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Exploring the Role of Green Building Technologies in Smart City Policies in South Africa.

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Abstract

The rapid urbanisation of South African cities has intensified the demand for sustainable, efficient, and innovative urban development strategies. In response, smart city initiatives and green building technologies have increasingly been positioned as central components of national and municipal policy frameworks. This article explores the role of green building technologies within smart city policies in South Africa, with a specific focus on how these technologies are framed, integrated, and prioritised in policy discourse. Adopting a qualitative research design, the study employs a document analysis methodology to examine key national and municipal policy documents, including the National Development Plan (NDP 2030), the Integrated Urban Development Framework (IUDF), selected municipal Integrated Development Plans, and reports from the Green Building Council South Africa. Thematic content analysis is used to identify dominant policy narratives, areas of convergence, and existing gaps in the integration of green building technologies within smart city strategies. The findings reveal that while green building technologies are increasingly acknowledged as critical to sustainable urban development, their incorporation into smart city policies remains uneven and fragmented. Policy emphasis tends to prioritise digital infrastructure and economic competitiveness, often at the expense of comprehensive environmental sustainability and coordinated implementation mechanisms. The article contributes to the growing body of literature on smart cities and sustainable urban governance by providing a policy-focused analysis of the South African context. It further offers recommendations aimed at strengthening policy coherence, enhancing intergovernmental coordination, and mainstreaming green building technologies as integral components of smart city development. This study underscores the importance of aligning innovation-driven urban policies with sustainability objectives to advance resilient and inclusive cities in South Africa.

Keywords: Smart cities, innovation, urban sustainability, green technologies & policy

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1. Introduction

1.1 *Contextualizing Urban Sustainability in the 21st Century*

According to Imafidon et al. (2024) today cities are growing so rapidly, by seeing many people moving into urban areas. However, this growth comes with challenges on environment, housing, energy, and transport. Due to this, government are searching for alternative ways that are new to make sure that the cities are more sustainable, cleaner, and smarter. To ensure effectiveness, it needs to focus on using green building technologies as one of the policies that will be effective. The 21st century came up with many changes in such a way that it can be traced to how people travel, work, and live. The major change is the rapid growth of cities by looking mostly at developing countries where their economies are trying to fit in with the system of developed countries. When cities grow, they require more usage of energy, cause more pollution, and produces more waste. As a result, it is more important to come up with better ways to manage urban areas and to plan (Imafidon, 2024).

Urban sustainability refers to making sure that cities meet the standards and the needs of people without affecting the lives of upcoming generations harder or without causing harm to the environment (Keivani, 2009). The sustainable city should be efficient, healthy, and safe. Furthermore, it should be in a position where it protects natural resources such as green spaces, fresh air, and clean water. This can be done through the use of smart solutions and new ideas that can bring sustainability immensely (Keivani, 2009). This can be important by including the use of renewable energy, improving public transport, and coming up with ways that use less water and energy, and reducing waste. Looking at these steps, it does not only help the environment, but the life of people living in cities will be better due to a healthy conducive environment (Keivani, 2009). Urban sustainability is more about coming up with findings on how to balance environmental care, social needs, and development. In the 21st century it is

about what actions can be taken to make cities become more sustainable where it is not about a choice any longer, but it is about a necessity.

1.1.1 *Smart Cities and Green Building Technologies as Policy Priorities*

Smart cities are cities capable of improving their citizens' life quality, offering a lasting opportunity for cultural, economic, and social growth in a healthy, safe, stimulating and dynamic environment (Casini, 2017). It is concerning cities that operate using data and technology to improve their working process. In smart cities, technologies are used to regulate services (waste collection, transport, and electricity) in smarter and more organized means. The aim is to make sure that people live their lives in an easier, more affordable, and healthier for people living in the city (Casini, 2017). One important aspect of smart city planning is green building technology. These are about building methods and design that reduce things that harm the environment. For instance, green buildings could use systems that use less water and electricity, collect rainwater, and use solar panels. These technologies have positive results in such a way that they help reduce their impact on the environment and lower the cost of running buildings.

According to Razmjoo et al. (2021) now, governments are having inclusiveness in a way that they include green building practices and smart ideas in their policies. This means that they are creating guidelines and laws that will help cities to use these kinds of tools. The creation of policies aims to enhance quality of life, make cities more prepared for any occurrences that might happen in the future, and fight climate change. in places such as South Africa, green building technologies are becoming more popular. They are being used in public buildings, offices, and new housing projects. The government, along with local communities and private companies, are now seeing the value in building in greener ways and smarter. These technologies have a positive impact in bringing local skills development and job creation. For instance, workers need to be trained to install energy-saving systems, smart meters, and install and maintain solar panels. As a result, it shows that smart cities are not only concerned with the environment, but it contributes to supporting the economy (Ramjoo et al, 2021).

1.1.2 *The South African Urban Landscape: Challenges and Opportunities*

1.1.2.1 Challenges

In South Africa, the city scape is influenced by the complicated historical background of apartheid space planning, high population growth, and the inequalities of infrastructures. The inequality in measurable development, which continues in most cities, is one of the major challenges. In the apartheid, the cities were planned in such a manner that they separated the races with the non-whites forced to live in the outskirts of the townships. Some low-income communities continue to reside in informal settlements or on marginalized land with inadequate access to services to this day (Department of Forestry, Fisheries and the Environment, 2024). This division makes the supply of infrastructure, like water, electricity, roads and sanitation more expensive.

Urban spread has been associated with this spatial inequality. Many South African cities can be described as low-density developments and thus, the provision of services to the residents is both inefficient and costly. Low-density places are expensive to offer due to the long distances that the infrastructure must cover, and the inability to utilize public transport effectively (City Energy, 2021). High transport emissions are also another effect of this spread since most of the residents of the sprawl use a personal car to travel long distances.

Furthermore, huge problem within the urban system is the decay of the infrastructure and under-investment. There are numerous cities that are finding it hard to sustain declining water and power systems. The government transparency report states that there was a level of insufficient infrastructure, water delivery systems have leaks and wastage, and most urban systems are exposed to failure because of the under-investment in their maintenance (DFFE, 2024). Even certain cities do not have adequate transport systems and internet connectivity, which hamper smart city plans (DFFE, 2024).

Unreliability and energy poverty are another major issue. Cities in South Africa are taking up a big portion of the national energy, but they experience constant load-shedding (rolling blackouts) and deteriorating electricity distribution systems (City Energy, 2021). Such power outages damage livelihood and economic activity, particularly in the poorer city centers. To illustrate, in Johannesburg, small businesses and households have been destabilized by blackouts, among other things (Mchunu, Onatu & Gumbo, 2023). Township informal houses mostly use unhealthy sources of energy such as paraffin or coal, which pose health hazards (City Energy, 2021; Pathways to Urban, 2021).

The local governments are also weak in governance and financial capacity. Municipalities struggle to put large infrastructure or smart city initiatives into practice and sustain them because corruption, mismanagement, and lack of fiscal resources make it difficult to fund them (Architect Africa, 2025). An example is that in Johannesburg, roads and bridges are falling apart, and most municipal budgets are exhausted through wasteful expenditure, hence it is hard to plan long-term (Architect Africa, 2025).

Housing shortages are a problematic issue on the social front. Informal settlements or crowded houses are habited by millions of people. Although government housing programs are important, they have failed to keep up with demand (City Energy, 2021; Pathways to Urban, 2021). The expansion of backyard shacks (informal houses constructed at the back of the formal houses) increases the pressure on already existing facilities like water and electricity since such houses tend to connect to the supply of the formal house. Most of these new homes at the time outgrow the eligibility conditions of the free basic services (Pathways to Urban, 2021).

