and international standards such as LEED and EDGE (Excellence in Design for Greater Efficiencies). These standards encourage the use of eco-friendly materials, efficient water management, and minimal environmental impact, with cities like Addis Ababa and Dar es Salaam leading efforts in green building certification (Makena et al., 2020).

Implementation of IoT for Building Automation and Monitoring: IoT-based automation and monitoring are increasingly used to optimize energy consumption, manage resources, and enhance occupant comfort. While IoT penetration remains low compared to global standards, initiatives led by international organizations and private investors are helping develop IoT infrastructure in East African smart buildings. This trend is especially visible in high-end commercial and residential buildings in Nairobi and Addis Ababa (Mbogo & Mulwa, 2022).

Technological Trends in East African Smart Buildings

Adoption of Building Information Modeling (BIM): BIM is increasingly recognized as a vital tool for planning and managing smart buildings. However, its adoption is mainly limited to large projects in Nairobi and Addis Ababa due to the high cost and lack of skilled professionals. BIM is mostly used by multinational construction firms in East Africa, with local firms gradually adopting it through training and collaborations (Waweru & Getachew, 2021).

Emerging Role of Artificial Intelligence (AI) and Data Analytics: While AI is not widely adopted in East African smart buildings due to technological constraints, there are emerging initiatives exploring its potential. AI systems in East African smart buildings could eventually improve energy management, predictive maintenance, and occupant satisfaction, though broader adoption remains a future goal (Githinji & Negash, 2023).

Policy and Regulatory Environment

Supportive Policies and Urban Planning: Government policies in East African countries are increasingly emphasizing sustainability, although specific policies for smart buildings are still evolving. Countries such as Kenya and Rwanda have made strides in green building policies and digital infrastructure development. For example, Nairobi's Green Economy Strategy and Implementation Plan support sustainable urban development, promoting policies conducive to smart buildings (World Bank, 2018).

Challenges of Inconsistent Policy Implementation: Despite efforts toward supportive regulations, policy inconsistencies and limited enforcement remain significant obstacles. Many East African countries lack clear frameworks to standardize smart building technology adoption, leaving developers uncertain about compliance requirements (UN-Habitat, 2020).

Despite the promising trends, several challenges hinder the widespread adoption of smart building technologies in East Africa. These include limited access to financial resources, insufficient technical expertise, and a lack of governmental support and policy frameworks (Samad et al., 2016). Additionally, the socio-economic context of East African countries often prioritizes immediate infrastructural needs over long-term sustainability goals, which can impede the integration of smart technologies.

Furthermore, the current literature indicates a need for comprehensive studies that focus on the socio-cultural factors influencing technology adoption in this region. Understanding the local context is vital for designing interventions that align with community values and practices (Abegunde et al., 2019).

2.5.2 Current Trends and Practices of SBC Implementation in Adama City, Ethiopia

Adama City, like many rapidly urbanizing cities in Ethiopia, faces growing pressures on infrastructure, energy, and environmental resources due to increasing population and urban expansion. The smart building concept (SBC) has been highlighted as a potential solution to address these challenges by promoting energy efficiency, improving building management, and enhancing occupant comfort through technology. However, the adoption of SBC in Adama is in its early stages, with limited implementation compared to other urban areas worldwide (UN-Habitat, 2020).

Current Trends in Smart Building Implementation

Limited but Growing Interest in Energy Efficiency: Due to frequent power shortages and high energy costs, there is an emerging focus on energy-efficient building designs in Adama. However, most energy-saving practices remain traditional, with limited integration of advanced technologies. Local construction firms have started to experiment with efficient lighting, insulation, and passive solar design, but fully automated systems and IoT-enabled devices are not yet widespread (Ministry of Urban Development and Construction, 2017).

Increasing Awareness of Sustainability and Environmental Impact: SBC practices aimed at reducing carbon footprints and enhancing sustainability are becoming more popular, particularly for government and institutional buildings. However, the lack of local expertise and technological infrastructure limits more comprehensive implementation of SBCs, as noted in studies by Gebeyehu and Tesfaye ,2021.

Limited Integration of IoT and Smart Devices: While IoT and real-time monitoring devices are essential for smart buildings, their adoption in Adama is limited due to high costs and limited expertise. The lack of infrastructure for data management and analysis further hinders the use of smart devices in building systems. Studies indicate that building operators in Adama primarily rely on manual monitoring rather than real-time data, resulting in limited energy optimization and predictive maintenance capabilities (World Bank, 2018).

Emerging Use of Building Information Modeling (BIM): BIM has seen some uptake in larger construction projects, mainly led by international contractors or organizations promoting modern construction standards in Ethiopia. However, challenges related to BIM adoption in Adama include high costs, a lack of skilled professionals, and limited software access (Amare, 2022).

Inconsistent Policy Frameworks: Although Ethiopia has introduced policies aimed at supporting sustainable development, a coherent and supportive regulatory framework specifically for SBC implementation in Adama is lacking. Inconsistent building codes, limited policy incentives, and regulatory ambiguities hamper the adoption of smart technologies in buildings. Policy reforms focusing on sustainable construction and digital innovation are underway, but they are still insufficient to drive widespread SBC adoption in Adama (UN-Habitat, 2020; Ministry of Urban Development and Construction, 2017).

Need for Financial Incentives: There is minimal government funding or tax incentives to encourage smart building practices. This lack of financial support makes SBC implementation challenging, particularly for private developers and small-to-medium-scale projects that cannot bear the high upfront costs of advanced smart technologies (World Bank, 2018).

Challenges to Smart Building Adoption in Adama

High Costs and Limited Financing Options: SBC technologies often require substantial upfront investment, which is prohibitive for many stakeholders in Adama. According to Yimam, 2023, limited financing mechanisms and high import costs for smart technology equipment discourage local developers from adopting SBC solutions. This financial barrier affects smaller projects and deters private sector investments.

Skill and Knowledge Gaps: Another significant barrier is the limited expertise among architects, engineers, and construction managers regarding SBC practices and technologies. A survey by Yimer et al., 2022 reveals that professionals in Adama need more training in SBC design and implementation, which impacts the feasibility of adopting advanced building management systems and automation technologies.

Low Public Awareness and Demand: Limited public awareness regarding the benefits of smart buildings leads to low market demand. Without understanding the long-term advantages, such as energy savings and improved comfort, property owners and developers are less likely to invest in smart building solutions (Gebeyehu & Tesfaye, 2021).

In Adama City, SBC implementation is currently limited but has potential for growth with adequate policy support, training programs, and financial incentives. Addressing specific challenges such as high costs, skill gaps, and limited public awareness can foster a more robust SBC adoption in Adama. This literature review highlights the need for context-sensitive solutions that accommodate Adama's unique challenges, such as economic constraints and infrastructural limitations, while aligning with broader trends in sustainability and technological innovation.

2.6 Factors for Successful Application of SBCs

This literature review explores the factors that enhance the smart building concept, contributing to the broader realization of smart cities proposed by different authors and scholars.

Mohd Asmoni et al. 2015, highlighted that many developed and developing countries have adopted a series of smart building-related policies, including mandatory regulations, financial incentives and tax concessions, to promote the development of smart building projects over the years, owing to the environmental, social, and economic benefits of smart buildings (Mohd Asmoni et al. 2015).

Javed et al., 2019, identified critical success factors (CSFs) for implementing smart building projects, such as stakeholder engagement, clear project objectives, effective communication, skilled workforce, and alignment with organizational goals. Sfakianaki, 2019 classified CSFs into five categories such as environmental factors, economic factors, social factors, design and technique factors and policy and regulation factors for the adoption and implementation of sustainable construction which smart building concepts form the larger part of the sustainable development goal. Wang and Zhang, 2021 present key success factors for smart building implementation based on a case study approach, including strategic planning, stakeholder collaboration, technology integration, data analytics capabilities, and continuous improvement processes. Liu et al., 2021 review enablers and barriers to smart building implementation, highlighting factors such as financial resources, technical expertise, regulatory frameworks, industry standards, user training, and change management strategies. Meanwhile, Owusu-Manu et al., 2021 identified the instrumentation and control factor, computer self-efficacy factor, participation and collaboration factor, viable funding strategy, top management support, connection with professionals and interoperability as factors influencing the adoption of a smart building.

Ejidike, C.C., 2022, identified also that the most significant drivers influencing the adoption of smart building technology in the Nigerian construction industry are participation and collaboration, energy and cost-saving, stakeholder's computer, data management, job creation, viable funding strategy, interoperability, health care, IT professional support, connection with professional, top management support, environmental protection, Stakeholder's engagement and Comfortability of users.

2.6.1 Factors Enhancing Smart Building Concepts

The following are details of the factors that enhance the smart building concept, contributing to the broader realization of smart cities proposed by several authors.

1. **Integration of Technologies and Collaboration with Technology Providers**

The integration of Internet of Things (IoT) technologies within smart buildings is fundamental in addressing requirements such as comfort, usability, security, and energy management. Global case studies indicate that technology integration is a critical enabler of energy efficiency, automation, and sustainable urban development (Albino, Berardi, & Dangelico, 2015). Rathore et al., 2016 emphasize that IoT-based systems facilitate real-time data collection and analysis, allowing for responsive adjustments in building operations that enhance occupant satisfaction and energy efficiency. Minoli et al., 2017 highlight the importance of next-generation building management systems that utilize IoT considerations for energy optimization, illustrating a direct link between smart buildings and the overarching goals of smart city development. Furthermore, Ullah et al., 2021 identified the integration of emerging technologies such as blockchain as a crucial factor by Blockchain can enhance security and interoperability in smart buildings, facilitating better data management and communication between different systems. This integration can play a significant role in the development of smart learning environments that are compatible with smart building concepts, making it an area of interest for future research.

Partnerships with local and international technology firms can provide access to advanced smart building technologies and expertise. Collaborative approaches have been shown to enhance technology transfer and innovation (Chesbrough, H., 2003).

2. **Policy Framework and E-Governance**

Governments that implement clear, consistent policies promoting smart technologies see higher rates of adoption and technological innovation (Khan et al., 2020). The Ethiopian government has been actively promoting sustainable urban development through policies that encourage investment in smart technologies (Federal Democratic Republic of Ethiopia, 2016).

Studies highlight how e-governance platforms streamline approvals and improve collaboration between governmental bodies, developers, and technology providers, leading to more efficient smart building projects (Gil-Garcia et al., 2020). The convergence of smart cities and e-governance is evident in how ICT-based tools enhance governmental approaches, allowing for increased participation from citizens (Rao & Prasad, 2018). Bokhari & Myeong, 2023 proposed that E-governance plays a crucial role in the integration of digital technologies and government services, which is essential for the successful implementation of smart building initiatives. Additionally, Apanaviciene et al., 2020 propose a framework for integrating smart buildings into smart cities, emphasizing cross-sector collaboration and citizen-centric governance, which can guide policymakers.

3. Public Awareness and Education

Raising awareness and deepening the understanding of smart building benefits among stakeholders, including builders, investors, and the general public, is essential for driving the adoption of smart buildings. According to Zhang et al., 2017, enhancing public understanding of the benefits of smart and sustainable buildings is crucial for driving adoption, as informed stakeholders are more likely to support such initiatives. Chomać-Pierzecka and colleagues, 2022, stated public awareness of the economic and environmental dimensions of energy transformation has been shown to influence the adoption of sustainable technologies. Additionally, Ejidike and Mewomo, 2023 highlighted the benefits of adopting smart building technologies in building construction, emphasizing the importance of public awareness and education in driving adoption.

In Africa, research underscores the role of education in overcoming barriers to smart building adoption. Watson et al., 2019 find that awareness programs focused on sustainability and smart technologies have positively impacted adoption rates in various African cities.

4. Environmental and Sustainability Considerations

As the world focuses on meeting climate action goals (such as the Paris Agreement), cities increasingly prioritize sustainable building practices to reduce their environmental impact (Jiang et al., 2018; Deakin & Reid, 2018). The integration of sustainability into smart building concepts is critical for climate change mitigation, as outlined in studies that focus on the intersection of urban development and environmental goals (Hodson & Marvin, 2010). Environmental and sustainability considerations play a crucial role in the adoption of smart building technologies (McCulloch et al., 2023). These considerations encompass the use of organic electronic products and their impact on the environment, making it essential for smart building projects to prioritize sustainability in their design and operations.

Emphasizing sustainability in building practices aligns with global trends and local needs for energy efficiency. Sustainable building practices are increasingly recognized as essential for urban development (International Energy Agency, 2020).

McCulloch et al., 2023 suggested that environmental and sustainability considerations play a crucial role in the adoption of smart building technologies and Bakare, Abdulkarim, Zeeshan, & Shuaibu, 2023 proposed that energy management contributes to the efficient utilization of resources and the reduction of environmental impact. Studies highlight also that sustainable design principles-including energy-efficient technologies, renewable energy integration, and waste reduction strategies are critical in the adoption of smart buildings (Häkkinen & Belloni, 2011; Berardi, 2013).

Green building certifications, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), drive the adoption of sustainable practices in smart building projects (Häkkinen & Belloni, 2011).

Research emphasizes that the use of **smart energy systems**, such as smart grids**,** energy-efficient HVAC systems**,** and renewable energy integration, is essential to reducing operational costs and environmental impacts in buildings (GhaffarianHoseini et al., 2016; Granell et al., 2019). In developing regions, research highlights that energy management solutions can also address challenges related to energy supply reliability, which is particularly relevant to this research in Adama City, where power supply constraints exist (Pueyo et al., 2013; Watson et al., 2019).

In developing cities, research suggests that adopting sustainable construction practices helps mitigate the effects of rapid urbanization, which often strains local resources and infrastructure (Maimunah et al., 2017; Lamine et al., 2019).

5. **Infrastructure Development**

Developing robust infrastructure, such as reliable power supply and internet connectivity, is crucial for smart building operations. The World Bank emphasizes the importance of infrastructure in supporting smart city initiatives (World Bank, 2018).

6. **Cost-Effectiveness and Resource Availability**

Taveres-Cachat et al. (2019) underscore the need for cost-effective solutions that incorporate IoT, fog, and cloud technologies. In a developing context like Adama City, affordability and access to resources are critical factors influencing the adoption of smart building technologies (Taveres-Cachat et al., 2019). The potential for open-source hardware and software solutions also presents an opportunity to lower costs and enhance accessibility.

7. **Investment in Research and Development**

Encouraging Research & Development can lead to innovations tailored to local conditions and needs. Investment in R&D is critical for adapting global smart building solutions to local contexts (United Nations Conference on Trade and Development, 2020).

8. **Capacity Building and Training Programs**

Training programs for architects, engineers, and construction workers on smart technologies can enhance local expertise. Capacity building is essential for the successful implementation of new technologies (UN-Habitat, 2019). Studies on smart cities, including smart building development, show that education is key to building a knowledgeable workforce capable of managing and implementing smart technologies. Mohanty et al., 2016 highlight that awareness campaigns and training programs are instrumental in increasing the adoption of smart buildings by reducing resistance to change and fostering a culture of innovation.

9. **Pilot Projects and Demonstrations**

Implementing pilot projects can showcase the benefits of smart buildings and encourage wider adoption. Pilot projects have been effective in demonstrating the feasibility and advantages of smart technologies in various contexts (Zhou et al., 2019).

10. **Data Analytics and Real-Time Decision Making**

Silva et al. (2017) highlight the importance of big data analytics in enhancing the performance of smart cities through real-time data processing and decision-making. The ability to analyze data effectively allows for better resource management and energy optimization within smart buildings, which is essential for sustainable urban development (Silva et al., 2017).

11. Energy Management and Benchmarking

Energy management is a pivotal factor in the success of smart buildings within smart cities. Francisco et al. (2020) propose a digital twin-enabled energy management system that allows for real-time urban building energy benchmarking, which is essential for efficient resource allocation and consumption monitoring. Such systems not only optimize energy use within individual buildings but also contribute to the resilience and sustainability of the city as a whole.

12. Urban Digital Twins

Urban digital twins have emerged as a critical tool in the planning and design of smart cities, providing a virtual representation of physical environments that supports participatory and collaborative processes. Dembski et al. (2020) discuss how these digital models can be employed to simulate building performance and urban dynamics, ultimately aiding in decision-making processes. The use of digital twins not only enhances the efficiency of smart buildings but also aligns with the efforts to create sustainable urban environments (Minoli et al., 2017).

13. Smart City Ontologies

The development of smart city ontologies has been shown to improve the effectiveness of smart city applications, including those related to smart buildings. Komninos et al. (2016) argue that establishing a comprehensive ontology allows for the integration of various applications across larger city entities, thereby enhancing interoperability among systems. This integration is crucial for harmonizing smart building features with the broader smart city framework, fostering a cohesive urban ecosystem.

14. Decision-Making Support through Advanced Algorithms

Advanced algorithms, such as the **BIM BD** (Building Information Modeling Big Data) processing algorithm based on Bayesian Network Structural Learning, are critical in the efficient use of complex data in smart cities. Xia et al., 2022 illustrate how such algorithms empower decision-makers by providing actionable insights derived from vast data sets, ultimately facilitating better planning and execution of smart building initiatives that align with smart city objectives.