Other significant stressors also include urban food insecurity and poverty. The food systems are strained due to increased urban population: many poor households are residing in the areas with

restricted access to fresh food, and there is not much land available to urban agriculture (Sustainable Cities, 2025). This poses social and health problems, particularly on low-income settlements (Multidisciplinary Digital Publishing Institute, 2025).

Moreover, cities in South Africa are susceptible to climatic hazards. Weak planning has led to many informal settlements being in flood prone areas or hillsides that are vulnerable to landslides or erosion (DFFE, 2024). Climate change makes these risks even worse and harms the infrastructure, and its maintenance is even more expensive (DFFE, 2024).

1.1.2.2 Opportunities

Despite these enormous challenges, the urban environment also presents a great opportunity to the green building technologies and intelligent city policies. One of the opportunities is high density, integrated urban development. Cities do not need to keep spreading out but should discourage more dense and mixed-use communities. Such models as 15-minute neighborhoods (when all necessary items are within a walking distance) could decrease the number of transport emissions, minimize infrastructure expenses, and enhance social cohesion (Circulareconomy, 2025).

The other opportunity is in nature-based solutions (NbS). The scholars have emphasized the role of green infrastructure (such as ecologically designed buildings, urban gardens, green roofs, and bioswales) in controlling stormwater, enhancing biodiversity, and alleviating the heat-island effect (Aliu & Aghimien, 2025). Incorporating green building methods, towns will be more resilient to climate change as well as sustainable in general.

There are also good opportunities in the direction of smart grids and energy-efficient technologies. The planning of a smart city will enable cities to incorporate renewable energy solutions, which may include solar power, battery storage, and microgrids that are decentralized. This would lessen the reliance on the national grid and would help in alleviating the effects of load-shedding. Energy management based on smart metering and data can be used to raise efficiency and minimize losses (PwC via SA J. of Industrial Engineering, 2023).

Another opportunity is provided by the adoption of social housing programs. Formal, safe housing of low-income groups can be offered in properly designed social housing development with green building materials and technologies to prevent excessive energy and water consumption (Sokhetye, 2025). Social housing can be incorporated into bigger sustainable urban nodes when connected to smart city models. The future of urban agriculture and transformation of the food system is also promising. Cities can promote food gardens in informal settlements, rooftops, or in green areas with the help of proper policies. Such urban gardens assist in combating food insecurity, creating jobs at the local level, and increasing the ecological value (MDPI, 2025; Neumann and Ngobese, 2025).

In terms of their finances, more people are showing interest in green infrastructure funding. The infrastructure investment gap can be sealed using international development funds, climate finance, and partnerships among other ways. As an example, novel financing schemes or incentives to sustainable buildings may direct capital to green building and smart city developments. Moreover, technological innovation forms new economic opportunities. It is claimed that the emergence of smart buildings (the use of sensors, automation, and data analytics) will give rise to new software, hardware, and service companies (SA J. of Industrial Engineering, 2023). This would help to generate job opportunities particularly among young people and aid in switching to the green economy.

Lastly there is better governance and institutional capacity which also presents a challenge and an opportunity. The policies of smart cities can enhance the national, provincial and local governments' coordination. Through online platforms, data openness and participatory planning, citizens can be more engaged in city-level decision making. This will result in better accountable, effective, and participatory urban governance.

1.1.3 *Research Aim*

This study will be aimed at investigating the presence of and support of green building technologies in South Africa smart city policies. This paper is aimed at realizing how such technologies have been identified in national and local policy documents and how they have been integrated as a part of broader sustainability objectives. Since the South African cities have a problem of inaccessible energy supply, strains in infrastructure, high urbanization, and environmental hazards, the study seeks to explore whether the current policy systems are defining green building technologies as viable solutions to these problems. One of the objectives of the study is to determine the degree of policy integration among various sectors.

A smart city design is related to numerous aspects of urban living, such as housing, transportation, water supply, and energy infrastructure. These industries tend to work in isolation hence resulting in disjointed planning. The study thus seeks to know whether the green building technologies are being dealt with in a coordinated manner in these sectors or whether the policies are dealing with them as divergent, independent measures. It involves analyzing whether the national and municipal plans promote cross-sector collaboration or whether individual sectors operate within national and city limits without any distinct connections to the vision of smart cities.

The other objective is to assess the difference between policy intentions on one hand and actual implementation on the other. Numerous policy statements provide powerful pledges to the idea of sustainability, innovation, and clever technologies, yet the truth is in the question of whether these concepts are supplemented by actionable measures. The research will focus on assessing whether there exist guidelines, realistic timelines and measurable targets of green building technologies in policies. It also seeks to research on the question of whether the municipalities possess skills, funds and institutional capacity to implement these plans. This entails assessing

the quality of policy language as it converts into practice on the ground as well as the quality of implementation strategies as being strong, weak, or nonexistent.

The study also seeks to analyze the relationship between green building technologies and the national development priorities and the global commitments. Some of the frameworks that South Africa has conformed to include the National Development Plan 2030, the Integrated Urban Development Framework, and the Sustainable Development Goals. Green building technologies are significant in achieving energy efficiency goals, climate resilience goals, sustainable housing, and better service delivery.

This is why the proposed study seeks to examine the question of whether smart city policies embody these commitments or not and whether they view green building technologies as critical to the achievement of these goals. Besides, the study will find the gaps in policies and the area where the guidance is not fully developed or clear. There are policies that might refer to sustainability and fail to provide specific actions or guidelines towards green building technologies. The study aims at pointing out the areas in which the policies lack depth, clarity, or coordination to be used in future policy formulations. This consists of determining whether some sectors are addressed compared to others and whether some of the crucial themes such as financing, development of skills and provision of regulatory support have been well addressed.

Lastly, the study seeks to develop an advanced insight into the positioning of South Africa in the wider global trend of smart and sustainable cities. With the emphasis on the role of green building technologies, the paper is intended to expose whether South Africa is moving towards the direction indicated by the global trends in smart urban development or whether its policy choice indicates a different direction, impacted by the local issues and opportunities.

1.2. Background and Context

1.2.1. *Global Evolution of the Smart City Concept*

The concept of a smart city has been developing over the years with the increasing pressures of population expansion, environmental pressure, and technological revolution on the cities. Initially, the concept of smart cities came into being in the period when urban areas started applying information and communications technologies (ICT) to enhance the management of urban services (Du Toit, 2023). Sensors, data platforms, and connected infrastructure became valuable to governments and companies in most developed nations, as it would improve and make transport, energy, water, and public safety more efficient and effective (Du Toit, 2023). The concept changed as it grew up to no longer be about technology but about governance and sustainability. The IoT (Internet of Things), big data, and artificial intelligence have been applied in cities to oversee the traffic flows, regulate the use of energy, and anticipate the breakdown of services (Lau, Marakkalage, Zhou, Hassan, Yuen, and Zhang, 2019).

The concept of information aggregation, or the synthesis of data generated by many sources, has emerged as an important tool to help in decision-making. To illustrate, urban applications of smart cities can be comprised of sensor data, satellite imagery, and mobile devices to monitor the urban phenomena (Lau et al., 2019). Meanwhile, the goal of smart cities is no longer efficiency. Expectations are rising that smart cities are expected to contribute to resilience, environmental sustainability, and well-being of the citizens. Contemporary smart city models are more focused on governance, social inclusion, participation, and infrastructure, rather than only the infrastructure (Tan & Taeihagh, 2020).

In developing states, researchers purport that building smart city projects does not only need plugging technology, but it should be accompanied by legislative transformation, capacity-building, and participatory governance (Tan & Taeihagh, 2020). The history of smart cities the world over is a process, however: starting with the ideas of a technological metropolitan utopia, to more practical approaches that emphasize data, sustainability, and citizen involvement. The increasing number of cities across the globe implementing smart city policies is becoming more balanced in terms of technological innovation and social and environmental objectives.