2.7 Barriers to Smart Building Concept Application

Despite the numerous benefits of the smart building concept in the construction industry, the concept has not taken full advantage due to the professional perception of the barriers, which has an immense effect on the adoption of the smart building concept in the building sector of the construction industry (Shen, Zhang, and Long, 2017). Researchers have investigated the barriers to the adoption of smart building concepts in the building sector of the construction industry of both developed and developing countries. In developing countries, economic barriers are the main obstacles in Smart Building projects construction (Bandara et al., 2019). Environmental barriers are widely recognized in the building sector of the construction industry and the smart building concept is seen as a feasible strategy for sustaining the construction industry's environmental, social and economic sustainable development (Olawumi and Chan, 2020). Bandara et al., 2019 identified barriers to implementing smart buildings: classified as Economic Barriers, Environment Barriers, Social barriers and Regulatory, Technical and Other Barriers. Jones and Brown, 2018 highlight key challenges in implementing smart buildings, such as the complexity of integrating various building systems, the need for specialized skills and expertise, and resistance to change among building occupants.

Recent studies have identified various barriers to the adoption of smart building technologies in developing countries, particularly in the construction industry (Baharetha et al., 2024, Affonso et al., 2024 and Vargas, R.V et al., 2022.). These barriers include the high cost of smart sustainable materials and equipment, lack of effective political guidance, inadequate design standards, and challenges in project management processes. Smart buildings play a crucial role in cities but face limitations due to these barriers (Affonso, E.O et al., 2024). Information is missing on specific recent studies focusing solely on the construction industry challenges in developing countries.

El-Motasem et al., 2021 identified Challenges of Smart Building Project in Egypt based on analysis of questionnaire survey by categorizing in phases as: Data Collection and Feasibility Study Phases challenges, Concept to Schematic Design Phases challenges, Detailed Design Phase challenges, Construction to Testing and Commissioning Challenges Phases challenges and Operation and Maintenance Phase challenges.

Ejidike, C.C., 2022 discovered barriers to smart building concept adoption in the Nigerian construction industry: the high cost of smart building materials, inadequate power supply, resistance to change from the use of traditional technology, poor maintenance culture, poor knowledge of smart building technology, inadequate well-trained labor in the practice of smart building construction and inadequate finance schemes. They also discovered that inconsistent government policy and a lack of local institutional facilities for research are significant barriers to adopting the smart building concept.

The following are challenges and limitations associated with the implementation of smart buildings, synthesized from various research insights.

1. Technological Challenges

One of the primary barriers to the application of smart building concepts is the lack of comprehensive end-to-end standards. Dameri and Rosenthal-Sabroux, 2014 emphasize that fragmented cybersecurity solutions and a scarcity of fully-developed vertical applications hinder the integration of smart technologies in building management. Moreover, Minoli, Sohraby, and Occhiogrosso, 2017 point out that the Internet of Things (IoT) presents significant considerations and requirements for energy optimization in smart buildings, highlighting the complexity involved in establishing effective building management systems.

2. Financial Constraints

Financial barriers are also prominent in the adoption of smart building technologies. Rathor and Saxena, 2020 note that the higher costs associated with green building technologies (GBTs) deter stakeholders from investing in smart infrastructure. Additionally, Fernández-Caramés and Fraga-Lamas, 2019 discuss the high financial costs involved in infrastructure maintenance and the impact of informal economies, which complicate the funding and implementation of smart building projects.

Inadequate Finance Schemes: Financial constraints are a well-documented barrier to the adoption of smart technologies in buildings, especially in developing countries. According to Aghimien et al., 2020, limited access to financial schemes, high upfront costs, and inadequate government support for financing smart and sustainable construction projects is primary obstacles in many African nations, mirroring the situation in Adama City.

High design costs: High design and construction costs are cited as significant barriers to the implementation of smart buildings. Chan et al., 2018 emphasize that the complexity and cost of integrating smart technologies into building designs often deter developers, particularly in regions where the market for such technologies is still in its infancy.

3. Awareness and Knowledge Gaps

A significant barrier is the lack of awareness regarding smart technologies and their benefits. Ke et al., 2018 highlight that privacy and security needs vary greatly across application domains, and the financial and human resources available for security implementation differ widely. This disparity creates a knowledge gap that affects the decision-making processes of stakeholders in adopting smart building technologies.

Poor Maintenance Culture: A poor maintenance culture is also linked to a lack of skilled personnel trained in maintaining smart building systems. Smart technologies require specialized knowledge for troubleshooting and updates, but in many cases, building managers lack access to professionals with the necessary expertise (Usman & Bamidele, 2021). Buildings that incorporate smart technologies such as advanced energy management systems, automated controls, and integrated safety features require consistent monitoring and upkeep to perform optimally (Musa & Odewale, 2019). **Carli et al., 2021**, notes that operational barriers like maintenance and user adaptation are often overlooked but crucial for long-term success.

There is often a lack of understanding among stakeholders about the long-term financial benefits of consistent maintenance, including lower repair costs and prolonged equipment lifespan (Akinola, 2019). There is a tendency to overlook regular maintenance until a system failure occurs, which can result in higher costs and reduced efficiency of smart building features (Ahmad, 2020). Studies have shown that inadequate maintenance can lead to faster degradation of smart systems, making them less reliable and less likely to achieve their intended energy-saving and sustainability goals (Adebola & Johnson, 2018).

4. Regulatory and Governance Issues

Governance challenges further complicate the deployment of smart buildings. Syed et al., 2021 report that challenges in IoT system deployment for smart cities reflect broader governance issues that can impede the effective application of smart building concepts. The interplay between regulatory frameworks and technological advancements requires further exploration, as existing laws may not adequately address the unique challenges posed by smart technologies.

Inconsistent Government Policy: emerged as the top barrier, underscoring the critical role of supportive government frameworks in SBC adoption at Adama. Research highlights that inconsistent or unclear government policies can significantly hinder the adoption of smart building concepts. Opeyemi et al., 2019 discuss how fluctuating regulatory frameworks and a lack of long-term government commitment can create uncertainty, leading to hesitation in investment and innovation within the construction industry.

5. Security and Privacy Concerns

The security and privacy of smart building applications are critical concerns. Lin and Bergmann, 2016 discuss the challenges posed by IoT privacy and security in smart home environments, which are directly applicable to smart buildings. The need for robust cybersecurity measures is underscored by the varying degrees of financial and human resources available for security implementations, as noted by Ke et al., 2018.

3. MATERIALS AND METHODS

3.1 Introduction

This chapter outlines the methodology employed to achieve the research objectives, presenting the research design and approach used. It details study area and population, sample size, sampling techniques, types of data, data sources, tools for data collection and analysis, methods of data analysis and presentation.

A detailed flowchart illustrating the overall research process, from data collection to the development of the framework, is presented below to clarify the progression and integration of each research stage.

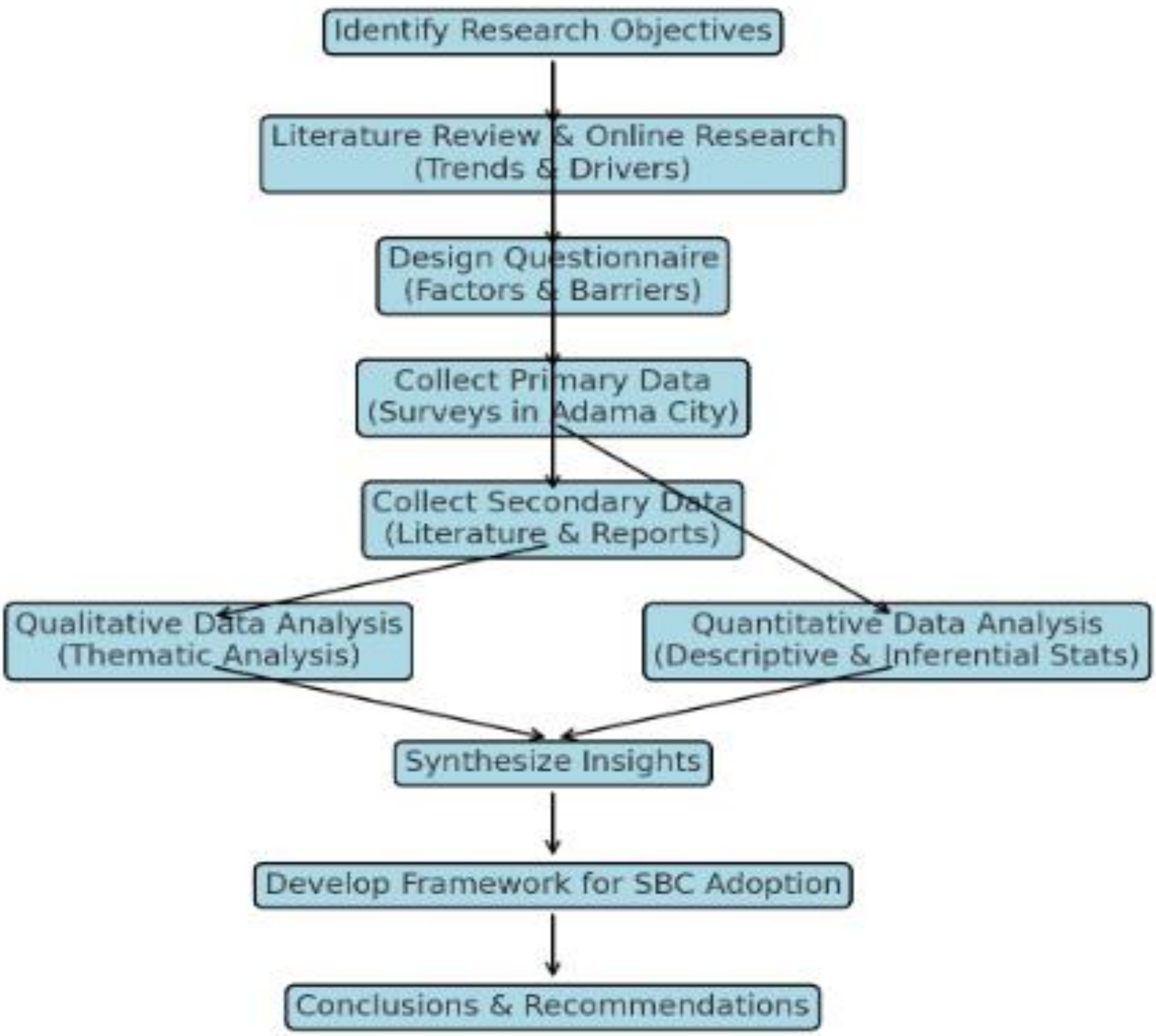

Figure 3.1 flowchart illustrating the overall research process, from data collection to the development of the framework

3.2 Research Design

Research design is a strategy that specifies how, when and where data will be collected and analyzed (Creswell and Poth, 2016). However, the design to be selected is based on the research approach that is more suitable for the study.

This study utilized a mixed research method approach, combining quantitative and qualitative methods. The quantitative component will involve a questionnaire survey study, while the qualitative component will involve literature review and online research.

3.3 Study Area

Adama is one of the cities of Oromia Region of Ethiopia located in the East Shoa Zone 99 km (62 miles) southeast of the capital, Addis Ababa. Adama is strategically situated along the highway connecting Addis Ababa with the eastern parts of the country, making it a crucial urban center for transportation and trade. The City is bordered to the south by the Arsi zone, to the southwest by the Koka Reservoir, to the west by Lume district, to the north by the Afar region, and to the east by the Boset district. The city is geographically situated between the base of an escarpment to the west and the Great Rift Valley to the east (Wikipedia, the free encyclopedia). The total area of Adama City covers around 54,301.15 hectares (Ada MaCity). Adama is located at latitude 8.514477 and longitude 39.269257 (GPS coordinates 8° 30' 52.1172" N and 39° 16' 9.3252" E), with an elevation of 1,712 meters.

According to recent estimates, Adama has a population of around 875,148 people, though the actual population may fluctuate depending on migration patterns, urbanization, and economic development, making it one of the fastest-growing cities in Ethiopia (Ada MaCity). The city's diverse population comprises different ethnic and social groups, reflecting its role as a regional hub. Adama serves as a key transportation hub and an educational center, home to Adama Science and Technology University. It is also known for its large stadium and several prominent hospitals. As the economic hub of the region and one of the first cities in Ethiopia to adopt smart city initiatives, Adama was selected as the focus for this study.

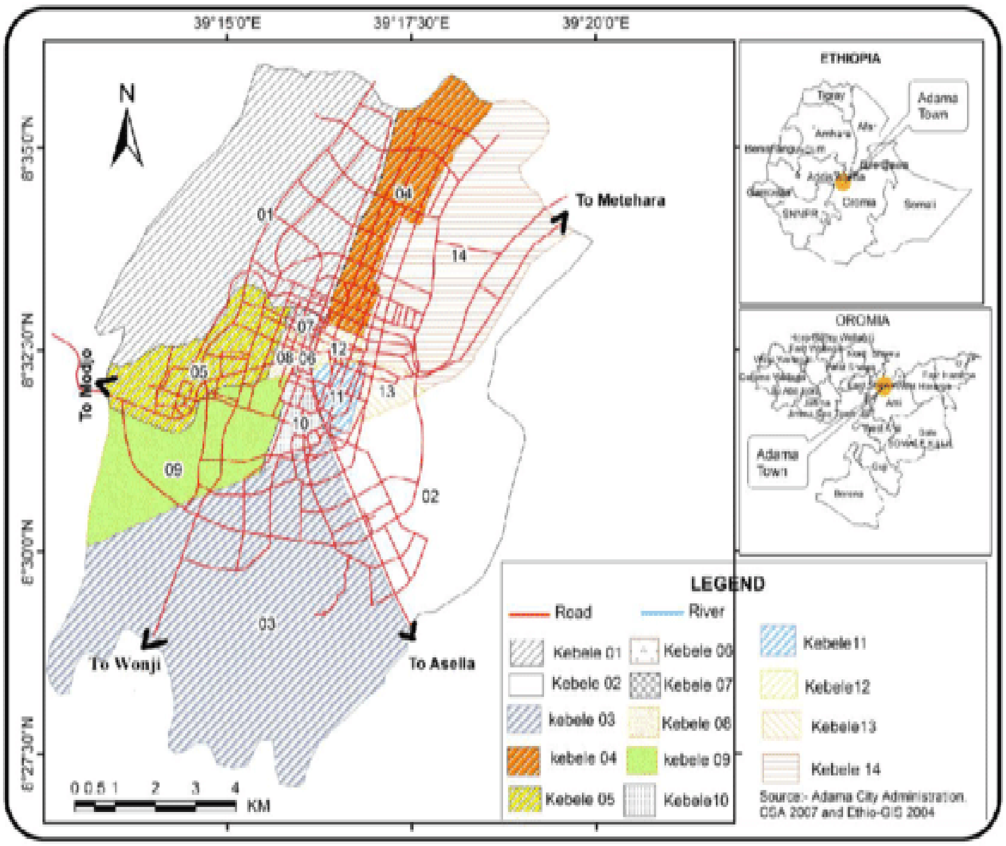

Figure 3.2 Location and administrative divisions of Adama city (ACA, ESRI ® map of 2015 and Messay, 2010).

3.4 Respondent Population

In statistics, a population is an entire group about which some information is required to be ascertained. According to Banerjee, A. and Chaudhury, the study population in epidemiological research does not correspond always with its demographic meaning of an entire group of people living within certain geographic or political boundaries. A population for a research study may comprise groups of people defined in many different ways (Banerjee, A. and Chaudhury, S., 2010).

By reviewing literature from diverse sources, a comprehensive understanding of the current trends and practices of the Smart Building Concept are explored.

For questionnaire survey on the drivers enhancing smart building adoption and barriers to smart building adoption in Adama city, the respondent population encompassed construction professionals including Architects, Engineers (Civil, Mechanical, and Electrical) and Quantity Surveyors practicing in Construction Authority, Design Offices, Contractors and

Building owners in the Adama city as they are the primary participants who have substantial involvement and responsibilities in smart building concepts in the Adama city.
In Adama City, Ethiopia, there is a significant presence of construction professionals, including consultants, contractors, and building owners, although specific numbers can vary.

According to directories and reports, the city hosts numerous construction companies and contractors. Based on sector insights and reports, the following estimates are anticipated (AddisBiz.com)(Construction in Ethiopia): Adama, being a key urban center, likely has a significant number of consultants in fields like architecture, civil engineering, and building design. Based on general estimates from the construction sector across Ethiopia, the number of consulting firms in Adama range from **20 to 40 firms**. There are about **26 registered construction companies** in Adama, according to specific reports on the construction sector in the city. This number includes contractors working in various construction and infrastructure development projects. The number of building owners would logically be higher, potentially ranging in the **100**, as many property developers and private individuals own buildings and properties in Adama. This includes both private real estate developers and those involved in public infrastructure projects.
Based on the above estimation, the sample population is tabulated as shown below:

Table 3-1Sample Population

SN	Professions	Population				
		Construction Authority	Consultants	Contractors	Building owners	**Total**
1	Architects	3	22	26	52	103
2	Engineers	8	21	28	51	108
3	Quantity Surveyors	4	20	26	50	100
	Total	**15**	**63**	**80**	**153**	**311**

Source: (AddisBiz.com)(Construction in Ethiopia) (2024)

3.5 Sampling Technique

For a literature review and online research on the current trends and practices of Smart Building Concept implementation: **Purposive (Judgmental) Sampling** approach is adopted. The reason for purposive (also judgmental) sampling is the better matching of the sample to the aims and objectives of the research, thus improving the rigor of the study and trustworthiness of the data and results (Campbell, S et al., 2020).