1.2.2. *Defining Green Building Technologies in the Policy Context*

Green building technologies are described as design, building and operation practices that reduce the adverse environmental impact of a building and enhance resource efficiency and occupant health. The Green Building Council of South Africa (GBCSA) defines a green building as a building that either minimizes or eradicates environmental degradation throughout its life cycle, i.e. planning and construction, operation and decommissioning (GBCSA, n.d.). Green buildings are designed to be energy efficient, conserve water, use sustainable materials and have healthy indoor environment (GBCSA, n.d.). Green building technologies in policy terms usually imply tangible steps and guidelines that can be encouraged by the governments. It involves energy-saving heating, ventilation, and lighting, passive design, rainwater collection, and low carbon materials (Ecolution Consulting, 2024).

It is also possible to have policies certified to established rating systems, including Green Star or Net Zero, to make sure that buildings have quantifiable environmental performance requirements (Ecolution Consulting, 2024). Certification tools based on green buildings are important. The GBCSA has a Green Star SA rating system that assesses buildings in a range of categories, which include energy, water, materials, emissions, interior environmental quality, and innovation (GBCSA, n.d.; Lourens, 2025).

The tools serve to offer a quantifiable and objective method by which governments, developers and owners measure the level of greenness of a building (GBCSA, n.d.). Green building technologies are not merely technical innovations, as far policy is concerned. They are a policy tool, the governments can incentivize or control sustainable building by use of building codes, tax benefits, grants and mandatory certification (U.S. Trade & Development Agency, 2024). Governments can create connections between environmental objectives (such as greenhouse gas emissions reduction) and economic growth and social welfare by integrating the green building technologies into the city planning and smart city policies.

1.2.3 Smart Cities in Africa: Trends and Policy Directions

Smart city policy is gaining momentum in Africa with the rising urbanization. Cities are becoming expansive, and infrastructure is usually stretched. Smart city approaches in Africa are thus more oriented towards enhancing service provision (water, transport, energy), resilience and economic opportunity (Sterling Access, 2025). Digital technologies are viewed as major solutions to these urban challenges by the African governments and development organizations, which is why the strategy tends to vary with high-income countries. To start with, some African smart city projects are centered on the so-called leapfrogging, which means that the new technologies should be used to switch to the new system instead of improving existing infrastructure (Smart Africa, 2017). It is an adoption of smart grid systems, mobile-based public services, and sensor-driven waste and transport management without developing massive legacy networks in the first place (Smart Africa, 2017).

Second, the discussion of African smart cities is focused on governance and inclusion. In contrast to pure technology-oriented ones, most African smart city models put an emphasis on community engagement, local capacity and community decision making (Tonnarelli, 2024). As noted by scholars, to be successful in Africa, smart cities should be accompanied by investments

but also social reforms, the enhancement of the institutions of the country, and the benefit of the local population (Tonnarelli, 2024; Tan and Taeihagh, 2020).

Third, the African smart city policies are related to overall development objectives. A lot of smart city plans are in line with the national plans to facilitate economic growth, creation of jobs and sustainable development (Sterling Access, 2025). The structures of smart cities can also serve as a transition between digital innovation and social progress, not efficiency or profit (Smart Africa, 2017). Nonetheless, it has some challenges. Smart city technologies face obstacles in their implementation because of financial difficulties, institutional capacity, and informal economy (Tan & Taeihagh, 2020).

Digital divide is also possible: in the case smart infrastructure is implemented only in rich districts, the disparities may become even greater. Scholars emphasize the fact that the frameworks used in Africa should be designed specifically and not copied directly into the world models of smart cities (Tonnarelli, 2024). Generally, there is a shift towards technological, developmental smart city policies in Africa, one that is sustainable, inclusive, and transformational in economic terms.

1.2.4 South African Policy Landscape

1.2.4.1. *National Development Plan (NDP 2030)*

The National Development Plan 2030 of South Africa is a vision statement whose aim is to eradicate poverty and alleviate inequality by 2030. It has one of its major chapters (Chapter 8) dedicated to the transformation of human settlements and the enhancement of spatial economy (National Planning Commission, 2012). According to the NDP, the cities of South Africa need to be more functional, sustainable and efficient. It underlines the importance of constructing cities in which people reside near employment, social services, and transport connections, to decrease the commuting expenses, as well as to diminish spatial disparity (National Planning Commission, 2012).

The NDP also seeks urban development in a green manner. It advocates the adoption of low-carbon technologies in the construction and infrastructure, compact urban form and enhanced resource utilization in settlements (National Planning Commission, 2012). To achieve these objectives, the NDP proposes planning reforms, stronger institutions and collaborations with the private sector (National Planning Commission, 2012). It all depends on green building technologies in the long run as part of an overall approach to making human settlements more sustainable and equitable.

The Integrated Urban Development Framework (IUDF) is the key policy tool of South Africa in terms of managing urbanization. The IUDF was adopted in 2016 and is intended to shape the way the cities and towns develop and become more inclusive, resource-efficient, resilient, and well-connected (COGTA, 2016). It was partly created by implementing the objectives of spatial transformation in the NDP (COGTA, 2016). The IUDF contains nine policy levels, that is, primary areas of action, such as integrated urban planning, infrastructure, transport, and sustainable human settlements (COGTA, 2016). The IUDF facilitates compact urban development that is mixed-use (COGTA, 2016). This is just in line with smart city concepts and green building: small-size design decreases energy needs, whereas the green technologies can become incorporated into the infrastructure planning.

Cooperative governance is also highlighted in the framework. It requests collaboration between national, provincial, and local government, and the involvement of the civil society and the private sector (COGTA, 2016). The IUDF envisages a new city deal, where the city spatial inequality is resolved, and investments are planned to change the current city footprints instead of extending them (COGTA, 2016; IUDF brochure, 2020). Moreover, IUDF expressly facilitates better utilization of resources, environmental resiliency, and sustainability (COGTA, 2016). It cites the necessity of infrastructural choices that lower ecological footprints, and

sustainable building. This renders the IUDF an effective policy framework of integrating green building technologies in the development of smart cities (COGTA, 2016).

1.2.4.2. *Integrated Urban Development Framework (IUDF)*

The Integrated Urban Development Framework (IUDF) serves as South Africa's main policy tool for navigating urbanization. Introduced in 2016, the IUDF is designed to steer the growth of cities and towns towards becoming more inclusive, resource-efficient, resilient, and interconnected (COGTA, 2016).

It was partly created to support the spatial transformation objectives outlined in the National Development Plan (NDP) (COGTA, 2016). The IUDF identifies nine key "policy levers" that highlight essential areas for action, such as integrated urban planning, infrastructure, transport, and sustainable human settlements (COGTA, 2016). By harmonizing these levers, the IUDF encourages compact, mixed-use urban development (COGTA, 2016). This approach aligns well with the concepts of smart cities and green building, as compact designs help lower energy consumption, and thoughtful infrastructure planning can incorporate green technologies.

Additionally, the framework stresses the importance of cooperative governance. It advocates for collaboration among national, provincial, and local governments, as well as the involvement of civil society and the private sector (COGTA, 2016). The IUDF envisions a "new deal" for cities, aiming to tackle spatial inequality and ensure that investments are strategically directed to transform existing urban areas instead of expanding outward (COGTA, 2016; IUDF brochure, 2020). Moreover, the IUDF explicitly champions the efficient use of resources, climate resilience, and environmental sustainability (COGTA, 2016). It highlights the necessity for infrastructure choices that minimize ecological impacts and promote sustainable building practices. This makes the IUDF a robust policy framework for integrating green building technologies into the development of smart cities (COGTA, 2016).

1.2.4.3. *Green Building Council South Africa (GBCSA) Initiatives*

In South Africa, the Green Building Council (GBCSA) is a non-profit, membership-based organization that was established in 2007 to spearhead the industrialization of the built environment to be green (World GBC, n.d.). GBCSA forms tools, training and certification of green buildings within the country (GBCSA, n.d.). The most conspicuous tool offered by it is the Green Star SA rating system that analyses the environmental performance of buildings in various categories, such as energy, water, materials, emissions, indoor quality, innovation, and others (GBCSA, n.d.; GBCSA Rating Tools, n.d.). The Net Zero certification of the buildings that exceed partial development and are aimed at neutralizing or even outweighing the carbon, water, and waste footprint is also provided by GBCSA (Ecolution Consulting, 2024).

These rating tools provide the private sector and the developers with a shared language and a standardized set of measurable performance criteria on a green building (GBCSA, n.d.). In addition to certification, GBCSA is an advocacy organization. It trains industry practitioners, advances practices of green building, and invites the public to collaborate with the businesses in the construction of sustainable buildings (World GBC, n.d.). GBCSA, by its activity, assists in coordinating building practice with national policy goals, such as the NDP and the IUDF. The practical examples are numerous: several commercial and residential buildings in South Africa have already received the high ratings of the Green Star, which demonstrates the real application of green technologies (Solid Green, n.d.). This is in line with the smart city objectives (efficient, data-driven buildings) and policy objectives (sustainability, resource efficiency).

1.1.3 Linking Smart Cities, Green Technologies, and the Sustainable Development Goals (SDGs)

The smart city strategies and green building technologies in South Africa relate to the Sustainable Development Goals (SDGs) of the United Nations. Specifically, SDG 11 Sustainable Cities and Communities is very relevant. SDG 11 advocates to have inclusive, safe, resilient, and sustainable cities (United Nations, n.d.). Policy makers can directly support most of the SDG 11 goals, such as decreasing the per capita environmental impact, enhancing housing, and facilitating integrated urban planning, by encouraging the use of green buildings and smart infrastructure (United Nations, n.d.). Other SDGs can also be supported with smart city policies. An illustration is smart energy systems and green buildings minimize greenhouse emissions, which is part of SDG 13 -Climate Action. Green buildings promote SDG 6- Clean Water and Sanitation through efficient use of water and sustainable building material. Another aspect of the smart city design that can be used to meet SDG 9 Industry, Innovation and Infrastructure and SDG 12 Responsible Consumption and Production is smart transport systems. Smart city strategies are being used in South Africa to complement green building technology projects to boost the development agenda of the country. Sustainable and integrated human settlements in line with the SDG principles are already advocated by the NDP and IUDF (National Planning Commission, 2012; COGTA, 2016).

Once the green building practices are mainstreamed in planning smart cities, these international goals become tangible: e.g. with Green Star certification, local governments can monitor the number of buildings that meet sustainable performance standards, which will be part of national reporting on SDGs achievement. Besides, the certification of green buildings and investments in smart cities can open the gates to international sources of climate financing. Numerous financing systems in the world are giving preference to SDG-related initiatives particularly emphasizing resilience, low-carbon infrastructure, and sustainable urban development

initiatives. Therefore, the inclusion of green building technologies into the smart city policies may help South Africa to be a destination of climate finance and public-private initiatives that will support SDGs.

1.2. Problem Statement

1.2.1. *Policy Ambitions vs. Practical Realities, Fragmented Governance and Institutional Silos, Limited Mainstreaming of Green Building Practices in Policy*

South African smart city policy is all about sustainability, but it does not match what happens on the ground. National documents like the *South African Smart Cities Framework* talk about clean energy systems, efficient buildings and digital innovation but local government cannot implement this because of lack of budget, staff and long-term planning capacity (Naidoo & CSIR/DCoG, 2021). Many municipalities do not have the technical skills to integrate green building technologies into their daily planning processes, so policies remain theoretical not practical. The gap between ambition and reality widens when municipalities are under pressure to focus on urgent issues like service delivery, informal settlement growth and aging infrastructure. These pressures push green building projects to the backburner (Das & Emuze, 2020).

Fragmented governance and institutional silos make these challenges worse. Departments of housing, energy, water, transport and environmental planning work in isolation from each other which prevents coordinated action on green building (Rana et al., 2023). Smart city planning requires inter sectoral cooperation, but South Africa's urban governance system is often described as disjointed with limited integration between national and municipal policies (South African Cities Network, 2020). When institutions work in silos, planning frameworks do not align and this results in duplication of work, slow approvals and difficulty in integrating new technologies into existing systems. Silos also limit communication between departments and reduce the ability of cities to adopt shared solutions like energy efficient building codes or green materials.

Due to this fragmentation, green building practices have not been mainstreamed carefully into everyday policy. Despite the legislative tools afforded South Africa such as SANS 10400-XA energy efficiency standard and Green Star certification system, less than ten percent of buildings in South Africa can be regarded as incorporating advanced sustainability standards (Sithole et al. 2024). Green buildings are becoming more known, but still on the top end of the spectrum mostly with commercial developments around this development rather than public building or affordable housing (Green Building Council South Africa 2025).

Most municipalities and major urban areas have only recently begun to update their building codes that must pass through due to careful city planning, so this governance falls behind has made it optional rather than standard practice. But this piecemeal mainstreaming does little to advance our national sustainability aspirations and, in fact, likely widens the chasm between policy intention and practice consequence. South African cities have long faced coordination challenges that stand in the way of implementing these kinds of integrated green building and smart city policies, urban researchers say system thinking is required (Brandt & Siebert , 2022).

The disconnection of smart city planning from environmental and building governance misses so many opportunities to integrate systems such as renewable energy in new housing projects or nature-based infrastructure for climate resilience (van der Merwe et al., 2019). However, in the absence of common modes and forms of governance for city-building that integrates these green building aspirations into mainstream urban development. Rather they are standalone pilot projects that never scale out into the urban system. Most are linked to the 3 big problems such as divide between policy ambition and practical reality, governance in silos, underwhelming levels of mainstreaming smart city policy.

As a result, green building technologies continue to sit on the "periphery" of planning rather than at its "core," energy performance contracting. This means cities are unable to make the best use of green design for energy efficiency, climate adaptation and urban facilities. The underlying problem appears to not be a lack of ambition, but rather the absence of systemic coordination and implementable measures that would translate those ambitions into broad-level green building implementation.

1.3 Justification for the Study

South Africa's up against some tough challenges right now, environmental, economic, and governance issues that really cannot wait. When scholars look at the water shortages, heat waves, and unreliable energy in so many cities, it is obvious that sustainable building design is not just a nice-to-have. It is essential.

Green building technologies cut energy use, make indoor spaces more comfortable, and help cities bounce back from climate shocks. They are a key piece of the puzzle for any smart city that wants to cut emissions and deliver on sustainable living (van der Merwe et al., 2019). If society wants smart cities that work, they need to figure out how to weave these technologies into policy, and fast. There is another problem such as governance. Right now, fragmented institutions and a lack of coordination make it hard for cities to scale up green building solutions (Rana et al., 2023). No one is sure who is responsible for what, and that slows everything down. Digging into these institutional roadblocks, this research can point out where policy frameworks fall short and how to fix them. Smart cities cannot exist without everyone working together, across sectors. If that does not happen, sustainability goals just are not going to be met. Then there is the economy.

South Africa's construction sector has been struggling with slow growth, little investment, and jobs disappearing. Green buildings offer a way out. They can spark demand for new tech, create green jobs, and give the whole sector a much-needed boost (Green Building Council South Africa, 2025). Looking at how green building fits into smart city policy is not just about saving the environment; it is about finding real strategies for economic recovery and future growth. Plus, energy-efficient buildings save money in the long run and add value, which means adopting these practices supports the financial health of both public and private projects (Grant et al., 2020).