For questionnaire survey on the factors enhancing smart building adoption and barriers to smart building adoption in Adama city, a **random probability sampling** technique is adopted. All the targeted professions (Architects, Engineers and Quantity Surveyors) in Adama City will have an equal chance and likelihood of being selected for participation in the study. This sampling technique aims to ensure representativeness and generalizability of the findings to the target population.

3.6 Sample Size

A sample is a section or subset of the study population selected to research a sampling process (Taherdoost, 2016). From the respondent population, the total population of registered construction professionals within the study area is 311.

According to Islam, 2018, the Yamane formula provides a simplified formula to calculate sample sizes. Using this formula the sample size for each professional are tabulated below:

n= $\boldsymbol{N}$ [$\mathbf{1}$+($\boldsymbol{e}\mathbf{2}$)]

Where: n = the sample size

N = the total population

e = the level of precision (10%) 1= unit (constant)

Table 3-2 Sample Size of the respondents

SN	Professions	Population					Sample Size
		Construction Authority	Consultants	Contractors	Building owners	**Total**	
1	Architects	3	22	26	52	103	51
2	Engineers	8	21	28	51	108	52
3	Quantity Surveyors	4	20	26	50	100	50
	Total	**15**	**63**	**80**	**153**	**311**	**153**

Source: Sampling Calculation Result (2024)

Therefore, a total of 153 questionnaires were randomly distributed to selected respondents, including construction professionals working in the Adama City Construction Authority, consulting firms, contractors, and building owners' offices, as part of this research.

3.7 Data Sources and Tools of Data Collection

To address the research objectives, various data sources and collection tools are utilized: For Research Questions 1, information on current trends and practices of Smart Building Concept implementation is gathered through literature review from academic journals, conference papers, reports and from online databases (such as Google Scholar, the African Development Bank (AfDB) Data Portal, and the UNECA Knowledge Hub). Government websites, industry publications, and research repositories are also explored to investigate ongoing SBC projects and initiatives. For Research Questions 2 and 3, structured questionnaires are distributed to construction professionals working in Adama City's Construction Authority, Consultants, Contractors and Building owners to capture their perceptions on drivers of SBCs and barriers to SBC adoption. The survey includes closed-ended questions to collect quantitative data, with paper-based questionnaires organized according to study variables.

3.8 Data types

The study utilizes both primary and secondary data to gain comprehensive insights into the application of Smart Building Concepts (SBCs) in Adama City. Primary data focuses on factors enhancing SBCs and the barriers to their adoption, gathered directly from professionals working in Adama City's Construction Authority, Consultants, Contractors and Building owners through a structured questionnaire. Secondary data, regarding current trends and practices of SBC implementation, are sourced from a thorough literature review. The study incorporates both qualitative data (non-numerical insights into trends of SBCs) and quantitative data (numerical responses from closed-ended survey questions related to the factors and barriers of adopting SBCs in Adama), enabling a mixed-methods approach to analysis.

3.9 Study Variables to Achieve Specific Objectives

For research objective 1: To identify the current trends and practices of Smart Building Concept implementation, with a focus on enhancing smart city realization, the study variables considered are: Technological Infrastructure**,** Building Design and Construction, Energy Management and Efficiency, Data Analytics and Connectivity, Regulatory and Policy Framework, Sustainability and Environmental Considerations, Stakeholder

Engagement and Collaboration, Industry Collaboration and Partnerships**,** Financial Investment and Funding and Education and Awareness**.**

For research question 2: To assess factors that enhance the applicability of Smart Building Concept, primary data is collected on important study variables such as: Policy Framework and E-Governance, Integration of Technologies and Collaboration with Technology Providers, Public Awareness and Education, Environmental and Sustainability Considerations, Infrastructure Development, Investment in Research and Development, Capacity Building and Training Programs, Pilot Projects and Demonstrations, and Energy Management.

For research question 3: To identify the **barriers** to the application of Smart Building Concepts, primary data is collected on important study variables such as: **1**. **Feasibility Study Phase barriers** (inadequate finance schemes, inconsistent government policy and Lack of research work), **2**. **Design phase barriers (**High design costs, high cost of smart building materials, poor knowledge of smart building technology), **3. Construction phase barriers** (inadequate power supply and inadequate well-trained labor) and **4. Operation and maintenance phase barriers** (poor maintenance culture and resistance to change from the use of traditional technology). This categorization helps identify at which stage the barriers are most impactful in the process of adopting smart building technologies.

3.10 Research Instrument

The Literature review and survey research design was used in this study. The Literature review is used for research objective 1 for analyzing official documents, policy papers, industry reports, and case studies related to Smart Building projects towards smart city realization. The questionnaire survey is used for research objective 2 and 3 to identify factors enhancing SBCs adoption and barriers of SBCs adoption in Adama city. The questionnaire consisted mainly of close-ended questions to ensure that quantitative data were adequately captured. According to Abawi, 2013, survey questionnaire is a primary data collection method consisting of a series of questions with multiple options for responses, intending to gather information from participants. A questionnaire was utilized as the research instrument to collect data from prospective professionals in this study. The questionnaire is divided into three sections. Section A seeks to obtain background information of the respondents. Section B contain the factors that can enhance the implementation of smart building concept and the specific barriers and challenges hindering the application of smart building concepts in Adama City and section C contains additional Comments of respondents.

3.11 Administration of the Questionnaire

The questionnaire was administered through physical distribution to professionals. A letter of information and informed consent were included as part of the materials provided to participants. Since the questionnaire was distributed in person, participants were able to read the informed consent form and confirm their voluntary participation. A total of 153 questionnaires were distributed to professionals working in the Adama City Construction Authority, consulting firms, contractors, and building owners' offices, with 120 questionnaires successfully collected. All 120 retrieved questionnaires were deemed suitable for analysis, resulting in a response rate of 78.43%.

3.12 Assurance of Confidentiality and Anonymity

The data collected was treated anonymously under research ethics rules. The findings of the survey were used for research purposes only. There were no risks, current or anticipated, to any research participant in this study. The researcher took the responsibility to protect the participants as an ethical commitment that considers the participant’s rights. Maintaining a high degree of confidentiality and anonymity was a priority for the researcher. No personal details of research participants were required, for example, names, identity numbers, and cell phone numbers. The questionnaire did not include sensitive biographical questions that might identify the participants. The data collection process does not involve access to confidential personal data. Participation in the research was voluntary, and the research participants were allowed to withdraw whenever they liked without any consequences.

3.13 Data Analysis Methods

For research question 1 **qualitative data** obtained from the literature review is analyzed **thematically** to identify patterns, themes, and insights related to current trends of SBCs application.

For research question 2 and 3 **quantitative** data collected through the questionnaire survey is analyzed using programs such as **STATA and Excel** to analyze data related to factors enhancing and barriers hindering the applicability of Smart Building Concepts in Adama City**.** The data analysis was provided using both descriptive and inferential statistics. This method included compiling all the data collected and the findings for the mean score ranking technique, factor analysis and agreement analysis techniques.

For research question 4 results obtained from both qualitative and quantitative are used to develop framework for practical application of SBCs in Adama city.

The analysis methods used are summarized below:

Table 3-3 Data Analysis Methods

S/N	Objectives	Analysis Method	Reason
1	Identify the current trends and practices of Smart Building Concept implementation	Thematic analysis	Appropriate method of organizing and summarizing the findings from a diverse body of both qualitative and quantitative research (Dixon-Woods, Agarwal, Jones, Young, & Sutton, 2005)
2	Identify the factors that can enhance the implementation of smart building concept	Mean Score and Factor Analysis	Factor analysis is used to identify underlying relationships between variables and reduce the data set into fewer, more manageable components that explain the most variance. Used to identify the critical factors enhancing SBC adoption, by exploring latent constructs.
3	Investigate the barriers hindering the application of smart building concepts	Mean Item score and agreement analysis technique (Kendall's coefficient of Concordance)	According to Chan et al.,2017, Kendall's is a non-parametric test used to ascertain the general agreement among rankings
4	Develop a framework to guide the successful implementation of smart building concepts in Adama City, taking into account the unique characteristics and challenges of the city as a case study in Ethiopia	Both qualitative and quantitative data analysis	

3.13.1 Thematic Analysis

Thematic analysis, the often-used methods of qualitative research, provides concise description and interpretation in terms of themes and patterns from a data set (Majumdar, A., 2022). Thematic analysis, through its theoretical freedom, flexibility, rich and detailed yet complex analytical account has emerged as the widely used and most effective qualitative research tool in social and organizational context. Thematic analysis is a useful way to understand experiences, thoughts, or behaviors across a data set. Additionally, due to the clear, easy-to-follow processes outlined by Braun and Clarke (2006, 2012, 2017), researchers have suggested that thematic analysis is an ideal analytic method for novice qualitative researchers (Nowell et al. 2017).

It was therefore considered a suitable method for analyzing data obtained from literature review in this study to identify the current trends of SBCs application.

3.13.2 Descriptive Statistics

Descriptive statistics enable to capture the important features from sample data using tables, charts and graphs then, the described sampling distributions pave the way to inferential statistics (Stapor, K. and Stapor, K., 2020). In this Thesis to assess factors enhancing and barriers hindering SBCs adoption in Adama city, the descriptive statistics were analyzed using the statistical data analysis software, **STATA** which fully computed the frequencies, percentile and mean item score (MIS) of the responses.

This thesis adopted 5-point Likert-type scale for research objective 3, to rate professionals responses. Akinrata, Ogunsemi, and Akinradewo (2020) considered elements with an Important Relative Index (RII) of 0.599 (i.e., a mean score < 2.995) to be irrelevant on a 5-point Likert-type scale. Also, Ade-Ojo and Awodele (2020) considered a mean score of 3.00 and above to be statically significant in measuring a 5-point Likert scale. Opawole and Jagboro (2016) considered a cutoff point of 3.50 appropriate on a 5-point Likert scale which is high compared to others. The cut-off point for this research was 3.00, while the Mean Score (MS) was used to rate each item (outcome). Standard Deviation (SD) is also used in cases where two outcomes have comparable MS values.

3.13.3 Inferential Statistics

Inferential statistics allows drawing conclusions about the whole population from which we took the sample (Stapor, K. and Stapor, K., 2020). A non-parametric test was used for the inferential statistics to analyze the skewed variable distribution of the respondents' results.

3.13.4 Agreement Analysis Technique

Agreement, also known as concordance, is a concept that is closely related to, but fundamentally different from, and often confused with correlation (Vetter, T.R. and Schober, P., 2018).This is specifically applicable: (1) when the same single observer or rater assesses at different times under the same experimental or conditions, which is referred to as intra rater reliability or (2) when multiple observers or raters evaluate the same barriers in a study or practice, which is referred to as inter rater reliability.

Kendall’s coefficient of concordance (Kendall's W) is a nonparametric test commonly employed to measure agreement among raters by assessing variables (Chan et al., 2018). This method does not require any specific distribution of each variable data tested. Kendall's W test was conducted to check the respondent's agreement on research objective 3, barriers to adopting the smart building concept in Adama city. Kendall's W ranges in value between 0 to 1, where a value of 0 indicates “no agreement” and 1 indicates “complete agreement (Chan et al. 2018). Meanwhile, Siegel and Castellan (1988) highlighted that the null hypothesis could be rejected. There is some agreement among the respondents if Kendall's W value generated from the test is a low significance (asymptote significance level 0.001).

3.13.5 Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis is used to regroup variables into a limited set of clusters based on shared variance. Hence, it helps to isolate constructs and concepts (Beavers, A.S et al., 2019). Factor analysis uses mathematical procedures for the simplification of interrelated measures to discover patterns in a set of variables (Child, 2006).

EFA is used when a researcher wants to discover the number of factors influencing variables and to analyze which variables ‘go together’ (DeCoster, 1998).

3.14 Method of Data Presentation and Analyses

Data analyses were achieved using appropriate descriptive and inferential statistics. For qualitative data, thematic analysis is used to investigate data from literature review and for qualitative data; descriptive statistical analysis extensively measures the characteristics of a study population, whereas inferential statistics draw up conclusions or inferences about a population from data sets. The data analyses were facilitated using the Statistical analysis software, STATA. The dependent variables are predicted in this study, while the independent variables are the predictors. The received data was carried out by mean score ranking and agreement analysis techniques using Kendall's coefficient of concordance.

Descriptive statistics are presented in tabular form, with data on frequency, mean, and standard deviation for responses related to SBC barriers and drivers. Charts and graphs visualize key patterns for easier interpretation.

3.15 Ethical Considerations

Ethical considerations, including informed consent, confidentiality, and data protection, are upheld throughout the research process. Participants' anonymity and privacy are ensured during data collection and analysis.

By employing a mixed research method approach with questionnaire survey study and document review methods, this study develop a framework to guide the successful implementation of smart building concepts in Adama City, taking into account the unique characteristics and challenges of the city as a case study in Ethiopia.

4. RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the analysis and discussion of the findings derived from both qualitative and quantitative data, aligning with the research objectives. Data collection and analysis were conducted in accordance with these objectives.

For research question 1, qualitative data from the literature review is analyzed thematically to identify recurring themes, patterns, and insights related to the current trends in SBC application.

For research question 2 and 3, quantitative data collected through the questionnaire survey is analyzed using descriptive and inferential statistics, with tools such as STATA and Excel, to examine the factors that enhance and barriers hindering the implementation of Smart Building Concepts in Adama City.

For research question 4, both qualitative and quantitative data from research objectives 1, 2, and 3 are combined to develop a comprehensive framework tailored to the unique characteristics of Adama City.

4.2 Current Trends and Practices of SBCs

Qualitative data obtained from the literature review, drawn from academic journals and articles, government reports, industry reports, media publications, and case studies related to smart building projects is analyzed thematically to identify the themes and insights of smart building initiative.

4.2.1 Thematic Analysis

The following steps are followed to identify the key themes from the literature.

Step 1: Familiarization/know our data

The data from the literature presented in literature review section are familiarized for coding and identify the themes.

Step 2: Coding and Generating Themes

Coding involves breaking down the text into meaningful segments and assigning codes to these segments based on their content and context. To begin the qualitative coding of the literature review, open coding is performed by identifying detailed and descriptive codes for the text.

These codes provide a structure for analyzing the document's content and identifying key trends, practices, and challenges in smart building concept adoption in East Africa and Adama City.

Here are some detailed and descriptive codes for the text from the document, organized by themes: These themes capture the main areas influencing the adoption and practices surrounding smart building concepts, reflecting trends, challenges, and recommendations for SBC implementation.

1. Energy Efficiency and Sustainability

Energy Efficiency in SBCs: Usage of AI and algorithms to reduce energy consumption, with a focus on sustainable energy sources (e.g., solar panels).

Green Building Standards Compliance: Adoption of standards like LEED and BREEAM for environmentally friendly materials and energy-efficient designs.

Renewable Energy Integration: Focus on using solar energy and passive design strategies to address frequent power shortages in East Africa and Adama City.

Sustainability Awareness: Growing awareness in Adama City about reducing carbon footprints and promoting sustainable practices.

2. Technological Integration

IoT and Real-Time Data Analytics: Deployment of IoT sensors for predictive maintenance, operational efficiency, and remote monitoring.

Automation in Building Systems: Automated HVAC systems, smart lighting, and occupancy sensors for efficient building management.

Building Information Modeling (BIM): Use of BIM in large projects to optimize design, construction, and maintenance; limited due to high costs.

Emerging AI in SBCs: Exploration of AI for predictive maintenance and energy management, though adoption remains low in East Africa.

3. User Experience and Design

User-Centric Design: Designing SBCs to adapt to occupants' needs (lighting, temperature, security) for better satisfaction and productivity.

Enhanced Occupant Comfort: Focus on integrating personalized settings and IoT for occupant convenience in high-end buildings.

4. Security and Privacy

Cybersecurity Protocols: Importance of cybersecurity in protecting data and preventing breaches within connected smart buildings.

5. Policy and Regulatory Challenges

Inconsistent Policy Frameworks: Lack of supportive regulations for SBCs in East Africa and Adama City; policy ambiguities and limited incentives.

Emerging Green Policies: Examples like Nairobi's Green Economy Strategy promoting sustainable practices, though SBC-specific policies remain underdeveloped.

Need for Financial Incentives: Minimal government funding or tax incentives for SBCs, impacting adoption among private developers.

6. Challenges in SBC Implementation

High Costs of SBC Technologies: High initial investment costs and limited financing options affecting adoption, particularly in Adama.

Skill Gaps and Training Needs: Lack of SBC-related expertise among professionals, with a need for training in advanced building management.

Low Public Awareness: Limited understanding of SBC benefits, resulting in low demand among property owners and developers.

7. Sociocultural and Economic Context

Socioeconomic Constraints: Prioritization of immediate infrastructure needs over SBC due to financial limitations.

Need for Localized Solutions**:** Call for context-sensitive solutions tailored to economic constraints and infrastructure limitations in Adama City.

Step 3: Reviewing Themes

To ensure that each theme accurately represents the key patterns and issues identified in the coding process, I'll evaluate each one based on relevance, coverage, and clarity in relation to the findings. Here's a breakdown of the themes, assessing their alignment with the patterns from the document:

1. Energy Efficiency and Environmental Sustainability

Evaluation: This theme effectively captures a primary focus area in SBC implementation. The document emphasizes sustainable practices, such as energy-efficient designs and renewable energy sources like solar. It also mentions compliance with green building standards, which aligns with this theme.

Strengths: Reflects a clear priority within SBCs, aligning with the text's frequent references to sustainability and energy conservation.

2. Technological Integration and Automation

Evaluation: This theme represents a core pattern within SBCs, particularly with respect to IoT, real-time data analytics, and Building Information Modeling (BIM). These technologies are frequently mentioned as essential tools for improving building performance and efficiency.

Strengths: Covers a broad spectrum of technological tools mentioned in the document, from predictive maintenance to automation.

3. User-Centric Design and Enhanced Occupant Experience

Evaluation: The theme accurately reflects the user-oriented aspects of SBCs, such as personalization of lighting, temperature, and security, all aimed at improving occupant satisfaction.

Strengths: Well-aligned with document content on creating responsive environments that enhance user experience.

4. Security and Privacy in Connected Buildings

Evaluation: This theme is relevant, as the document highlights the necessity of cybersecurity in connected, technology-driven buildings. As SBCs involve significant data collection, this theme addresses a crucial risk.

Strengths: Directly reflects document mentions of cybersecurity and privacy in SBCs.

5. Policy and Regulatory Support for SBC Implementation

Evaluation: This theme captures the complexity around regulatory frameworks for SBCs, addressing inconsistent policies, enforcement issues, and green building standards.

Strengths: Covers a wide range of regulatory challenges and government initiatives, reflecting key insights from the document.

6. Financial Constraints and Incentives

Evaluation: Financial barriers are a recurrent issue in the document, making this theme highly relevant. It reflects the need for subsidies, incentives, and financing mechanisms to encourage SBC adoption, especially among private developers.

Strengths: Captures a critical barrier well and aligns with the discussion of high costs and limited government funding.

7. Knowledge Gaps and Professional Training Needs

Evaluation: The document frequently mentions the lack of technical skills as a barrier to SBC adoption, making this theme relevant and necessary. Training needs in SBC-related skills are essential for professional capacity building.

Strengths: Represents an actionable area for improving SBC adoption by addressing the expertise deficit.

8. Socioeconomic and Cultural Considerations

Evaluation: This theme appropriately reflects the socioeconomic limitations and cultural aspects that impact SBC adoption in regions like East Africa. It highlights the need for solutions tailored to specific economic and infrastructural realities.

Strengths: Accurately represents the localized challenges mentioned in the document, focusing on the need for region-specific approaches.

9. Public Awareness and Demand for SBCs

Evaluation: The theme is relevant as low public awareness and limited understanding of SBC benefits are noted as significant adoption barriers.

Strengths: Aligns well with document insights on the need for public education initiatives to foster demand.

Overall, each theme is well-founded in the data and provides a comprehensive picture of the document's findings.

Step 4: Defining and naming themes

Here's a refined list of the final themes, with clear definitions and explanations for how each theme helps in understanding the data:

1. Energy Efficiency and Environmental Sustainability

Definition: This theme focuses on reducing energy consumption, integrating renewable energy sources, and adhering to green building standards in smart building implementations.

Explanation: By emphasizing energy-efficient designs, renewable energy use (e.g., solar panels), and green building certifications (LEED, BREEAM), this theme reveals how SBCs align with broader sustainability goals. This understanding clarifies the motivations behind SBC adoption in regions like East Africa, where energy efficiency and environmental responsibility are prioritized due to infrastructure constraints and frequent power shortages.

2. Technological Integration and Automation

Definition: This theme covers the integration of technologies such as the Internet of Things (IoT), artificial intelligence (AI), real-time data analytics, and Building Information Modeling (BIM) to enhance building operations and efficiency.

Explanation: The adoption of these advanced technologies enables smart buildings to optimize performance, predict maintenance needs, and improve energy management. This theme helps in understanding the foundational role of technology in SBCs, illustrating how automation and data-driven processes are central to creating efficient, adaptable buildings.

The theme also highlights the challenges and opportunities associated with technology adoption in developing regions.

3. User-Centric Design and Enhanced Occupant Experience

Definition: This theme centers on designing SBCs with features that improve comfort, productivity, and user satisfaction, including customizable settings for lighting, temperature, and security.

Explanation: By focusing on the user experience, this theme underscores the demand for SBCs to create environments that meet occupants' needs and improve quality of life. This understanding reflects the growing emphasis on personal comfort and satisfaction in SBCs, especially in high-end projects. It also illustrates the added value that SBCs bring by aligning with human-centered design principles.

4. Security and Privacy in Connected Buildings

Definition: This theme addresses the importance of cybersecurity and privacy protection in SBCs, given their reliance on interconnected and data-driven systems.

Explanation: As SBCs collect and use significant amounts of data, this theme emphasizes the need for robust security measures to prevent breaches and protect sensitive information. Understanding this theme sheds light on the potential risks associated with SBC technology and the critical role of cybersecurity in creating safe and reliable smart buildings. It also reflects an essential requirement for building trust in smart technologies among users.

5. Policy and Regulatory Support for SBC Implementation

Definition: This theme covers the governmental policies and regulatory frameworks that impact SBC adoption, including green building codes, sustainable urban planning, and incentives for SBC initiatives.

Explanation: This theme reveals the regulatory landscape’s impact on SBC growth, highlighting how policy consistency and support can accelerate adoption, while gaps and ambiguities may hinder it. Understanding this theme helps clarify the role of government in fostering or challenging SBC progress, particularly in East Africa, where regulatory environments are still evolving.

6. Financial Constraints and Incentives

Definition: This theme explores the financial challenges of SBC adoption, including high costs, limited financing options, and the lack of government incentives, and identifies financial strategies that can encourage SBC investment.

Explanation: Recognizing financial barriers and potential incentives sheds light on the economic feasibility of SBCs. This theme helps identify the need for supportive financing mechanisms (like subsidies or tax incentives) that could make SBCs more accessible. It also reveals a critical challenge for stakeholders, especially private developers and smaller-scale projects, highlighting the role of financial incentives in overcoming adoption hurdles.

7. Knowledge Gaps and Professional Training Needs

Definition: This theme highlights the need for SBC-specific expertise among local professionals, covering gaps in technical knowledge and training requirements for architects, engineers, and construction managers.

Explanation: Understanding this theme emphasizes the need to build technical and management capacity for SBC adoption. It highlights the importance of professional development programs to bridge skill gaps and foster an SBC-ready workforce, especially in regions like East Africa. This theme also identifies training as a foundation for sustainable SBC growth, as skilled professionals are essential for successful implementation.

8. Socioeconomic and Cultural Considerations

Definition: This theme considers the unique socioeconomic contexts and cultural aspects that impact SBC adoption, such as local economic constraints and infrastructure limitations.

Explanation: This theme provides insight into how local economic realities and cultural values shape the feasibility and acceptance of SBCs. By addressing these factors, the theme emphasizes the importance of context-sensitive approaches for SBCs that are adapted to the specific needs and limitations of different regions, such as Adama City. It reinforces the understanding that SBC solutions must be flexible and align with local priorities.

9. Public Awareness and Demand for SBCs

Definition: This theme focuses on the level of public understanding and demand for SBCs, examining how awareness (or lack thereof) influences market demand and SBC adoption.

Explanation: Low public awareness can limit the market demand for SBCs, as property owners and developers may not fully understand the benefits of these systems. This theme highlights the need for educational campaigns to build public support, showcasing the long-term advantages of SBCs, such as cost savings and improved comfort. By understanding this theme, stakeholders can address one of the barriers to SBC adoption through targeted awareness initiatives.

4.3 Background Information of Respondents

The first section of the questionnaire presented the respondent's background information. Demographic characteristics of respondents were scrutinized, including gender, Age, academic qualifications, field of profession, and years of professional experience. A total of 153 questionnaires were distributed to professionals working in the Adama City Construction Authority, consulting firms, contractors, and building owners' offices. Of these, 120 were completed and returned, resulting in a response rate of 78.43%. The respondents provided information on their gender, age, educational background, profession, professional qualifications, and experience in the construction industry, which enhanced the study's reliability regarding their knowledge of smart building concepts.

Table 4-1 Tabulation of background information of Respondents

. tabulate Gender

Gender	Freq.	Percent	Cum.
Male	86	71.67	71.67
Female	34	28.33	100.00
Total	120	100.00	

. tabulate Age

Age	Freq.	Percent	Cum.
25-35	56	46.67	46.67
36-45	54	45.00	91.67
46-55	10	8.33	100.00
Total	120	100.00	

. tabulate Educationalqualification

Educational qualificati on	Freq.	Percent	Cum.
BSc	76	63.33	63.33
MSc	44	36.67	100.00
Total	120	100.00	

. tabulate Profession

Profession	Freq.	Percent	Cum.
Architecture	30	25.00	25.00
Engineer	68	56.67	81.67
Quantity Surveyor	22	18.33	100.00
Total	120	100.00	

.
.
. tabulate Professionalexperience

Professiona l experience	Freq.	Percent	Cum.
5-10	66	55.00	55.00
11-20	54	45.00	100.00
Total	120	100.00	

Source: Field Survey and Stata analysis result (2024)

Table 4.1 reveals that 71.67% of the respondents were male, while 28.33% were female professionals. Regarding age distribution, 46.67% of the respondents were between 25-35 years, 45% were between 36-45 years, and 8.33% were aged 46-55. The educational qualifications show that 36.33% hold a B.Sc degree, and 36.67% have a master’s degree in fields such as Engineering, Architecture, and Quantity Surveying. According to Ghansah et al. (2020), the educational background of the respondents reflects their development skills and critical thinking ability, which strengthens the reliability of the data collected.

In terms of profession, 25% of the respondents were Architects, 56.67% were Engineers, and 18.33% were Quantity Surveyors. As for professional experience, the survey indicates that 55% of respondents have 5-10 years of work experience, while 45% have 11-20 years of experience.

This demographic data highlights the diversity and professional backgrounds of the respondents, which could influence their perspectives on the adoption of the Smart Building Concept (SBC). The strong representation of Engineers, master’s degree holders, and professionals with 5-10 years of experience may shape the perceptions observed in the study's findings.

4.4 Factors Enhancing Smart Building Concept Application in Adama City

This section presented the factors that can enhance the implementation of smart building concept among professionals in the Adama smart City in realization of smart city initiative. Data were gathered using a well-structured questionnaire from construction professionals including Architects, Engineers (Civil, Mechanical, and Electrical) and Quantity Surveyors practicing in Construction Authority, Consultants, Contractors and Building owners in the Adama city. A 5-point rating scale; 1=Not significant; 2=Rarely Significant; 3= neutral; 4= Significant; 5= highly significant was utilized to rank the factors enhancing the adoption of the smart building concept in the Adama city.

Data analysis tools such as Excel and STATA were utilized to analyze the quantitative data collected from the surveys. Descriptive and inferential statistical methods were applied to assess the survey results, enabling the evaluation and interpretation of the data to draw meaningful conclusions.

Table 4.2 shows a record of data representing 120 professionals rating the significance of factors enhancing the adoption of smart building concepts (SBCs) in Adama city across different factors. The ratings range from 1 (Not significant) to 5 (Highly significant).

Table 4-2 Summary of filled questionnaire of 120 respondents on factors enhancing SBCs adoption in Adama city

S/N	Factors	1	2	3	4	5
F1	Policy Framework and E-Governance	10	16	20	30	44
F2	Integration of Technologies and Collaboration with Technology Providers	6	20	30	40	24
F3	Public Awareness and Education	8	18	24	30	40
F4	Environmental and Sustainability Considerations	4	10	36	40	30
F5	Infrastructure Development	12	18	20	36	34
F6	Investment in Research and Development	16	20	34	30	20
F7	Capacity Building and Training Programs	10	24	30	40	16
F8	Pilot Projects and Demonstrations	12	22	28	36	22
F9	Energy Management	20	30	24	26	20

Source: Field Survey (2024)

Columns 1, 2, 3, 4, 5: represent a 5-point scale, where respondents rated the importance or significance of each factor. 1=Not significant; 2=Rarely Significant; 3= neutral; 4= Significant; 5= highly significant. The numbers under each column represent the count of respondents who gave that rating**.**

F1 (Policy Framework and E-Governance)**:** Most professionals (44) rated it highly significant, but a small group (10) found it not significant. F2 (Integration of Technologies and Collaboration with Technology Providers): The majority considers this significant or neutral, with some (6) finding it not significant. F3 (Public Awareness and Education)**:** Similar to F1, but with more ratings spread across neutral and significant. F4 (Environmental and Sustainability Considerations): Most rated it neutral or significant, but few found it not significant. F5 (Infrastructure Development): Mostly positive responses, with a few lower ratings. F6 (Investment in Research and Development): A spread of responses, with some respondents being neutral or indifferent. F7 (Capacity Building and Training Programs): The majority found it significant or neutral. F8 (Pilot Projects and Demonstrations): Mixed responses, with the highest number of professionals giving a neutral or significant rating. F9 (Energy Management)**:** More professionals found this factor less significant compared to others.

Both descriptive statistics and Exploratory Factor Analysis (EFA) techniques have been used to identify the significant factors enhancing SBCs in Adama city.

1. Descriptive Statistics and Mean Ranking

Mean ranking is adopted to summarize the data and rank the factors based on their mean scores to get an initial understanding of how the professionals perceive the importance of each factor.

Table 4.3 shows the respondent ranking of the factors significant in enhancing the adoption of SBCs among professionals in Adama City, using the 5-point Likert scale 1= not significant, 2= rarely significant, 3= neutral, 4=significant; 5=highly significant.

Table 4-3 Ranked Factors Influencing the Adoption of Smart Building Concepts in Adama city

S/N	Factors	Mean	Rank
F1	Policy Framework and E-Governance	3.68	1
F2	Integration of Technologies and Collaboration with Technology Providers	3.47	5
F3	Public Awareness and Education	3.63	3
F4	Environmental and Sustainability Considerations	3.68	1
F5	Infrastructure Development	3.52	4
F6	Investment in Research and Development	3.15	8
F7	Capacity Building and Training Programs	3.23	7
F8	Pilot Projects and Demonstrations	3.28	6
F9	Energy Management	2.97	9

Source: Field Survey and Excel Analysis Result (2024)

Table 4-4 Mean estimation of Factors Influencing the Adoption of Smart Building Concepts in Adama city

Variable	Obs	Mean	Std. Dev.	Min	Max
F1	120	3.68	1.32	1	5
F2	120	3.47	1.14	1	5
F3	120	3.63	1.27	1	5
F4	120	3.68	1.05	1	5
F5	120	3.52	1.32	1	5
F6	120	3.15	1.27	1	5
F7	120	3.23	1.16	1	5
F8	120	3.28	1.24	1	5
F9	120	2.97	1.35	1	5

Source: Field Survey and STATA analysis result (2024)

The following bar chart represents the descriptive analysis of the factors enhancing the implementation of smart building concepts (SBCs) in Adama City. It shows the mean scores of the key factors, with Policy Framework and E-Governance (F1) and Environmental Sustainability (F4) ranked highest, while Energy Management (F9) is ranked lowest.

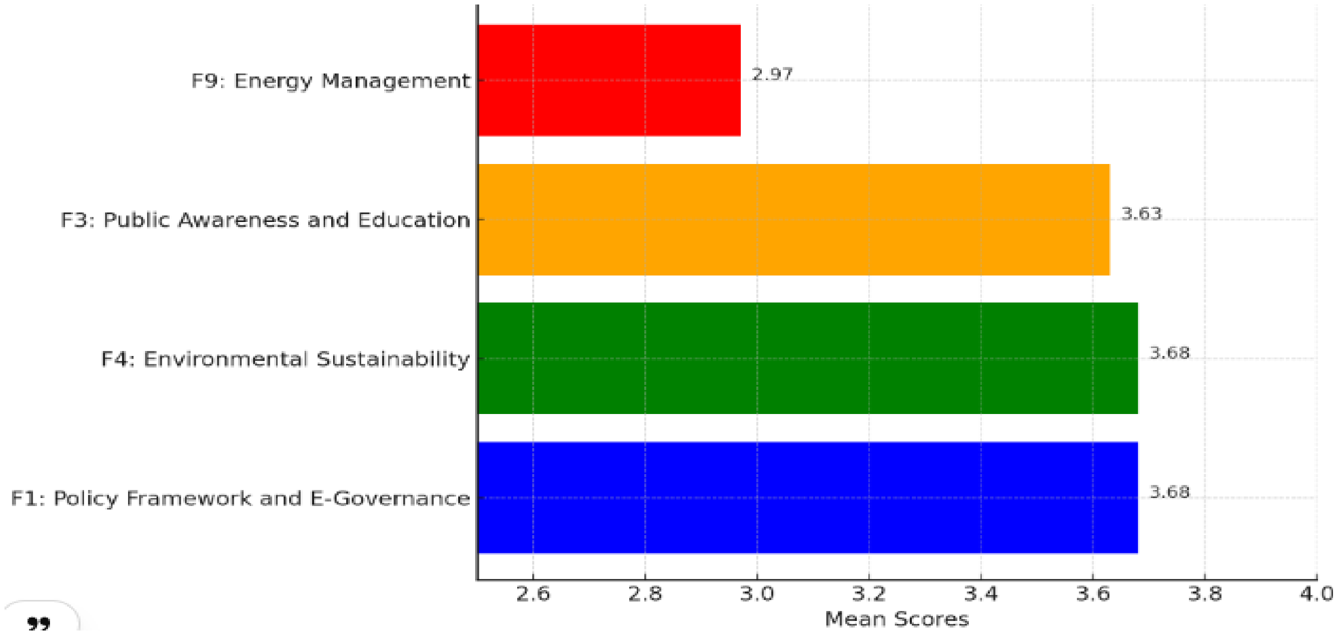

Figure 4.1 Bar chart representing the descriptive analysis of the factors enhancing the implementation of smart building concepts in Adama City

According to Ade-Ojo and Awodele, 2020, a mean score of 3.00 and above considered being statically significant in measuring a 5-point Likert scale.