This research matters because it adds to what we know about a place that, honestly, does not get enough attention, South Africa, and really, most of Africa. Most of what we hear about smart cities comes from richer countries. Their infrastructure, government systems, and tech just don't match what you find in the Global South (Brandt & Siebert, 2022). South African cities have their own mix of problems: uneven growth, inequality everywhere you look, not enough funding, and lots of informal settlements. These realities call for green building solutions that fit the local context.

In South Africa, this study fills a big gap and shows how green building could work when cities are dealing with all this complexity. There is also a social reason for digging into this topic. When there is a bringing of green buildings into affordable homes or public spaces, people save money on energy, live healthier lives, and end up in better, more comfortable communities (van der Merwe et al., 2019). Smart city plans that include green building tech can push back against inequality, making sustainable living possible for everyone, not just those who already have plenty. That is right in line with South Africa's own goals around fairness, resilience, and making life better for everyone. One last thing, smart city policies need to be real. Right now,

a lot of strategies talk about a big game about sustainability but do not actually say how to put green building tech in place, pay for it, or keep track of progress (Naidoo & CSIR/DCoG, 2021).

This study looks at the gap between what is promised and what is happening. The goal is to come up with solid, practical advice for policymakers, developers, and planners—stuff they can use. With the right guidance, future investments can really move the needle of making cities greener and more sustainable.

2. Literature Review

2.1. *Conceptualizing Smart Cities: Theories and Frameworks*

People talk about smart cities as places where digital tools and data shape how we live, work, and move around. The idea is simple: use technology to make cities more sustainable, efficient, and livable. But behind that buzz, there's a lot of debate about what makes a city "smart." One big theory that can be heard about is technological determinism. This one explains that as cities get more sensors, data networks, and automation, those technologies start to steer how the city works. Think of smoother traffic, better water management, and safer streets because of smarter systems (Kitchin, 2014). Supporters of this idea usually zero in on how new tech gets rolled out and how it can tighten up control and coordination across a city. But there's another way to look at it. The socio-technical systems approach pushes back against the idea that tech alone calls the shots. It says real-world things like culture, politics, money, and community values shape how digital tools get used (Hollands, 2015). They cannot just drop a new gadget into a city and expect magic.

Communities, governments, and even local policies decide whether a piece of tech succeeds or fails. Plus, this approach keeps reminding us that unless smart city systems tackle inequality and include everyone, they don't really work. Connected to that is the governance angle. Here, it's all about who makes the decisions, who sets the rules, and how different groups, especially residents, get a say in what happens next. Researchers like Meijer and Bolívar (2016) say smart

city projects work best when people get involved, not just experts or officials. Residents should help plan, monitor, and judge these projects so they solve real problems. Sustainability is another big piece of the puzzle.

This approach says technology should help cities protect the environment, build up the economy, and include everyone at the same time. It's not just about speed or shiny new apps, it's about long-term resilience, tackling climate change, saving energy, and managing resources better (Ahvenniemi et al., 2017).

Tech should cut waste and emissions, and make cities healthier, not just faster. Then there's the triple-bottom-line idea. This one measure smart cities by how well they do on three fronts: environment, society, and economy. It's a way to see if things like green buildings or renewable energy aren't just good for business, but also for people and the planet (Elkington, 1997). The goal here is balance don't trade off the environment for a quick profit. The human-centered model is all about people. It says smart cities need to boost quality of life, bring everyone in, and treat people fairly. This model focuses on well-being, social bonds, and empowering marginalized groups by making sure digital tools and services reach everyone (Komninos, 2015). This really matters in places where gaps between rich and poor are still huge.

Another important framework is the integrative model. Instead of looking at tech in isolation, it connects the dots between systems like transport, energy, waste, housing, and water. The idea is to get everything working together through digital coordination less waste, more resilience, stronger cities (Angelidou, 2015). Of course, not everyone's convinced smart cities are all upsides. Critics point to risks like privacy issues, surveillance, unequal access, and the clout of big tech companies controlling city data. Without strong rules and real safeguards, smart cities can end up making old inequalities even worse (Sadowski, 2019). That's why a lot of scholars keep pushing for ethical guidelines and tighter oversight.

2.2. Global Perspectives on Green Building Technologies

Green building technologies cover everything from advanced construction methods to smart systems that cut down on resource use, save energy, and make healthier spaces for people. They've become a big part of the push for global sustainability and climate-friendly city planning. All over the world, people see green buildings as a major way to shrink a city's carbon footprint since buildings use up so much energy (International Energy Agency, 2021).

A lot of cities and countries rely on certification systems like LEED, BREEAM, and Green Star. These rating systems set the bar for how to design, build, and run buildings with the environment in mind. They help track things like energy efficiency, water savings, waste reduction, and indoor air quality (U.S. Green Building Council, 2020). Plus, these standards push developers and cities to build responsibly and stick to green policies. In places with more resources, green buildings often come packed with renewable energy tech. They will see solar panels, geothermal heating and cooling, wind turbines, and energy storage systems all working together to cut out fossil fuels. Germany and Sweden, for example, have strong policies that support "energy-positive" buildings places that make more energy than they use (European Commission, 2020). There's a clear link here between green buildings and bigger climate action plans. Water-saving tech is another big piece of the puzzle.

Think greywater reuse, low-flow toilets, rainwater collection, and smart sprinklers all tools that fight water waste. In regions facing water shortages, like Australia, Singapore, and parts of the Middle East, these systems have caught on fast in both homes and offices (Chong et al., 2018). Smart tech is everywhere in green buildings now. Things like smart meters, automated building controls, and sensor-driven lighting or ventilation help cut energy waste and give real-time data

on how things are running. These systems fit right in with the digital tools cities use for smart urban planning, making green buildings a key part of the bigger smart city picture (Zhao et al., 2019). But it's not just about saving energy or water.

Green buildings also put people's health in front and center. Increasingly, you'll find buildings using non-toxic materials, better ventilation, and designs that let in natural light. Research shows these features can cut down on breathing problems, sharpen thinking, and even make people more productive (Allen et al., 2016). That's why health-focused green design is really taking off worldwide. Money talks, too. Governments like those in the US, Singapore, and the UK are offering tax breaks, subsidies, and grants to get more builders and owners on board with green upgrades and new builds. Studies prove these incentives work, they boost adoption rates, especially in the private sector (Zuo & Zhao, 2014). With these financial nudges, cities can hit their climate goals faster and bring emissions down in the building sector.

Another big shift is that more countries are tying green building standards to their national climate policies. Lots of governments now include energy-efficient buildings in their targets under big deals like the Paris Agreement. Green buildings help countries hit emission reduction targets and build resilience against climate risks (United Nations Environment Programme, 2020). Research from around the world keeps pointing out just how important green building technologies are for sustainable, smart cities. Experts say they work best when plugged into bigger city systems such as smart power grids, better public transport, and creative ways to handle waste. This whole-system approach connects green buildings to the heart of smart city development by improving energy use, cutting emissions, and using digital tools to guide decisions.

2.3. Policy Integration of Sustainability and Innovation

When governments try to blend sustainability with innovation in policy, it gets real, they must build rules, incentives, and systems that push for eco-friendly tech but don't forget about people or the economy. A lot of countries are setting up national and city-level policies to get everyone

on board with green building tech. It all ties into those bigger smart city plans you keep hearing about. The idea is to protect the planet, use resources wisely, and keep cities moving forward with new digital tools.

Most of the time, this starts with a big picture framework. Think about climate action plans, energy efficiency roadmaps, and green infrastructure guidelines, all those government blueprints that steer how cities grow.