Therefore, all factors except F9 are significant factors (since above mean score of 3) and presented according to their rank: 1) Policy Framework and E-Governance, 2) Environmental and Sustainability Considerations, 3) Public Awareness and Education, 4) Infrastructure Development, 5) Integration of Technologies and Collaboration with Technology Providers, 6) Pilot Projects and Demonstrations, 7) Capacity Building and Training Programs and 8) Investment in Research and Development.

According to this analysis, the above factors are the significant factors enhancing the adoption of the smart building concepts in the Ethiopian construction industry, specifically in Adama city.

4.4.1 Critical factors enhancing the adoption of the smart building concepts in Adama city

Since I used a 5-point Likert scale and the objective is identifying critical factors, **Factor Analysis (EFA)** is the most appropriate method. It helps reveal the most important factors driving adoption, which aligns well with my objective.

2. Exploratory Factor Analysis (EFA)

Purpose: Factor analysis is used to identify underlying relationships between variables and reduce the data set into fewer, more manageable components that explain the most variance. It can help reveal latent factors influencing SBC adoption.

Exploratory Factor Analysis (EFA) is used to uncover potential factors by analyzing the data and identifying latent variables. In this case EFA method is used to identify the critical factors enhancing SBC adoption, by exploring latent concepts. The Analysis was performed using **Stata software,** and the results are presented in the table below:

Table 4-5 Exploratory Factor Analysis Result of Factors Influencing the Adoption of Smart Building Concepts in Adama City

Factor analysis/correlation Number of obs = 120

Method: principal-component factors Retained factors = 3

Rotation: (un rotated) Number of params = 24

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.39112	0.88361	0.3768	0.3768
Factor2	2.50751	1.16261	0.2786	0.6554
Factor3	1.3449	0.81128	0.1494	0.8048
Factor4	0.53361	0.0272	0.0593	0.8641
Factor5	0.50641	0.19114	0.0563	0.9204
Factor6	0.31527	0.11767	0.035	0.9554
Factor7	0.1976	0.05421	0.022	0.9774
Factor8	0.14339	0.0832	0.0159	0.9933
Factor9	0.06019	.	0.0067	1

LR test: independent vs. saturated: chi2(36) = 743.47 Prob>chi2 = 0.0000

Source: Field Survey and STATA analysis result (2024)

Table 4-6 Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Factor3	Uniqueness
F1	-0.7801	-0.3711	0.3673	0.1187
F2	-0.9324	-0.2576	0.0479	0.0621
F3	0.1064	-0.2614	0.897	0.1158
F4	-0.3881	0.6874	0.0813	0.3703
F5	0.6267	-0.6206	-0.1079	0.2105
F6	0.6679	-0.4346	0.3349	0.2528
F7	0.4401	0.5291	0.4684	0.307
F8	0.8314	0.424	-0.0703	0.124
F9	-0.1655	0.8538	0.22	0.1953

Source: Field Survey and STATA analysis result (2024)

The **Principal Component Factor Analysis** performed retained 3 factors, accounting for approximately 80.48% of the total variance in the dataset. Here's the interpretation of these results:

Eigenvalues and Variance Explained

Factor 1 has an eigenvalue of 3.39, explaining 37.68% of the variance, Factor 2 has an eigenvalue of 2.51, explaining 27.86% of the variance and Factor 3 has an eigenvalue of 1.34, explaining 14.94% of the variance. Together, these three factors explain 80.48% of the total variance in the data, indicating that the majority of the variability can be captured by these factors.

Factor Loadings

The factor loadings tell us how strongly each variable (factor) is associated with each of the three retained factors. F1 (Policy Framework and E-Governance) loads strongly onto Factor 1 (-0.7801), suggesting that this factor is strongly related to general governance and policy aspects, F2 (Integration of Technologies and Collaboration) also loads heavily onto Factor 1 (-0.9324), indicating that both F1 and F2 share common variance and might represent a similar underlying construct, F3 (Public Awareness and Education) has the highest loading on Factor 3 (0.8970), suggesting it is a key component of the third factor, potentially linked to social aspects such as awareness, F4 (Environmental and Sustainability Considerations) and F9 (Energy Management) load onto Factor 2, with high factor loadings of 0.6874 and

0.8538, respectively suggesting that Factor 2 represents aspects related to environmental concerns and energy management and F8 (Pilot Projects and Demonstrations) loads strongly onto Factor 1 (0.8314), indicating its close association with governance and technological integration factors.

Uniqueness

The "uniqueness" value represents the variance in each variable that is not explained by the factors. Lower uniqueness values indicate that the variable is well-explained by the factors. For example, **F2** has a uniqueness value of 0.0621, meaning that 93.79% of its variance is explained by the retained factors, making it a highly important variable in the model.

Interpretation of Factors

Factor 1: captured elements related to policy, governance, integration of technologies and Pilot projects, as indicated by the high loadings for F1, F2, and F8, Factor 2: represents environmental and sustainability concerns and Energy Management, as indicated by F4 and F9 and Factor 3: is likely associated with public awareness and education, given the high loading for F3.

Therefore, the critical factors enhancing the adoption of the Smart Building Concept in Adama City, based on the Factor Analysis results, are those variables that have the highest loadings on the retained factors and explain a large proportion of variance. Specifically:

Factor 1 (Policy and Technology Integration): Policy Framework and E-Governance, Integration of Technologies and Collaboration and Pilot Projects and Demonstrations. These variables have high loadings on Factor 1, suggesting that **policy, governance, and technological integration** are the most critical factors in promoting SBC adoption in Adama City. Their significant contribution to the variance shows that strong policies and collaboration with technology providers are key drivers of implementation.

Factor 2 (Environmental Sustainability and Energy Management): Environmental and Sustainability Considerations and Energy Management. Factor 2 is defined by these environmental and energy-related concerns, highlighting the importance of **sustainability practices** and **efficient energy management** in fostering SBC. adoption.

Factor 3 (Public Awareness and Education): This factor indicates that **public awareness** and **educational** efforts are also crucial in ensuring successful adoption of SBCs, focusing on societal readiness and understanding.

The **three factors** extracted suggest that the main drivers of Smart Building Concept adoption in Adama City are related to (1) policy and technological integration, (2) environmental and energy considerations, and (3) public awareness and education. These results provide useful insights into which areas policymakers and practitioners should focus on to enhance the implementation of SBCs.

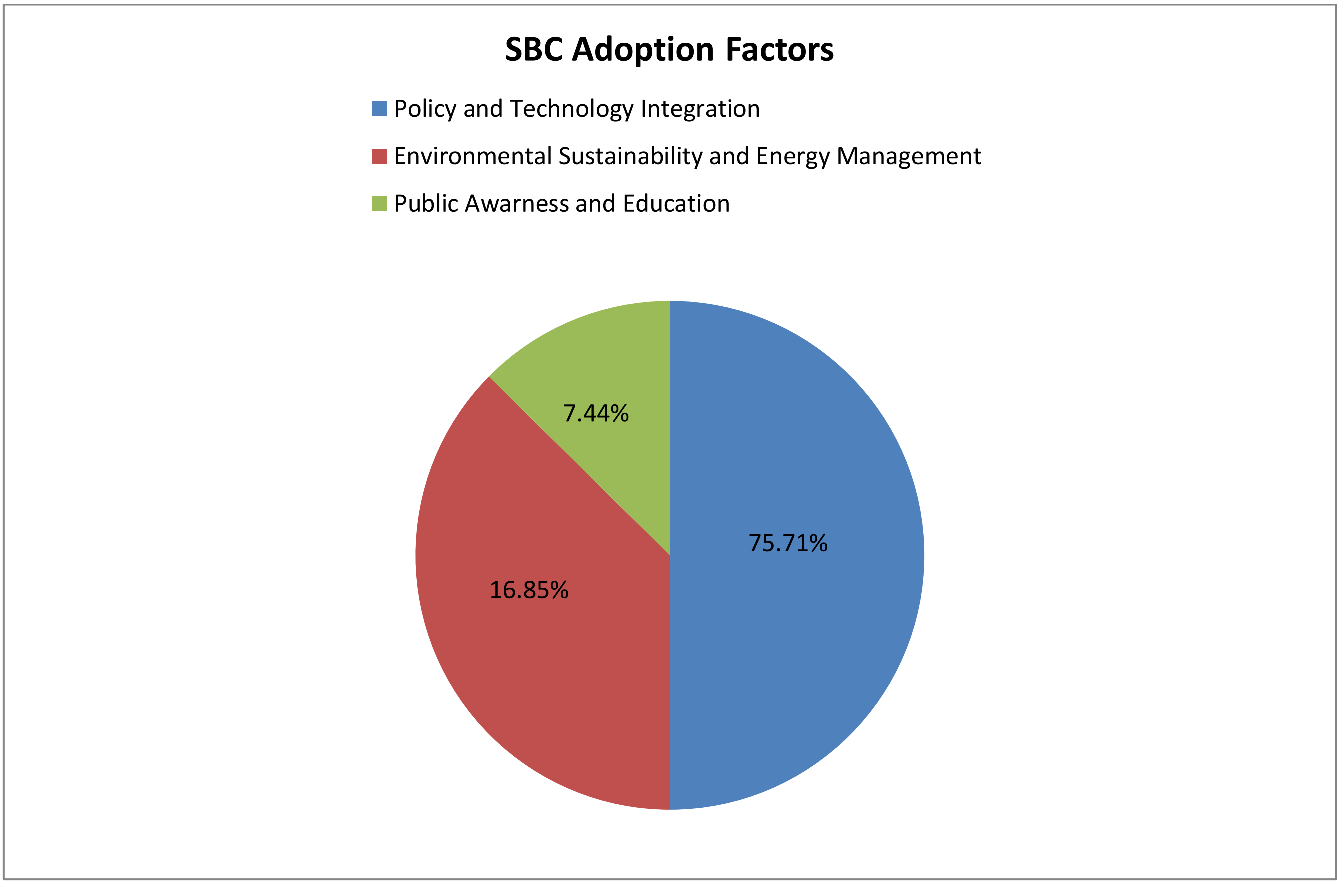

Figure 4.2 pie chart showing the proportion of variance explained by each factor group from the Exploratory Factor Analysis

Based on this analysis, the majority of the variance is accounted for by Policy and Technology Integration (75.71%), followed by Environmental Sustainability and Energy Management (16.85%), and finally, Public Awareness and Education (7.44%).

4.5 Barriers to Smart Building Concept adoption in Adama City

This section presented the barriers to adopting the smart building concept in the Ethiopian construction industry, Adama city. Data were gathered using a well-structured questionnaire from construction professionals including Architects, Engineers (Civil, Mechanical and Electrical) and Quantity Surveyors, who are practicing in the Construction Authority and Design Offices in Adama City. A 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) was used to rank the barriers to the adoption of the smart building concept in Adama's construction industry.

Table 4.7 shows a record of data representing 120 respondents rating the significance of barriers to the adoption of smart building concepts (SBCs) in Adama city across different phases. The ratings range from 1 (Not significant) to 5 (Highly significant).

Table 4-7 Summary of Completed Questionnaires from 120 Respondents on Barriers to the Adoption of SBCs in Adama City

S/N	Barriers to the Adoption of SBCs	1	2	3	4	5
	I. Feasibility Study Phase Barriers					
B1	Inconsistent Government Policy			20	50	50
B2	Inadequate Finance Schemes		10	30	40	40
B3	Lack of Research Work		20	40	30	30
	II. Design Phase Barriers					
B4	High Design Costs	10	20	40	30	20
B5	High Cost of Smart Building Materials		10	30	50	30
B6	Poor Knowledge of Smart Building Technology		20	40	30	30
	III. Construction Phase Barriers					
B7	Inadequate Power Supply			40	40	40
B8	Inadequate Well-Trained Labor		20	40	30	30
	IV. Operation and Maintenance Phase Barriers					
B9	Poor Maintenance Culture		10	40	40	30
B10	Resistance to Change from Traditional Technology	10	20	30	30	30

Source: Field Survey (2024)

The above table lists barriers to the adoption of smart building concepts (SBCs) rated by Adama city professionals across different project phases (Feasibility Study, Design, Construction, and Operation/Maintenance). Each barrier is rated on a 5-point scale (from 1 to 5), and the numbers in the columns represent the count of respondents who selected each rating.

I. Feasibility Study Phase Barriers:

Inconsistent Government Policy: most respondents rated this barrier highly, with 50 rating it as "4" and another 50 rating it as "5." This indicates a strong consensus that inconsistent government policy is a significant barrier. Inadequate Finance Schemes: 40 respondents rated it as "5," and 40 as "4," showing that inadequate financing is also seen as a major challenge. Lack of Research Work: There's a more even distribution here, but still, many (30 rated it "4" and "5") consider lack of research a key issue.

II. Design Phase Barriers:

High Design Costs**:** Responses vary, with 30 people rating this as "4" and others lower. High design costs are perceived as a moderate barrier. High Cost of Smart Building Materials: This is rated higher, with 50 respondents marking "4" and 30 marking "5," indicating that material costs are a significant obstacle. Poor Knowledge of Smart Building Technology: Similar to High Cost of Smart Building Materials, with an even distribution of responses across the scale, indicating this is a notable barrier but not as overwhelmingly rated as the top challenges.

III. Construction Phase Barriers:

Inadequate Power Supply: This has a uniform rating of "4" and "5," suggesting that inadequate power is a widespread and severe barrier during the construction phase. Inadequate Well-Trained Labor: Responses are more spread out, though it is still viewed as a significant challenge (30 rating it as "4" and "5").

IV. Operation and Maintenance Phase Barriers:

Poor Maintenance Culture: Most respondents (40) rated this as "4," with 30 rating it as "5," making it a prominent barrier during the operational phase. Resistance to Change from Traditional Technology: There's a diverse range of responses, but many (30) rate it as a "4" and "5," highlighting resistance to change as a relevant issue.

Major Barriers: Inconsistent government policy (B1), inadequate finance schemes (B2), high material costs (B5), and inadequate power supply (B7) are the most significant barriers, with high concentrations of ratings in the "4" and "5" categories.

Moderate Barriers: Lack of research (B3), poor knowledge of smart building technology (B6), and inadequate well-trained labor (B8) also present challenges but with more evenly spread ratings.

Lesser Barriers: Resistance to change (B10) and high design costs (B4) are barriers, but less significant compared to others.

To obtain a clear picture of which barriers are more widely recognized as hindering Smart Building adoption in Adama city and which ones may require further investigation or awareness, **Descriptive Statistics** and **Kendall's W Test** techniques have been used to identify the significant barriers to the adoption of SBCs in Adama city.

1. Descriptive Statistics

Before doing more advanced analysis, it's always useful to look at the descriptive statistics to understand the central tendency (mean, median) and spread (variance, standard deviation) of the barriers. The mean, standard deviation, and frequency distribution for each of the barriers (B1 through B10) are computed to get an overview of how the professionals rated these factors.

Table 4-8 Mean and Standard Deviation Estimation of Barriers to Smart Building Concept Adoption in Adama city

Variable	Obs	Mean	Std. Dev.	Min	Max
B1	120	4.25	0.72	3	5
B2	120	3.92	0.96	2	5
B3	120	3.58	1.04	2	5
B4	120	3.25	1.17	1	5
B5	120	3.83	0.90	2	5
B6	120	3.58	1.04	2	5
B7	120	4.00	0.82	3	5
B8	120	3.58	1.04	2	5
B9	120	3.75	0.93	2	5
B10	120	3.42	1.26	1	5

Source: Field Survey and STATA analysis result (2024)

Table 4.8 provides a descriptive summary of the ten variables (B1 to B10), including the mean**,** the standard deviation and the minimum and maximum values for each variable.

B1- Inconsistent Government Policy: a generally positive perception between agrees and strongly agrees (Mean = 4.25) and the scores are clustered around the mean with little variation, as indicated by a lower standard deviation (Std. Dev = 0.72), B2 Inadequate Finance Schemes (Mean = 3.92, Std. Dev = 0.96): has a slightly lower mean than B1, suggesting moderate agreement in which the standard deviation indicates a bit more variability in responses, reflecting a wider spread of opinions, B3, B6, and B8 **-** Lack of Research Work, Poor Knowledge of Smart Building Technology and Inadequate Well-Trained Labor (Mean = 3.58, Std. Dev = 1.04): have the same mean and standard deviation, indicating moderate agreement with a wide range of responses, B4 - High Design Costs (Mean = 3.25, Std. Dev = 1.17): the lowest mean among all variables, suggesting respondents are less likely to agree on this factor with higher standard deviation showing greater variability in opinions, B5 and B9 **-** High Cost of Smart Building Materials and Poor Maintenance Culture (Mean = 3.83, 3.75; Std. Dev = 0.9, 0.93): have similar moderate means and moderate variability in responses, B7 - Inadequate Power Supply (Mean = 4.00, Std. Dev = 0.82): high mean, indicating strong agreement among respondents, with a low spread of opinions and B10 **-** Resistance to Change from Traditional Technology (Mean = 3.42, Std. Dev = 1.26): The lowest mean and highest standard deviation, suggesting both a lower level of agreement and a wider range of responses.

Generally, variables B1 **(**Inconsistent Government Policy)**,** B7 **(**Inadequate Power Supply**)**, and B2 (Inadequate Finance Schemes) appear to have the highest levels of agreement, making them key barriers in adopting SBC in Adama city according to this descriptive analysis. Variables like B4 (High Design Costs) and B10 (Resistance to Change from Traditional Technology) have lower levels of agreement, with wider variability in responses, which may indicate either lesser significance or more diverse opinions.

Table 4-9 Mean item score of Barriers to Smart Building Concept Adoption in Adama city

S/N	Barriers to the application of SBCs	Mean	Rank
	I. Feasibility Study Phase Barriers		
B1	Inconsistent Government policy	4.25	1
B2	Inadequate finance schemes	3.92	3
B3	Lack of research work	3.58	6
	II. Design Phase Barriers		
B4	High design costs	3.25	10
B5	High cost of smart building materials	3.83	4
B6	Poor knowledge of smart building technology	3.58	6
	III. Construction Phase Barriers		
B7	Inadequate power supply	4.00	2
B8	Inadequate well-trained labor	3.58	6
	IV. Operation and Maintenance Phase Barriers		
B9	Poor maintenance culture	3.75	5
B10	Resistance to change from the use of traditional technology	3.42	9

Source: Field Survey and EXCEL analysis result (2024)

All the barriers (B1 to B10) have a mean score greater than 3.00, indicating that they are all statistically significant according to the criteria established by Ade-Ojo and Awodele, 2020.

Therefore, the following: Feasibility Study Phase Barriers (Inconsistent Government policy, inadequate finance schemes and Lack of research work). Design Phase Barriers (High design cost, High cost of smart building material and Poor knowledge of smart building technology). Construction Phase Barriers (Inadequate power supply and Inadequate well-trained labor) and Operation and Maintenance Phase Barriers (Poor maintenance culture and Resistance to change from the use of traditional technology) can be considered relevant barriers in the context of smart building concept adoption in Adama City.

2. Kendall's W Test (Measure Agreement among Respondents)

Kendall's W, also known as Kendall's coefficient of concordance, is used to assess the level of agreement among respondents concerning the significance of barriers. This test evaluates the consistency of rankings across multiple respondents.

Table 4-10 Kendall's coefficient of concordance showing the pairwise correlation between the barriers to the adoption of SBCs in Adama city

```
. ktau B1 B2 B3 B4 B5 B6 B7 B8 B9 B10
(obs=120)
```

	B1	B2	B3	B4	B5	B6	B7	B8
B1	0.6303							
B2	0.5602	0.7143						
B3	-0.5602	-0.6022	0.7423					
B4	0.6162	0.6443	-0.7003	0.7703				
B5	-0.2661	-0.2801	0.1821	-0.2381	0.7003			
B6	0.3501	0.2521	-0.3361	0.2801	-0.2101	0.7423		
B7	-0.5322	-0.6723	0.5882	-0.6022	0.2801	-0.2521	0.6723	
B8	-0.0140	-0.1120	0.1961	-0.1541	-0.0140	0.1961	0.0980	0.7423
B9	0.5322	0.6303	-0.6162	0.6303	-0.1541	0.2661	-0.5882	-0.1261
B10	0.5882	0.6583	-0.7143	0.7143	-0.1961	0.2941	-0.6162	-0.1541

	B9	B10
B9	0.7143	
B10	0.6863	0.7843

Source: Field Survey and STATA analysis result (2024)

The output from stata using the **Kendall Tau (ktau)** command shows the pairwise correlation between the variables (B1-B10) in terms of rank agreement. This test evaluates how well the rankings of one variable agree with those of another, reflecting the monotonic relationship between variables.

Interpretation of Kendall Tau Coefficients:

Coefficients close to +1 imply a strong positive association (as one variable increases, the other also increases), coefficients close to -1 imply a strong negative association (as one variable increases, the other decreases) and coefficients around 0 suggest little or no rank correlation between the variables.

Positive Correlations: B1 and B2 have a Kendall Tau correlation coefficient of 0.5650, indicating a moderate positive rank agreement.

Negative Correlations: B1 and B3 have a correlation of -0.5650, showing a negative rank correlation, meaning as B1 increases, B3 tends to decrease. Meaning that when B1 is ranked high, B3 is ranked low, and vice versa. This shows that B3 perceived differently compared to B1.

Strong Correlations: B1 (inconsistent government policy) and B4 (high design costs): 0.6162, indicating a fairly strong positive correlation, B2 (Inadequate finance schemes) and B10 (Resistance to change from the use of traditional technology): 0.6583, indicating a strong positive correlation, B4 (High design costs) and B9 (poor maintenance culture): 0.6303, indicating a fairly strong positive correlation and B9 (poor maintenance culture) and B10 (resistance to change from the use of traditional technology): 0.6863, suggesting a high agreement in the rankings between these two variables. This shows that if one barrier is ranked high, the other is also likely to be ranked high, suggesting that these are perceived as important in a similar way.

Moderate Correlations: B3 (Lack of research work) and B7 (Inadequate power supply): 0.5882**,** moderate positive rank agreement, B1-B2 (0.5602): Moderate positive rank agreement.

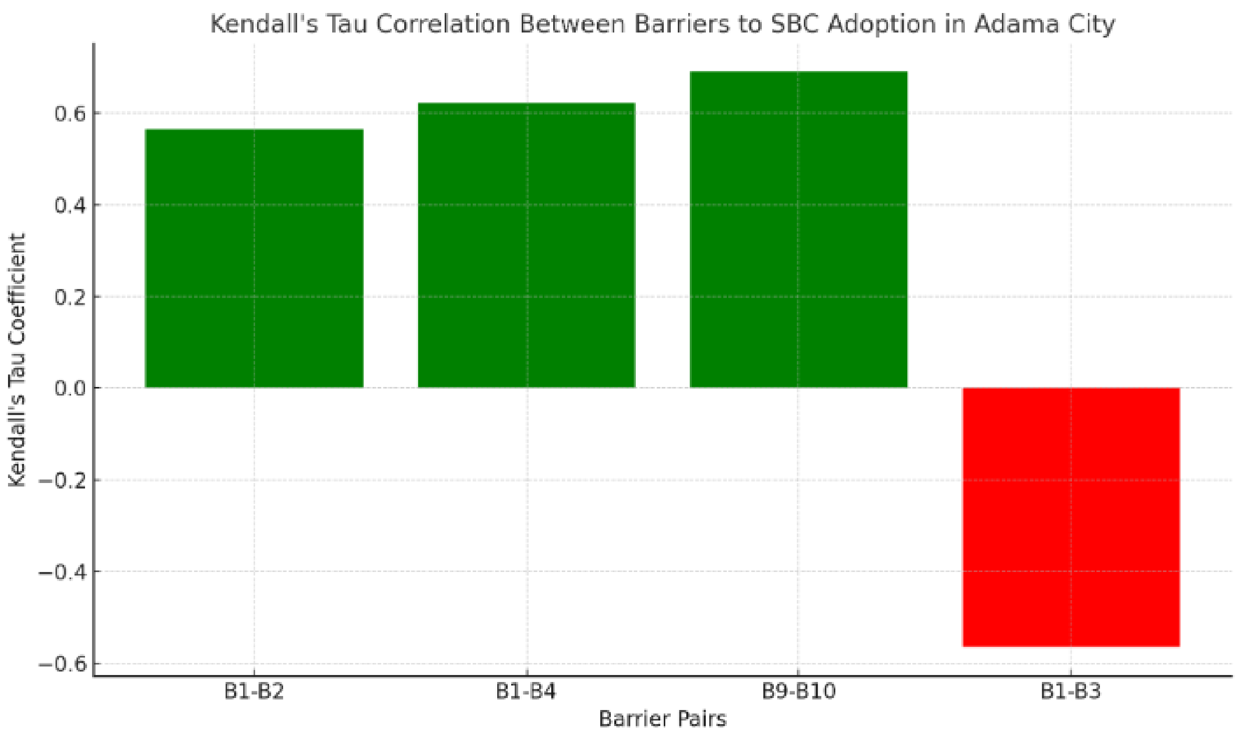

Figure 4.3 a bar chart displaying the Kendall's Tau correlation coefficients between selected barriers to the adoption of smart building concepts (SBCs) in Adama City

This visualization illustrates the agreement or disagreement in rankings across different barriers. The chart highlights both positive (green) and negative (red) correlations.

4.5.1 Critical Barriers in the adoption of SBCs in Adama city

From the above correlations, **B1 (Inconsistent Government policy)**, **B2 (Inadequate finance schemes)**, **B4 (High design costs)**, and **B9 (Poor maintenance culture)** emerge as **critical barriers** based on their high positive correlations with other factors. These barriers are frequently ranked similarly to each other, reflecting their perceived significance. **B3 (Lack of research work)** also appear critical but show varying degrees of correlation. It has strong negative correlations with several other barriers, which might indicate divergence in how it's perceived relative to other barriers.

4.6 Discussions of the Findings

4.6.1 Current Trends and Practices of SBCs Application

The findings from the analysis of the document on smart building concept implementation reveal several critical insights into the trends, challenges, and enablers for SBC adoption, particularly in developing regions like East Africa and Adama City. Below is a detailed discussion of these findings, organized by the themes:

Energy Efficiency and Environmental Sustainability

Findings: A major focus in SBCs is on reducing energy consumption and enhancing environmental sustainability. The integration of renewable energy sources (e.g., solar power) and adherence to green building standards like LEED and BREEAM are prominent trends, indicating a strong alignment with global sustainability goals. This is particularly crucial in regions like East Africa, where power shortages are common and energy costs are high.

Implications: This focus on sustainability underscores a commitment to addressing energy challenges and environmental impact through SBCs. However, the high costs associated with renewable technologies remain a challenge, suggesting a need for financial support to make these systems more accessible.

Technological Integration and Automation

Findings: SBCs heavily rely on technologies such as IoT, AI, and BIM to enhance building operations, enable real-time monitoring, and support predictive maintenance. The integration of these technologies allows for automation, resource optimization, and data-driven decision-making. However, the adoption of advanced technologies is still in its early stages in East Africa, largely limited by high costs and a lack of technical infrastructure.

Implications: This finding highlights the transformative potential of technology for SBCs but also reveals significant barriers to widespread implementation. Investing in digital infrastructure and technical training could help overcome these obstacles, enabling SBCs to operate more efficiently and sustainably.

User-Centric Design and Enhanced Occupant Experience

Findings: SBCs increasingly focus on occupant needs, offering customizable settings for lighting, temperature, and security to improve comfort and productivity. This trend is particularly evident in higher-end commercial and residential projects, where occupant satisfaction is a priority.

Implications: User-centric design adds value to SBCs by addressing personal comfort and productivity. This insight suggests that SBCs must balance technological functionality with human-centered design principles to create environments that enhance quality of life, which may drive demand in both commercial and residential markets.

Security and Privacy in Connected Buildings

Findings: Security and privacy emerge as critical concerns due to the reliance on interconnected systems and data collection in SBCs. As more buildings become "smart," they face increased risks of data breaches, necessitating robust cybersecurity measures.

Implications: This finding highlights a potential area of vulnerability for SBCs. Ensuring data security is essential not only for protecting occupants but also for fostering trust in smart technology. This may require dedicated resources for cybersecurity as an integral part of SBC design and implementation.

Policy and Regulatory Support for SBC Implementation

Findings: The regulatory environment significantly influences SBC adoption. Supportive policies, such as green building codes and urban planning incentives, can facilitate SBC development, while inconsistent policies and a lack of clear guidelines hinder progress.

Implications: The findings suggest that coherent and supportive regulatory frameworks are critical to scaling SBCs, particularly in emerging markets. Government initiatives that provide clear standards and promote sustainable practices could accelerate SBC adoption. This also points to a need for regulatory alignment across sectors involved in urban development and technology.

Financial Constraints and Incentives

Findings: High costs and limited financing options are major barriers to SBC implementation. Many stakeholders, especially smaller-scale developers, find it challenging to invest in smart technologies without financial incentives, such as subsidies or tax breaks.

Implications: Addressing financial constraints is essential for making SBCs viable in developing regions. Governments and financial institutions could play a pivotal role by offering targeted incentives and financing mechanisms to lower the barrier to entry for SBC adoption, potentially enabling broader and more equitable access.

Knowledge Gaps and Professional Training Needs

Findings: A lack of expertise in SBC-related technologies and practices among local professionals poses a barrier to adoption. There is a clear need for capacity building through training and professional development in areas like IoT, BIM, and sustainable building management.

Implications: Building a skilled workforce is a foundational step toward successful SBC adoption. Investment in professional training can create a pipeline of knowledgeable professionals who can manage, implement, and innovate within the SBC space. This finding also suggests that knowledge transfer partnerships with international organizations could help bridge these gaps.

Socioeconomic and Cultural Considerations

Findings: The socioeconomic context and cultural values in regions like East Africa significantly shape SBC adoption. Economic constraints often prioritize basic infrastructure over advanced SBC technologies, and cultural factors influence how new technologies are perceived and accepted.

Implications: This insight underlines the importance of developing SBC solutions that are context-sensitive and adaptable to local needs. Tailoring SBC initiatives to fit regional economic and cultural landscapes can improve adoption rates and effectiveness, suggesting that one-size-fits-all approaches may not work for diverse markets.

Public Awareness and Demand for SBCs

Findings: Limited public awareness of the benefits of SBCs dampens demand. Without a clear understanding of the long-term advantages, potential users may be reluctant to invest in smart buildings.

Implications: Raising awareness through education and outreach campaigns could be a vital strategy for increasing demand. The findings suggest that improving public understanding of SBC benefits—such as energy savings, increased comfort, and sustainability—may drive greater market interest and support for SBC initiatives.

The findings reveal a multifaceted landscape for SBC adoption, characterized by both promising trends and considerable challenges. Sustainability and technological integration stand out as fundamental motivators for SBCs, driven by the need to address energy demands and improve operational efficiency. However, policy inconsistencies, financial barriers, and skill gaps create significant obstacles, particularly in developing regions like East Africa and Adama City. Additionally, socioeconomic and cultural factors highlight the necessity of adaptable, localized approaches that consider specific regional needs.

To accelerate SBC adoption, a collaborative approach involving government, private sector, and educational institutions is essential. By addressing these barriers through supportive policies, targeted incentives, professional training, and public education, stakeholders can foster a conducive environment for SBCs that is sustainable, inclusive, and responsive to local realities.

4.6.2 Factors Enhancing Smart Building Concept Application in Adama City

Results from both descriptive statistics and Exploratory Factor Analysis (EFA) identified the key factors enhancing SBCs in Adama city.

Key Findings

Descriptive Analysis: The data from the Likert scale showed the professionals' perceptions of the significance of the factors. According to the result, the most significant factors were: F1 (Policy Framework and E-Governance) – Ranked first with a mean of 3.68, F4 (Environmental and Sustainability Considerations) – also ranked first with a mean of 3.68, F3 (Public Awareness and Education) – Ranked third with a mean of 3.63 and F9 (Energy Management), with a mean score of 2.97, was the least significant, falling below the cutoff for significance (mean score ≥ 3).

Exploratory Factor Analysis (EFA): revealed three major factors that explain about 80.48% of the total variance in the data, indicating that the variability in the professionals' responses can be condensed into three key drivers:

Factor 1: Policy and Technology Integration

This factor captured Policy Framework and E-Governance (F1), Integration of Technologies and Collaboration (F2), and Pilot Projects and Demonstrations (F8), highlighting the critical importance of governance and policy-related factors combined with technology and collaboration.

Factor 2: Environmental Sustainability and Energy Management

This factor included Environmental and Sustainability Considerations (F4) and Energy Management (F9), reflecting concerns around sustainability and the efficient use of energy.

Factor 3: Public Awareness and Education

The third factor is driven by Public Awareness and Education (F3), stressing the importance of educating stakeholders and the general public on SBCs.

Factor 1: Policy Framework & E-Governance and Technology Integration

The results clearly show that Policy Framework, E-Governance and Technology Integration play a vital role in driving the adoption of SBCs. This finding aligns with studies such as Bokhari & Myeong, 2023 which proposed that E-governance plays a crucial role in the integration of digital technologies and government services, which is essential for the successful implementation of smart building initiatives. Here's how this finding align with existing research:

Policy Framework and Governance: Research consistently shows that an effective policy framework and governance are essential to the successful adoption of smart building concepts. Governments that implement clear, consistent policies promoting smart technologies see higher rates of adoption and technological innovation (Khan et al., 2020). In particular, policy frameworks are pivotal in driving regulatory processes, financial incentives, and public-private partnerships for smart buildings.

E-Governance: E-governance plays a critical role in enabling smart building adoption by improving regulatory processes, transparency, and coordination between different stakeholders. Studies highlight how e-governance platforms streamline approvals and improve collaboration between governmental bodies, developers, and technology providers, leading to more efficient smart building projects (Gil-Garcia et al., 2020). Bokhari & Myeong, 2023 proposed that E-governance plays a crucial role in the integration of digital technologies and government services, which is essential for the successful implementation of smart building initiatives. Additionally, Apanaviciene et al., 2020 propose a framework for integrating smart buildings into smart cities, emphasizing cross-sector collaboration and citizen-centric governance, which can guide policymakers.

Technology Integration: The integration of technology, such as the Internet of Things (IoT) and Building Management Systems (BMS) is fundamental to the smart building concept.