The United Nations' Sustainable Development Goals (SDGs), for example, give countries a set of targets for sustainable cities, clean energy, and smarter consumption (United Nations, 2015). These guides push cities to use things like efficient lighting, renewable energy gear, and water-saving tech in their building codes. Zoom in a bit, and you'll see cities getting creative with their own policies. They roll out smart city plans aiming to cut emissions, sort out waste, improve buses and trains, and build greener buildings. It's not just government, either these plans pull in developers and researchers, too (Batty et al., 2012). Working together, they try out new tech, swap ideas, and figure out what works. Rules matter, too. Building codes now often demand better energy performance, and planning laws nudge designers to use less stuff. These regulations shape what materials and tech developers use. And it works, research shows that tougher rules really do boost green building and shrink environmental footprints (Janda, 2011). Money always comes into play.

Innovative building tech isn't always cheap at the start, so governments throw in rebates, tax breaks, grants, or low-interest loans to help cover the cost. They also team up with private investors through public-private partnerships to get more green projects off the ground (Wang et al., 2018). Tech is a big piece of the puzzle. Governments back smart systems like building automation, smart meters, and energy trackers. These tools collect data that helps cities save energy and manage resources more efficiently. By plugging digital tech into building policies, cities can build better energy grids and even let people share energy across networks (Gómez et al., 2019).

There's a social side, too. If policy doesn't include everyone, it misses the point. More governments now mix social housing with green building standards, making sure even low-income folks get the benefits of sustainable homes (Turcu, 2012). So, innovation isn't just about shiny new tech, it helps cut inequality and protect the environment at the same time. The countries that really make this work usually have strong leadership and coordination. Ministries, city agencies, businesses, and community groups all need to be in sync. That's how smart city policies and green building efforts line up with national climate goals, local plans, and what people need on the ground.

2.4 South African Scholarship on Smart Cities and Green Development

In South Africa, research on smart cities and green development has picked up speed lately. The country's dealing with fast-growing cities, limited resources, and deep-rooted social gaps. Researchers keep coming back to how South Africa's approach to smart cities really mirrors its national goals, things like better public services, job creation, cutting emissions, and building resilience (South African Government, 2020). One big topic is how smart tech fits in with the country's ongoing service delivery problems.

Cities in South Africa juggle power cuts, water shortages, old infrastructure, and neighborhoods still divided by the past. Researchers say smart grids, water sensors, and digital tools can help cities run better and keep officials accountable (Naidoo, 2021). These systems cut down on waste and let cities manage what little they have more wisely. Green building tech gets a lot of attention, too, especially since the government's signed onto some serious climate commitments. Green buildings tick several boxes for the National Development Plan and the National Climate Change Response White Paper, energy efficiency, renewables, and better city design (Department of Environmental Affairs, 2011).

More companies are adopting green building standards, thanks in part to the Green Building Council South Africa, which sets benchmarks like Green Star SA (GBCSA, 2020). But it is not all smooth sailing. High upfront costs, a shortage of technical know-how, and not enough awareness among developers and policymakers' slow things down (Darko & Chan, 2018).

Researchers keep saying: South Africa needs stronger policies and incentives to speed up the use of energy-efficient materials, smart systems, and renewable energy in buildings. Governance comes up a lot in literature. Studies make it clear that smart city projects don't work without solid teamwork across national and local governments, clear direction, and real partnerships with businesses and universities (Mouton & Islam, 2021). When these groups pull together, cities can test new ideas and build the skills needed for smarter, greener growth.

Social inequality is another theme that researchers refuse to ignore. They argue that smart city plans must speak to the needs of poorer communities and not just leave them further behind. Tech like green building and smart systems should make housing more affordable, boost access to energy, and cut household bills (Maphoto & Singh, 2020). The goal is to be the first city that improves life for everyone, not just a lucky few. Finally, there's a lot of focus on urban resilience. Researchers dig into how cities can use green tech, smart water systems, and energy-wise buildings to face climate threats—droughts, heatwaves, flooding (Ziervogel, 2019). The message is simple: climate adaptation must be baked into any smart city strategy.

2.5 Identified Gaps in Literature

While the writings about smart cities and green building technologies are growing both internationally and in South Africa, certain gaps do still exist. One of the significant gaps is the scant investigation of the extent to which green building technologies are incorporated into

smart cities policy. There are numerous studies on smart cities or green buildings, but they fail to demonstrate the adequate integration of these concepts in South African policy. There is a need to investigate the nexus between environmental objectives, technological advancement and urban governance in more detail.

Another gap concerns the little information on how lower tier municipalities enforce adaptive smart city and sustainability policies at the South African national level. Much of the literature tends to center on national policy frameworks and does not focus on how policies are captured at the city level. There is a dearth of studies on the municipal level preparedness, proficiency, and institutional frameworks to promote the integration of green building technologies in the smart city model.

Another missing piece is research on low income or informal settlements. Much of the smart city literature is about fancy homes or commercial towers. but south Africa's city landscape includes big informal neighborhoods with no running water or electricity. Little research exists on how green technology and digital systems could be adapted to support affordable housing and help people save resources. More research is needed to understand how sustainability and tech can solve inequality. There also is a lack of study on how green buildings and smart cities affect people. Many reports talk about the environment and the tech benefits, but not many look at how these things change lives, including communities, and give people a voice. There is little information on how users feel, how communities get involved, and how the public trusts the use of digital and green tech.

Another key missing part is looking at how green building works overtime in South Africa. Many checks on work still to be done or buildings not yet built, but not many follow how these new systems hold up over time when used in different weather and life settings. They need to learn more about what gets broken, how much people save, and what effect it has on nature over time. Finally, there is not enough African views in the world smart city ideas. Most of the work is from Europe, Asia and North America where the money and tech are different. South African cities have their own problems like unfair wealth; past city designs and lack of tech.

We need more work that shows what Africans go through in their cities and what will work best for them. These missing pieces show that we need more real, open, and in the field work to know how to get South African smart city plans to use these tech ideas in a way that makes sense to their lives and places.

3. Methodology

3.1. Research Design: Qualitative, Exploratory

This study takes a close, open-ended look at how green building stuff fits into smart city plans in South Africa. Going with a qualitative approach lets us really dig into the meanings, aims, and vibes of these policies. It is a good route since policy papers are full of tricky concepts you cannot just measure.

The exploratory setup is handy since the whole link between green buildings and smart city policy is new in South Africa. Not much research exists on it yet (Creswell & Poth, 2018). This lets the researcher find fresh angles and see patterns that might be missed with more rigid methods. Having a flexible, qualitative setup matters because it lets the researcher roll with the punches when looking at policy papers, which can jump around in focus and how they're laid out. The setup allows for reading and comparing policies from national, city, and industry levels. By checking these papers, the study figures out how green building concepts are worded in smart city talk. It also checks how these concepts match South Africa’s goals for getting better as a country. So, using this kind of approach helps expose the heart of what policies care about, where the holes are, and how green building is thought about when looking at the bigger picture of cities growing in a way that lasts.

3.2 Method: Document Analysis

This research mainly looks at documents. It is a popular way to do qualitative research because it gives you a way to look at and understand written info in a step-by-step way (Bowen, 2009). It works well if you're studying policies because policies are official documents that show what the government wants to do, its plans, and how it plans to do it. Looking at these documents helps me see how they describe green building tech, what goals they are trying to reach, and

how they fit into plans for smart cities. In reading the policies, the information picked a bunch of times and jotted down notes about the big ideas. Then, looked at the notes to see if there were any themes, things that kept popping up, or what they meant relating to green building and smart cities.

Doing it this way is nice because they can see what the policies say plainly but also kind of read between the lines. Plus, they do not have to worry about stuff like getting a hold of policymakers for interviews or if people remember things right, since the policies are written down and do not change. Looking at documents also lets you see how different levels of government think. Like, national policies might talk about big goals, but city plans might get into detail. Combining these together, good results in terms of better idea of how green building tech is being used in South Africa's planning.