Successful integration requires a solid infrastructure supported by government policies and collaboration with private technology providers. Global case studies indicate that technology integration is a critical enabler of energy efficiency, automation, and sustainable urban development (Albino, Berardi, & Dangelico, 2015).

This finding is particularly aligned with research on **smart city and building adoption in developing countries**, where governance structures and policy frameworks play a more prominent role in driving innovation. Developing African cities (such as Nairobi and Kigali) demonstrates that **consistent policies and government initiatives** are vital to overcoming financial and technical barriers in implementing smart infrastructure.

Factor 2: Environmental Sustainability and Energy Management

The prominence of Environmental and Sustainability Considerations and Energy Management suggests that professionals view sustainability as critical for SBC adoption in Adama city. This research aligns with global trends where environmental concerns are increasingly driving innovation in construction, such as McCulloch et al., 2023 which suggested that environmental and sustainability considerations play a crucial role in the adoption of smart building technologies and Bakare, Abdulkarim, Zeeshan, & Shuaibu, 2023 which proposed that energy management contributes to the efficient utilization of resources and the reduction of environmental impact. Here’s how this finding align with broader research:

Sustainability in Smart Cities and Buildings

According to research on smart cities, sustainability is a key driver for smart building adoption, as integrating environmental and energy-efficient practices leads to better long-term outcomes for cities (Ahvenniemi et al., 2017). Studies highlight that sustainable design principles-including energy-efficient technologies, renewable energy integration, and waste reduction strategies are critical in the adoption of smart buildings (Häkkinen & Belloni, 2011; Berardi, 2013).

Green Building Certifications

Studies show that green building certifications, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), drive the adoption of sustainable practices in smart building projects (Häkkinen & Belloni, 2011). These certifications focus on improving energy efficiency, reducing carbon footprints, and promoting sustainable materials, aligning with the importance placed on environmental considerations in Adama City.

Energy Management as a Key Factor

Research emphasizes that the use of **smart energy systems**, such as **smart grids**, **energy-efficient HVAC systems**, and **renewable energy integration**, is essential to reducing operational costs and environmental impacts in buildings (GhaffarianHoseini et al., 2016; Granell et al., 2019). In developing regions, research highlights that energy management solutions can also address challenges related to energy supply reliability, which is particularly relevant to this finding in Adama City, where power supply constraints exist (Pueyo et al., 2013; Watson et al., 2019).

Climate Change and Urban Sustainability

The integration of sustainability into smart building concepts is critical for climate change mitigation, as outlined in studies that focus on the intersection of urban development and environmental goals (Hodson & Marvin, 2010).

Many studies explore how smart buildings contribute to reducing greenhouse gas emissions and improving resource efficiency in urban areas. As the world focuses on meeting climate action goals (such as the Paris Agreement), cities increasingly prioritize sustainable building practices to reduce their environmental impact (Jiang et al., 2018; Deakin & Reid, 2018). In developing cities, research suggests that adopting sustainable construction practices helps mitigate the effects of rapid urbanization, which often strains local resources and infrastructure (Maimunah et al., 2017; Lamine et al., 2019). This focus on sustainability is critical for long-term urban resilience, aligning with this finding in Adama City.

Sustainability and Energy Efficiency in Africa

In the context of Africa, research on sustainable urbanization, especially in growing cities like Nairobi, Cape Town and Kigali, highlights similar themes. These studies show that professionals in these regions also emphasize the importance of energy management and environmental sustainability as key drivers for adopting smart building concepts (UN-Habitat, 2016; Maimunah et al., 2017). This regional research aligns with this thesis finding, as cities across Africa seek to balance rapid urban development with sustainability goals.

Factor 3: Public Awareness and Education

Public Awareness and Education was found to be a critical factor. This is consistent with studies that argue public knowledge and awareness are key to the successful adoption of smart technologies. For instance, Chomać-Pierzecka and colleagues, 2022 and Ejidike and Mewomo, 2023. The following are several global and regional studies that align with this study:

Public Awareness in Sustainable Building Adoption

Research emphasizes the importance of public awareness and education in promoting sustainable building practices. According to Zhang et al., 2017, enhancing public understanding of the benefits of smart and sustainable buildings is crucial for driving adoption, as informed stakeholders are more likely to support such initiatives. Ejidike and Mewomo, 2023 highlighted the benefits of adopting smart building technologies in building construction, emphasizing the importance of public awareness and education in driving adoption.

The Role of Education in Smart City Initiatives

Studies on smart cities, including smart building development, show that education is key to building a knowledgeable workforce capable of managing and implementing smart technologies. Mohanty et al., 2016 highlight that awareness campaigns and training programs are instrumental in increasing the adoption of smart buildings by reducing resistance to change and fostering a culture of innovation.

Regional Studies in Africa

In Africa, research underscores the role of education in overcoming barriers to smart building adoption. Watson et al., 2019 find that awareness programs focused on sustainability and smart technologies have positively impacted adoption rates in various African cities. Increasing public and professional knowledge about the benefits of SBCs helps mitigate doubt and accelerates their integration into the urban fabric.

Generally, the above findings suggest that policymakers and practitioners should focus on developing robust policy frameworks, integrating sustainable practices, and increasing public awareness to successfully promote SBC adoption in Adama city.

4.6.3 Barriers to Smart Building Concept Adoption in Adama City

The analysis was conducted using **descriptive statistics** and **Kendall's W Test**.

Descriptive Statistics: The mean and standard deviation values for each barrier (B1-B10) provide an overview of how construction professionals in Adama City rated the significance of each barrier.

Top Barriers: Inconsistent Government Policy had the highest mean score (4.25), indicating that respondents strongly agree this is a significant barrier, Inadequate Power Supply also had a high mean (4.00), reflecting the consensus that insufficient power infrastructure is a critical issue in the smart building adoption process and Inadequate Finance Schemes with a mean of 3.92 highlights the financial challenges that hinder smart building investments.

Moderate Barriers: High Cost of Smart Building Materials and Poor Maintenance Culture scored moderately high, with means of 3.83 and 3.75, respectively, indicating these are perceived as important barriers, though not as severe as those mentioned above.

Lower Barriers: High Design Costs received relatively the lowest mean (3.25), showing that while considered a barrier, it is not as significant as others and Resistance to Change from Traditional Technology also had a relatively low mean (3.42), though it still falls above the threshold of 3.00, indicating relevance.

Overall, all barriers had mean scores greater than 3.00, which suggests they are all statistically significant in hindering the adoption of SBCs in Adama city according to the descriptive analysis.

Kendall's W Test: Kendall's W Test was used to measure the agreement among respondents about the rankings of these barriers. The results indicate a moderate to high level of concordance in the rankings across the professionals surveyed.

Strong Correlations: Inconsistent Government Policy showed a strong positive correlation with High Design Costs suggesting that as government policies become more inconsistent, the design costs for smart buildings tend to increase, highlighting a connection between policy stability and the financial burden of design, Inadequate finance schemes and Resistance to change from the use of traditional technology showed a strong positive relationship, indicating that inadequate financial schemes are closely linked to resistance in adopting new technologies over traditional methods, High design costs and Poor maintenance culture shows a fairly strong positive association, implying that higher design costs may be linked to a poor maintenance culture, where financial constraints during the design phase could also affect long-term upkeep and Poor Maintenance Culture had a high correlation with Resistance to change from the use of traditional technology, reflecting the view that maintenance issues and reluctance to adopt new technologies are closely linked. This suggests that regions or organizations with poor maintenance cultures are also highly resistant to adopting new technologies, likely preferring traditional methods that are perceived as easier or more familiar to maintain.

Mixed Correlations: Lack of Research Work had some negative correlations with barriers like Inconsistent Government Policy, which indicates that while respondents see research as a barrier, it may be perceived differently than policy or infrastructure issues.

Inconsistent Government Policy

Inconsistent Government Policy emerged as the top barrier, underscoring the critical role of supportive government frameworks in SBC adoption at Adama. Research highlights that inconsistent or unclear government policies can significantly hinder the adoption of smart building concepts. Opeyemi et al., 2019 discuss how fluctuating regulatory frameworks and a lack of long-term government commitment can create uncertainty, leading to hesitation in investment and innovation within the construction industry.

Inadequate Finance Schemes

Inadequate Finance Schemes also scored highly, indicating that financial challenges are major hurdles in Adama. Financial constraints are a well-documented barrier to the adoption of smart technologies in buildings, especially in developing countries. According to Aghimien et al., 2020, limited access to financial schemes, high upfront costs, and inadequate government support for financing smart and sustainable construction projects is primary obstacles in many African nations, mirroring the situation in Adama City.

High design costs

High design costs identified as fairly strong barrier, aligns with several studies in the broader construction and smart building fields. High design and construction costs are cited as significant barriers to the implementation of smart buildings. Chan et al., 2018 emphasize that the complexity and cost of integrating smart technologies into building designs often deter developers, particularly in regions where the market for such technologies is still in its infancy.

Poor maintenance culture

The barriers related to **poor maintenance culture** suggest that even when financial and technical solutions are available, cultural and operational barriers can slow the adoption process. This aligns with research by **Usman & Bamidele, 2021**, which stated that in many cases, building managers lack access to professionals with the necessary expertise and **Carli et al., 2021**, which notes that operational barriers like maintenance and user adaptation are often overlooked but crucial for long-term success.

In summary, the key barriers to SBC adoption in Adama City - government policy, financial schemes, high design cost, and cultural resistance are well-aligned with global trends in the smart construction industry such as Baharetha et al., 2024, Affonso et al., 2024, Vargas, R.V et al., 2022, Ejidike, C.C., 2022 and El-Motasem et al., 2021. Addressing these issues will require coordinated efforts from policymakers, industry professionals, and the public to create a conducive environment for smart building technologies.

4.7 Framework for successful implementation of SBCs in Adama City

The study identifies critical insights across three objectives, all related to the adoption and application of Smart Building Concepts (SBC) in Adama City, Ethiopia, contributing to smart city realization. Below are the common findings for each of the thesis objectives:

Current Trends in Smart Building Concepts

Trends driving SBCs: Energy Efficiency and Environmental Sustainability, Technological Integration and Automation, User-Centric Design and Enhanced Occupant Experience, Security and Privacy in Connected Buildings, Policy and Regulatory Support and Socioeconomic and Cultural Considerations.

Challenges: Financial Constraints and Incentives, Knowledge Gaps and Professional Training Needs and Public Awareness and Demand for SBCs

Factors Enhancing SBCs Application

Strong Policy Frameworks and Technology Integration: Policy and e-governance frameworks combined with technology are crucial to facilitating the adoption of SBCs, **Environmental and Sustainability Considerations**: Focus on energy management, green building practices and public awareness is necessary for SBC success and **Public Awareness and Education**: Educational campaigns and raising awareness about the benefits of SBCs can promote broader acceptance and implementation in Adama.

Barriers to Smart Building Concept Adoption

Inconsistent Government Policy: Lack of consistent government policies and standards makes it difficult for stakeholders to adopt SBCs, **Financial Constraints**: High costs of smart technologies, along with inadequate financing schemes, are key barriers, **High Design costs**: These high upfront costs deter stakeholders, particularly in regions with limited financial resources or incentives for sustainable or smart infrastructure. High design costs can also be linked to the perception that smart buildings are more expensive than traditional ones, making developers and clients reluctant to invest and **Poor maintenance culture**: Poor maintenance culture can lead to a rapid deterioration of building systems, resulting in higher operating costs and reduced performance over time.

Overall, smart building technologies present a major opportunity to advance urban development in Adama. However, ensuring policy consistency, enhancing technological readiness, securing financial investment, and fostering stakeholder engagement are crucial to overcoming challenges and driving successful implementation in Adama and across Ethiopia.

Based on the information extracted from the thesis i.e qualitative and quantitative data analysis result, I developed a framework for successfully adopting the smart building concept in Adama city, Ethiopia, to realize a smart city. This framework addresses the unique characteristics and challenges of the local context, informed by research findings.

1. Policy and Regulatory Frameworks

A solid policy and regulatory foundation is crucial for the successful implementation of SBCs. In East Africa, countries like Rwanda and Kenya have demonstrated the importance of national strategies in supporting smart city projects.

National and Local Policies: Develop clear and consistent policies that promote the integration of SBCs into urban planning. This should include tax incentives, grants, and subsidies to encourage adoption, similar to Rwanda's Smart Rwanda Master Plan.

Strengthen E-Governance Systems: Implement e-governance platforms that streamline processes for building approvals, compliance checks, and data sharing among government agencies, developers, and technology providers. Efficient governance will facilitate smoother project execution, aligning with findings that robust governance structures are essential for SBC success.

Sustainability and Green Building Regulations: Enforce policies that mandate sustainable practices in construction, such as green building certifications, energy efficiency, and the use of renewable energy sources.

Public-Private Partnership Regulations: Establish frameworks that foster collaboration between the government, private sector, and international organizations to fund and implement smart building initiatives.

Long-term Policy Consistency: Ensure that policies remain consistent over time to provide long-term security for investors and builders. Inconsistent government policies have been identified as a key barrier in Adama City.

2. Technological Integration and Innovation

Advanced technologies like IoT, AI, and data analytics are central to smart building concepts. East African countries, especially Rwanda and Kenya, have successfully integrated these technologies into their smart city projects.

- **IoT and AI Integration**: Deploy IoT devices and AI for real-time monitoring and automation of building functions such as lighting, security, and energy management. This integration will optimize building performance and reduce operational costs.

- **Data-Driven Decision Making**: Leverage data analytics to improve building efficiency, reduce waste, and enhance the user experience. This should include the use of predictive maintenance systems and energy optimization algorithms.
- **Collaboration with Tech Providers**: Foster partnerships with technology providers to ensure access to cutting-edge solutions. The integration of technology with building design is a critical success factor for SBCs.
- **Interoperability Standards**: Establish interoperability standards to ensure that different technological systems can seamlessly communicate and operate together, avoiding technology silos.

3. Financial Viability and Investment Strategies

Investment is one of the critical factors for successful SBC adoption. The cost of implementation, especially for smart building materials and technologies, is a significant barrier in Adama City.

Public-Private Partnerships (PPP): Establish public-private partnerships to fund smart building projects. Tanzania's Dar es Salaam Metropolitan Development Project is an example of how PPPs can be used to secure significant funding.

Financial Incentives: Introduce financial incentives such as tax rebates, low-interest loans, and grants for developers and investors to lower the cost of implementing SBCs.

Return on Investment (ROI) Models: Demonstrate the long-term financial benefits of smart buildings, including energy savings, maintenance cost reduction, and increased property value, to attract private sector investment.

International Funding: Engage international donors and financial institutions to fund large-scale smart city projects, focusing on infrastructure, training, and capacity-building programs.

4. Capacity Building, Education, and Public Awareness

One of the key drivers for SBC adoption is public awareness and education. Without understanding the benefits of smart buildings, it is difficult to foster demand or ensure smooth implementation.

Training Programs: Invest in training programs for professionals, including architects, engineers, and construction workers, to equip them with the necessary skills to design, build, and maintain smart buildings. This addresses the barrier of inadequate trained labor identified in Adama City.

Public Education Campaigns: Launch public education campaigns to inform residents and stakeholders about the benefits of smart buildings, such as energy efficiency, cost savings, and improved living conditions.

University-Industry Collaboration: Partner with local universities to develop courses and research programs on smart building technologies and sustainability, fostering innovation and building local expertise.

User-Friendly Smart Building Systems: Ensure that the smart building systems are designed to be user-friendly, making it easier for occupants to interact with and benefit from the technology.

Stakeholder Engagement Platforms: Establish knowledge-sharing platforms where professionals, policymakers, and the public can exchange insights and best practices on SBCs. This aligns with findings that multi-stakeholder collaboration is essential for overcoming technical and operational barriers.

5. Infrastructure Development

A strong infrastructure is essential to support the integration of smart building technologies. Lack of adequate infrastructure was identified as a barrier in Adama City.

Upgrading Power and Communication Networks: Improve power supply reliability and develop robust communication networks, including high-speed internet and fiber optics, to support IoT devices and data exchange in smart buildings.

Smart Grid and Renewable Energy Integration: Develop smart grids that allow for the integration of renewable energy sources such as solar and wind. This will help address sustainability goals and energy efficiency.

Pilot Projects: Implement pilot projects to demonstrate the feasibility and benefits of smart buildings. These pilots can serve as testing grounds for new technologies and as showcases to attract investment.

Infrastructure Planning: Integrate smart infrastructure planning with urban development initiatives, ensuring that future growth supports smart city technologies.

6. Environmental Sustainability

Sustainability is a major focus of smart city initiatives in East Africa, with countries like Kenya and Rwanda leading the way in green building practices.

Energy Efficiency Standards: Mandate energy efficiency standards for all new buildings, ensuring that smart buildings contribute to overall energy conservation.

Green Building Certifications: Promote the adoption of green building certifications (such as LEED) to ensure that buildings meet environmental and sustainability standards.

Water and Waste Management: Incorporate smart water management systems and waste management technologies into building designs to reduce resource consumption and promote sustainability.

Sustainable Construction Materials: Encourage the use of environmentally friendly construction materials, such as recycled or sustainable materials, to reduce the environmental impact of building projects.

7. User-Centric and Adaptable Design

Focus on Occupant Comfort and Productivity: Implement systems that allow building occupants to adjust lighting, temperature, and security settings. These customizable features enhance user satisfaction and productivity, making SBCs more attractive in commercial and residential spaces alike.