3.3 Selection of Policy Documents

3.3.1. National (White Papers, NDP, IUDF)

At the national level, South Africa has White Papers, the National Development Plan (NDP), and the Integrated Urban Development Framework (IUDF). These are key documents because they lay out the long-term goals for development and keeping things sustainable. The NDP shows where South Africa wants to be by 2030, like having good environmental practices and energy-saving infrastructure (National Planning Commission, 2012). The IUDF helps shape urban areas and focuses on making cities smart and sustainable (Department of Cooperative Governance, 2016). White Papers on things like energy, housing, and the environment give government departments extra guidance on dealing with climate change and encouraging good building practices. Because these national policies create a base for what cities and specific industries do, they are super important to this study.

3.3.2. Municipal (city strategies, integrated development plans)

City hall papers, things like city plans and development roadmaps, lay out how places like Johannesburg, Tshwane, and Cape Town are tackling city growth, climate change, and energy. These papers are more into the nitty-gritty than national rules do. For example, some cities have

plans for green building rules, solar power, and better transport (City of Cape Town, 2020). Developing road maps are really important because they show how cities plan to meet national targets locally. They also reflect what resources cities have and what problems they face. Looking at these city papers helps us see how green building ideas are being used in cities.

3.3.3. Sectoral (housing, energy, transport)

When talking about sector policies, it is about stuff related to homes, energy, and getting around. They picked these areas because they really have an impact on how green building stuff gets used in South African cities. Like, the National Housing Code has rules about saving energy and using sustainable materials (Department of Human Settlements, 2009). Energy plans, like the Integrated Resource Plan, talk about renewable power and cutting down on electricity waste (Department of Energy, 2019). Transportation plans cover low-emission travel and planning infrastructure.

These policies show how different parts of the government either help or hold back the use of green building tech. Plus; they tell us if these areas are on the same page as smart city ideas at the national and city levels. By looking at papers from different fields and levels of government, we can get a better handle on how green building tech fits into smart city plans. This way, we make sure to grab both the big ideas and the real-world plans.

3.4 Analytical Approach: Thematic Content Analysis

3.4.1. Coding Strategy

The initial step of coding is referred to as open coding. During the open coding stage, the researcher reads each document and underlines statements that relate to sustainability, technology, urban planning, energy use, housing development, or environmental management. The researcher labels these statements with short descriptors. After open coding, the researcher moves to the axial coding stage. At this stage, the researcher compares and organizes the initial codes into categories based on any relationship between them. For example, codes that relate to "energy efficiency," "solar technology," and "building standards" may be grouped together in a higher order category related to types of green building technologies. The final stage of

coding is called selective coding in which the researcher identifies core themes in the data that best explains how policies link green building technologies to smart city approaches.

This systematic coding strategy provides a useful framework to support the process of ensuring that the major themes are grounded in the actual text of the documents. It also reduces the potential for researcher bias, as the researcher must justify how initial codes ultimately were combined into themes.

3.4.2. Key Themes of Analysis

The analysis is guided by several major themes. Promotion of building energy efficiency is one of them. Numerous policies emphasize the necessity to decrease the consumption of energy and advance renewable energy technologies. The other theme is sustainable urban development where policymakers aim at minimizing environmental effects by means of improved planning and infrastructural development.

The third theme is innovation and technology that encompasses the application of digital, smart meter, and new building materials. Fourth theme can be as policy and governance. This theme discusses the theme of policy-supporting and policy-contradicting policies, as a way of promoting green building technologies. Other themes are climate resiliency, quality of housing, and funding mechanisms. The concept of climate resilience is reflected in the policy that talks about adaptation to extreme weather, and the concept of housing quality is reflected in sectoral policies that focus on safe and efficient living conditions. One can fund it through incentives, grants or partnerships to fund green buildings. These themes are useful because they enable the study to know the strong points and the weaknesses of the South African policies.

3.5 Research Limitations

The research has several shortcomings. The availability of policy documents and their quality is one of the constraints because document analysis will require such documents. Certain

policies are old obsolete or incomplete, and this restricts the precision of the analysis. The second weakness is that the documents will capture official directives and not practicality. There may be policies that talk about the high support of green building technologies, but this does not necessarily imply that the same objectives are implemented in practice.

These policies can only be confirmed through interviews or field studies, which cannot be done without. Another weakness is that there is the risk of interpretation bias. Despite thematic content analysis giving a systematic approach, the researcher still gives out interpretations according to what he/she understands. This can affect the codes and themes development. Also, the specific national, municipal and sectoral documents are the subject of the study. Although these documents are pertinent, they might not reflect everything which influences green building technologies. Also, policies in certain cities can be in greater detail than in others, which will provide an uneven analysis. The other constraint is that the policy contexts vary with time. New policies can be introduced, and old policies can be updated. Due to this, the study presents a picture and not an ultimate decision. Irrespective of these shortcomings, the study is also informative on the way green building technologies are appreciated in the policy of smart cities in South Africa.

4. Results

4.1. Policy Recognition of Green Technologies in Smart City Strategies

The policies of a smart city in South Africa consider green building technologies as important increasingly. National plans like the National Development Plan (NDP), the Integrated Urban Development Framework (IUDF) emphasize the inclusion of clean energy systems, environmentally conscious buildings, and efficient urban infrastructure in supporting the sustainable cities (National Planning Commission, 2012; Department of Cooperative Governance, 2016).

These policies indicate that government bodies accept green building as a major component of the long-term city change. They also perceive technology as something that is needed in enhancing the quality of life and reducing the environmental effects. At the local level, green

technologies are referred to in Cape Town, Johannesburg and eThekwini smart cities or climate action plans. The Climate Change Strategy of Cape Town involves residential and commercial buildings being committed to the use of energy-efficient buildings, solar photovoltaic (PV) facilities, and water saving methods (City of Cape Town, 2021).

The Smart City Strategy of Johannesburg also acknowledges the necessity of environment-friendly building systems that will decrease the amount of electricity consumed and enhance the comfort inside of a building (City of Johannesburg, 2020). These reports indicate that green building technologies are presented as the ones that facilitate digital innovation, environmental aspiration and climate resilience. Although the recognition is evident, the policies differ in the extent of detail that they offer. There are policies that provide measures that should be taken, like energy-efficient building codes and lighting, and those where the general statements are made, and their instructions are not precise.

Voluntary rating instruments like the Green Star SA and Net Zero certifications have been presented by the Green Building Council South Africa (GBCSA) and have affected the language of municipal policies and allowed cities to implement quantifiable sustainability principles (GBCSA, 2022). Nevertheless, these tools have not come to be uniformly incorporated in local government strategic plans. Most cities talk about green buildings and are not necessarily involved in firm implementation strategies. While the support of renewable energy can also be found in national energy policies (including the Integrated Resource Plan or IRP), the latter has an indirect connection to green buildings by promoting energy-efficient technologies (Department of Mineral Resources and Energy, 2019).

Although the IRP does not target buildings directly, it establishes an enabling environment through the promotion of distributed renewable generation, e.g. rooftop solar systems. This assists the smart city initiatives in taking up the greener energy models and lower strain on the electricity grid. The other recognition is through international commitments of South Africa. Being one of the signatories to the Paris Agreement, the country is under pressure to lower carbon emissions, and green building technologies are used to achieve these requirements

(South African Government, 2022). These larger promises are usually used to explain their environmental ambitions in smart cities.

Since cities are the major source of carbon emissions, the implementation of environmentally friendly building technologies has become a significant element of national climate response. Although this has been acknowledged, policy to action gaps in translation exist. Green technologies have been recognized in many policies but have little funding support or technical advice. The local governments usually have the problem of capacity, limited budgets and slow processes of approval. Consequently, the magnitude of implementation varies across various municipalities. The identification of green building technologies is at the policy level, but the implementation is still poor.