Feedback-Driven Improvements: Use occupant feedback to refine SBC design and functionality over time. This approach ensures that SBCs remain user-centric and responsive to changing needs, which will increase acceptance and encourage broader adoption.

Inclusive Design for All Demographics: Ensure SBCs are designed to be accessible and relevant to the local culture and socioeconomic conditions, addressing the local community's specific needs and values. Adaptable, context-sensitive SBC designs are more likely to gain public acceptance and usage.

8. Overcoming Barriers to SBC Adoption

Several barriers, such as inconsistent government policy, inadequate finance schemes, high design costs and poor maintenance culture were identified as critical barriers for adoption of SBC in Adama city. High cost of smart building materials, lack of research, and resistance to change, were also identified as significant barriers in Adama City.

Mitigate High Design Costs:

Promote local expertise and capacity building: Investment in training local architects, engineers, and designers can help reduce reliance on expensive foreign expertise, lowering design costs. Offering specialized courses on smart building design can also increase the number of skilled professionals available.

Foster technology collaboration: Encourage collaboration between local industries and international technology providers to create cost-effective solutions tailored to the local context.

Government support for research and development: Support research into low-cost smart building materials and technologies that are suited to the local environment and economy.

Implement training and certification programs: Train local maintenance personnel and offer certifications for professionals responsible for smart building upkeep. This ensures the technology is properly managed and maintained over its lifecycle.

Raise awareness on the importance of maintenance: Run public and industry awareness campaigns highlighting the value of regular maintenance for the long-term success of smart buildings.

Adopt maintenance-friendly technologies: Choose smart building systems that are easy to monitor and maintain with minimal technical expertise, and offer remote monitoring options to assist in early identification of issues.

Cost Management: Address the high costs of smart building materials by offering subsidies or incentivizing local production to reduce import dependence.

Change Management: Implement change management strategies to overcome resistance to new technologies by involving stakeholders early in the planning process and providing training on the benefits of SBCs.

Government-Led Initiatives: Initiate government-led programs that demonstrate the benefits of SBCs to reduce resistance and build confidence in the concept.

4.7.1 Framework Implementation Strategy

Phase 1: Policy and Capacity Building Foundation

Establish a foundational policy framework with clear SBC regulations and engage stakeholders to ensure policies align with local needs. Launch initial awareness and educational campaigns to build a baseline understanding of SBC benefits among professionals and the general public.

Phase 2: Infrastructure Development and Pilot Projects

Begin with targeted infrastructure upgrades, especially in technology and energy management. Roll out pilot projects in strategic locations, providing real-life examples of SBC benefits. Gather data and feedback from pilot projects to identify best practices and potential improvements for future large-scale deployments.

Phase 3: Expansion and Continuous Improvement

Scale up SBC adoption by incentivizing private sector involvement, offering flexible financing, and providing continued professional training. Establish a monitoring and feedback system for ongoing improvement, ensuring SBCs remain responsive to both technological advancements and user needs.

4.7.2 Comprehensive Framework Diagram for SBCs Adoption in Adama City

This comprehensive framework incorporates key findings from current trends drivers of SBC adoption and the specific factors enhancing and hindering SBC implementation in Adama City. It emphasizes the need for policy support, technological readiness, financial strategies, capacity building, infrastructure development and user-centric and adaptable design, all while addressing barriers to adoption. The framework can serve as a strategic guide for stakeholders to facilitate the successful implementation of Smart Building Concepts in Adama City, Ethiopia.

The following figure shows the diagrammatic representation of the comprehensive framework for the successful adoption of smart building concepts in Adama City, Ethiopia. The framework visually organizes the key components, including policy support, technological innovation, financial investment, capacity building, infrastructure development, environmental sustainability, user-centric and adaptable design and overcoming barriers, along with their sub-components and relationships.

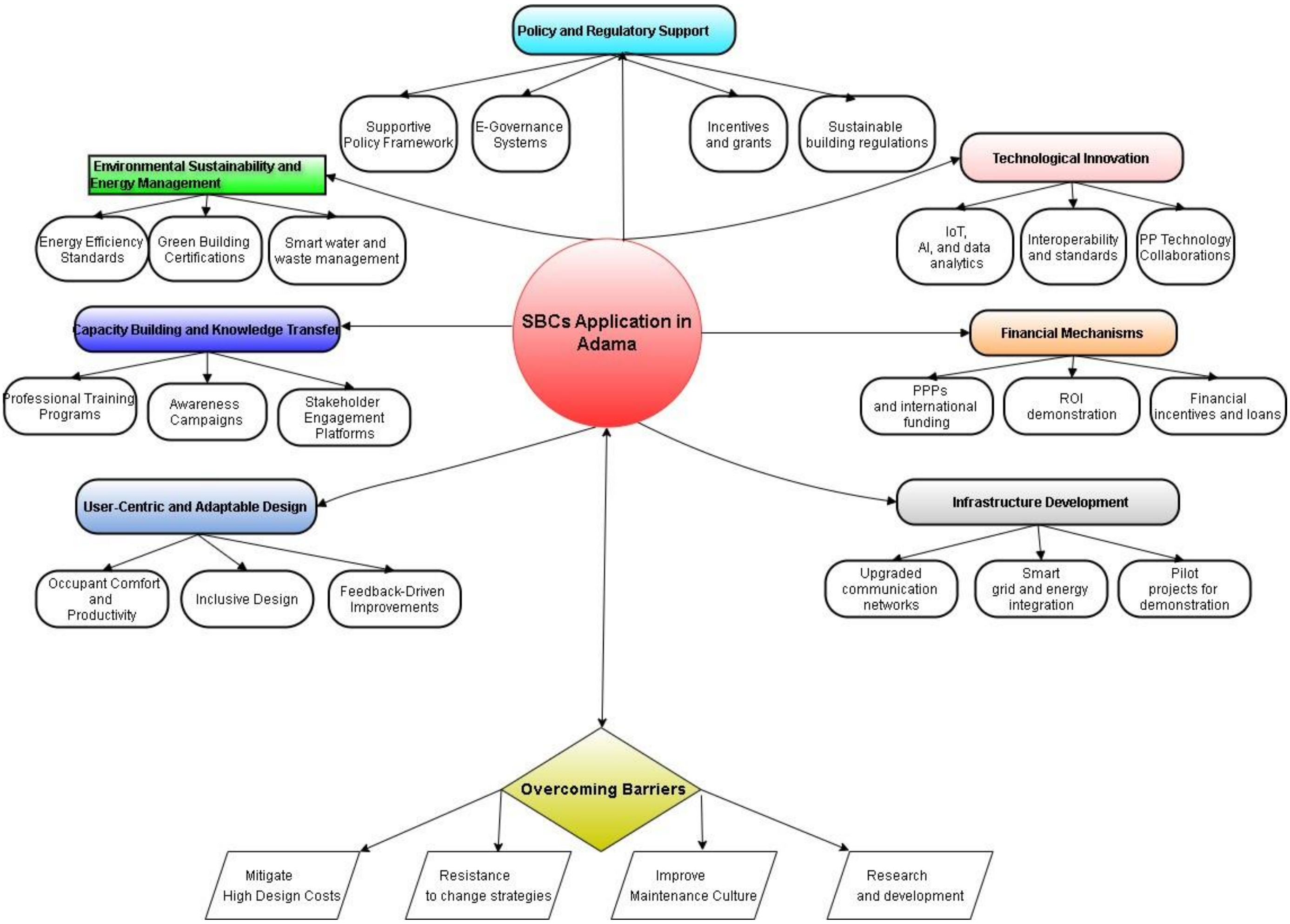

Figure 4.4 the key components for successful implementation of SBCs in Adama City

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This research aimed to investigate the key factors influencing the successful application of the Smart Building Concept in the context of Adama City, Ethiopia, with the goal of enhancing smart city realization. The research explored the following objectives, including current trends and practices of SBCs, factors enhancing and barriers to adoption of SBCs in Adama city and the development of a comprehensive framework for successful implementation.

Current Trends and Practices of SBC: The study reveals that the current trends in smart building concepts (SBCs) are increasingly focused on energy efficiency, sustainability, and technology integration. Globally, there is a marked shift towards implementing SBCs that leverage IoT, automation, and data analytics to enhance building performance, reduce operational costs, and improve environmental outcomes. In Adama City, while interest in SBCs is emerging, practices remain largely traditional due to barriers such as high initial costs**,** limited technological infrastructure**,** and low public awareness**.** The use of Building Information Modeling (BIM)**,** IoT-based monitoring**,** and energy-efficient designs are prominent in larger, modern projects, though adoption across smaller projects and public infrastructure remains low.

Factors enhancing the successful implementation of SBC: The research identified key factors that enhance SBC adoption including a strong policy framework and e-governance, which provide essential guidance and regulatory support. The integration of advanced technologies like IoT and smart energy management systems, along with public awareness initiatives, are also vital in encouraging SBC adoption. Furthermore, sustainability and environmental considerations such as energy efficiency and carbon reduction goals are increasingly viewed as pivotal to SBC application, emphasizing the importance of green building practices in aligning with global climate objectives.

Barriers to SBC Adoption in Adama City: While there are robust drivers supporting the adoption of SBCs in Adama City, significant barriers impede the broader implementation of SBCs. The inconsistent government policies and inadequate financial schemes create uncertainties that discourage investment in SBC technologies. Additionally, the high design and construction costs associated with smart buildings limit accessibility, especially for smaller projects. Limited public awareness and technical expertise gaps further challenge SBCs adoption, as many stakeholders lack knowledge of the benefits and operational requirements of smart technologies. Addressing these challenges can pave the way for a more integrated and sustainable approach to smart building development, aligning with Adama's broader urban and environmental goals.

Framework for SBC Adoption in Adama City: This study proposes a comprehensive framework for adopting smart building concepts in Adama City, tailored to address the city's unique socio-economic, regulatory, and environmental landscape. The framework prioritizes policy alignment, financial incentives, technology integration, and capacity building as key pillars to support SBC adoption. The proposed framework provides a structured pathway for Adama City to transition towards smart building adoption, enhancing its potential as a model for sustainable urban development in Ethiopia.

In general, the successful adoption of the Smart Building Concept in Adama City requires a multifaceted approach that involves policy reforms, technological innovation, stakeholder collaboration, and continuous investment in infrastructure and capacity building. By addressing the identified barriers and leveraging the drivers, Adama City can progress toward becoming a model smart city in Ethiopia.

Recommendations

Strengthening Policy and Regulatory Frameworks: It is essential for policymakers to establish consistent, supportive policies to encourage SBC adoption. Incentives such as tax breaks, grants, and subsidies can encourage construction firms to incorporate smart technologies. Additionally, sustainable building regulations should be strictly enforced to align with international best practices.

Enhancing Technological Integration and Innovation: The integration of IoT, AI, and data analytics should be prioritized in building management systems. Developing partnerships with technology providers and international firms can accelerate the adoption of cutting-edge technologies. Standardized platforms for interoperability should also be introduced to ensure seamless integration across different smart technologies.

Expanding Financial Incentives and Investments: Public-private partnerships (PPPs) and international funding sources should be further explored to address the high initial costs of SBC adoption. Financial institutions should also offer tailored loans and credit facilities to developers and builders willing to implement smart technologies.

Promoting Public Awareness and Professional Capacity Building: Awareness campaigns targeting the public, investors, and professionals should be launched to showcase the benefits of SBCs. Additionally, targeted training programs should be provided to professionals, including engineers, architects, and construction workers, to enhance their skills in implementing smart technologies.

Improving Infrastructure Development: Investments in upgrading communication networks, energy grids, and water management systems are crucial to supporting smart buildings. Demonstration projects and pilot smart buildings should be implemented to demonstrate the practical advantages and feasibility of adopting SBCs in Adama City.

Fostering Environmental Sustainability: integrating sustainable practices by promoting green building certifications, energy efficiency standards, and smart waste management systems. Environmental sustainability should be a core component of all smart building projects to align with global sustainability goals.

Overcoming Barriers through Research and Development (R&D): invest in Research and Development focused on local solutions for smart buildings. This could involve partnerships between universities, research institutes, and the construction industry to create context-specific innovations that address the unique challenges faced by Adama City.

By implementing these recommendations, Adama City can overcome the barriers identified in the research and move towards the successful adoption of smart building concepts, ultimately contributing to the broader smart city realization in Ethiopia.

Recommendation for Further Research

1. Explore the implications of integrating advanced technologies, such as IoT and AI, in enhancing the functionality and efficiency of smart buildings.
2. Examine the role of smart building technologies in promoting environmental sustainability and energy efficiency within urban environments.
3. Develop methodologies for assessing the long-term impacts of smart building technologies on urban sustainability and quality of life in Adama City.
4. Evaluate the outcomes of pilot projects that implement smart building technologies to understand best practices and potential challenges.

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APPENDICES

Questionnaire Survey on Thesis entitled Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia – The Case of Adama City

Dear Participant,

I am **Yonas Tayu**, a postgraduate student in the Department of **Construction Engineering and Management at Adama Science and Technology University**. I am conducting research on the **Application of Smart Building Concept to Enhance Smart City Realization in Ethiopia**, with a specific focus on the case of **Adama City**. The aim of this research is to develop a framework for the successful implementation of smart building concepts in Adama City to enhance smart city realization in Ethiopia. To achieve this aim, the objectives are set to;

i. To identify the current trends and practices of smart building concept implementation, with a focus on enhancing smart city realization.

ii. To assess the factors enhancing the implementation of smart building concepts in the context of smart city development.

iii. To investigate the barriers hindering the application of smart building concepts.

iv. To develop a framework to guide the successful implementation of smart building concepts, taking into account the unique characteristics and challenges of the city as a case study in Ethiopia.

As the world rapidly urbanizes and embraces technological advancements, the concept of smart cities has gained significant attention as a means to improve sustainability, efficiency, and quality of life for residents. Smart buildings play a crucial role in this context, as they integrate cutting-edge technology to optimize energy consumption, enhance occupant comfort, and enable seamless communication within urban environments.

Adama City, located in Ethiopia, is experiencing rapid urban growth and faces various challenges related to infrastructure development, resource management, and environmental sustainability. By exploring the application of smart building concepts in Adama City, I aim to understand how these innovations can contribute to the realization of a smart city and address the unique needs of this urban setting.

Your participation in this questionnaire survey is invaluable as it will provide insights into the current trends, challenges, and opportunities associated with implementing smart building concepts in Adama City. Your input will help inform strategies and recommendations for enhancing the integration of smart technologies in the city's built environment.

Thank you in advance for your time and contribution to this important research endeavor!

Sincerely,

Yonas Tayu

Section A: Background Information

This section of the questionnaire is designed to collect the necessary background information of respondents. Please note that your response will remain anonymous. Your co-operation is appreciated. Tick the correct description as applicable in the question.

1. Gender: Male [ ] Female [ ]
2. Age: Below 25 [ ] 25-35 [ ] 25-35 [ ]
   46-55 [ ] Above 55 [ ]
3. Kindly indicate your highest educational qualification completed.

a) Diploma/Level [ ]

(b) Advanced Diploma [ ]

(c) B.Sc. [ ]

(d) M.Sc. [ ]

(e) Ph.D [ ]

(f) Others please specify ………..

4. Please indicate your professional background?

(a) Architect [ ]

(b) Builder [ ]

(c) Quantity surveyor [ ]

(d) Engineer [ ]

Others please specify………………………………………….

5. Kindly indicate the year of your professional experience in the field?

a) Less than 5 year [ ]

(b) 5 - 10years [ ]

(c) 11 - 20 years [ ]

(d) More than 20 years [ ]

Section B: Objective 2: Factors enhancing the implementation of smart building concepts in the context of smart city development.

Please rate the following factors that can enhance the implementation of smart building concepts among professionals in Adama City on a scale of 1 to 5 in order of significance: 1=Not significant; 2=Rarely Significant; 3= neutral; 4= Significant; 5= highly significant.

S/N	**Factors**	**1**	**2**	**3**	**4**	**5**
F1	Policy Framework and E-Governance	1				
F2	Integration of Technologies and Collaboration with Technology Providers	4				
F3	Public Awareness and Education	2				
F4	Environmental and Sustainability Considerations	5				
F5	Infrastructure Development	3				
F6	Investment in Research and Development	8				
F7	Capacity Building and Training Programs	7				
F8	Pilot Projects and Demonstrations	6				
F9	Energy Management	10				

Objective 3: investigate the barriers hindering the application of smart building concepts.

Please rate the following barriers to the application of smart building concepts in Adama City. Kindly rank in order of importance using the following 5-point scale rating scale; 1=strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.

S/N	Barriers to the application of SBCs	1	2	3	4	5
I.	**Feasibility Study Phase Barriers**					
B1	Inconsistent Government policy					
B2	Inadequate finance schemes					
B3	Lack of research work					
II.	**Design Phase Barriers**					
B4	High design costs					
B5	High cost of smart building materials					
B6	Poor knowledge of smart building technology					
III.	**Construction Phase Barriers**					
B7	Inadequate power supply					
B8	Inadequate well-trained labor					
IV.	**Operation and Maintenance Phase Barriers**					
B9	Poor maintenance culture					
B10	Resistance to change from the use of traditional technology					

Section C: Additional Comments

What do you think is the most important factors for enhancing smart building realizations in Adama City?

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Thank you for participating in this survey! Your responses will contribute to the research on enhancing smart city realization in Adama City through the application of smart building concepts.