4.2 Weak Integration Across Sectors

4.2.1. Housing and Urban Infrastructure

Housing backlog is a problem in South Africa that determines the integration of green technologies into the built environment. Major housing developments are regularly oriented on price and speed of delivery over the long-term environmental effectiveness (Turok and Scheba, 2018). Consequently, green building technologies have employed disparity in the state-sponsored housing projects. Although the policies favor sustainable building, some real projects are not based on a sustainable building approach since most of them use the traditional materials and modes of construction since they are inexpensive and readily available. In the Breaking New Ground (BNG) policy, sustainable human settlements are already mentioned, yet green building technologies including insulation, greywater reuse, and passive solar design are not enforced (Department of Human Settlement, 2004).

Technology is thus seen as optional but not mandatory elements of smart cities by many municipalities. This vague connection between the dwelling and environmental objectives minimizes the possible effects of green technologies. There have been some pilot developments

utilizing energy-saving solutions, but these are small-scale. As an illustration, some of these social housing in Cape Town and Johannesburg have solar water heaters or efficient lighting.

Nevertheless, such interventions are usually done by way of donor-funded or research-based interventions instead of practice. Unless there is greater integration of policies, the green building technologies will be restricted to local neighborhoods instead of influencing the overall housing sector. There is also poor integration in urban infrastructure. Green technologies are rarely applied in the use of roads, public facilities, and community amenities. As an example, smart lights, sustainable drainage systems or climate-resilient materials are not commonly installed. The urban budgets are more biased towards repair rather than innovation in the case of under-resourced regions. The penetration of green building technologies will not be much until the infrastructure planning process embraces the sustainability standards in totality.

4.2.2. Transport and Energy Efficiency

A significant contributor to the emission in South African cities is transport. Nevertheless, transport planning does not necessarily include the introduction of green building technologies, although these two areas have a high level of interrelation. Through renewable energy systems, it is possible to directly connect smart transport infrastructure like electric vehicle (EV) charging stations to green buildings. However, the focus of most municipal transport schemes remains on road widening and not low-carbon mobility (South African Cities Network, 2021). This minimizes chances of matching building technologies with greater urban energy efficiency objectives.

There are energy efficiency policies, but the application differs. The National Energy Efficiency Strategy encourages efficient lighting and solar water heaters as well as better building envelopes (Department of Mineral Resources and Energy, 2016). These interventions are in direct relation to smart city objectives. Most of the municipalities, however, do not have the enforcement capacity to enforce the building efficiency standards. Consequently, energy

efficient designs are being utilized more in the high-income developments than the low-income or government aided developments. Green technologies are also not well integrated in the public transport systems.

As an example, Bus Rapid Transit (BRT) models in Johannesburg and Cape Town incorporate certain energy-saving options, yet they are not entirely aligned with the carbon-cutting objectives since they continue to be based on the use of diesel buses (Walters, 2021). The combination of green buildings and transport hubs, such as solar canopies, shade buildings or regenerative braking systems, is not extensive. Moreover, the electricity crisis in the country has compelled the adoption of emergency energy systems by the municipalities instead of long-term green designs. Intensive load-shedding has driven cities to install diesel generators, rather than investing in renewable building systems. These short-term decisions influence the way smart cities strategies are developed and lower the level of energy-efficient technologies implementation in social buildings.

4.2.3 Waste and Water Management

The issue of water scarcity and waste management offers a good chance of green building technologies, and there is a very low level of integration. The municipal water
departments are frequently independent of urban planning teams, and in this way, it is not easy to implement water-effective designs on a large scale (Enqvist & Ziervogel, 2019). Greywater recycling, water-saving fixtures, and rainwater harvesting among others are listed in the policies but are not standardized in all housing, commercial, and public projects. Repeat droughts experienced in South Africa indicate the necessity of water-saving structures. The drought crisis in Cape Town in 2018 showed that technologies at the household level can decrease demand, although these technologies have not become an integral part of building codes or smart city policies yet (Ziervogel, 2019).

Rather, they are promoted but not compulsory and this results in inequitable adoption. Gaps are also indicated in waste management policies. Green buildings may also encourage the reduction

of waste by providing recycling facilities on the site, composting, and construction techniques that lead to minimal waste of materials. Nevertheless, building policies are hardly related to the municipal waste strategies.

The waste systems in most cities are still based on landfills, and this restricts the ability of green buildings to support the practices of the circular economy (Godfrey and Oelofse, 2017). Smart waste technologies are not prevalent in South African municipalities, e.g. sensor-enabled bins or waste-to-energy. In the instances that they exist they tend to be pilot projects, as opposed to integrated programs. The role played by buildings in the reduction of waste will not be high without better coordination between the environmental departments and urban planning.

4.3 Innovative Practices in Selected Municipalities

Nevertheless, not all municipalities show unpleasant trends, others prove to be promising in terms of innovation. Cape Town has been regarded as a green building technology leader. The city facilitates the use of solar PVs, water-saving technology, and the green building standards of both community and private projects (City of Cape Town, 2021).

The smart design that is employed by MyCiTi public transport system also helps decrease the level of emissions and promotes integrated mobility. Johannesburg has also launched several pilot eco-districts and energy efficient governmental buildings. Attempts to promote renewable energy, enhanced urban green areas, and the use of low-carbon transport can be seen in the Joubert Park Solar Project and in the Corridors of Freedom urban development framework (City of Johannesburg, 2020).

Through these projects, it is reflected how the use of integrated design can help to enhance the environment, as well as to support social development. Climate adaptation efforts in eThekwini (Durban) have also been successful. The municipality applies the use of green roofs, water-sensitive city form, and natural infrastructure developments to enhance climate resilience (eThekwini Municipality, 2020).

The Green and Sustainable Building Guidelines in the city give an incentive to the developers to adopt resource efficient construction methods. Durban demonstrates that natural systems can be used together with building technologies in smart cities as the city is dedicated to ecosystem-based adaptation. Solar-powered public facilities, energy saving lights, and eco-friendly municipal buildings were also tried by other municipalities like Tshwane and Nelson Mandela Bay.

Though the projects are not very large, they prove the increased attention to sustainability. The innovations are also largely supported through public-private partnerships, donor funding, and civil society organizations. The GBCSA is also certifying commercial buildings in large cities, which aids in the increase of standards even in the situations when the government is not enforcing it (GBCSA, 2022).

Despite these accomplishments, the innovations are still lopsided. Cities that are well-equipped have more green technologies, and small cities are limited in financial and technical resources. This paves way to unequal development of the country and restricts development of smart cities on the national level. Even in major cities, innovations frequently remain concentrated in the business central areas rather than diffusing them to the low-income neighborhoods.

4.4 Policy Tensions: Economic Growth vs. Environmental Sustainability

One of the biggest problems of South Africa has been the conflict between the economy and environmental sustainability. Policymakers tend to have more focus on job creation and housing provision and economic growth rather than green technologies, particularly in places facing poverty and unemployment (Turok, 2016). Although green buildings have the potential of saving costs in the long run, certain areas of short-term politics do not concur with the long-

term costs incurred in building the green building. Budgets of municipal entities are low, and green technologies are believed to be costly.

The result of this is that some policymakers prefer traditional construction approaches that are relatively cheap in the short run. This leads to the fact that sustainability standards are even considered as being lower than fast service delivery (Cirolia, 2020). The tension influences the implementation of smart city policies and delays the implementation of green building technologies. These policy tensions are also determined by the influence of the private developers.

Green designs can be applied in high-income neighborhoods due to the increase in property value, but low-income residential projects cannot afford to pay extra expenses. In the absence of subsidies or incentives, green technologies can increase inequality as it will be available to more affluent people. A second conflict is due to the dependence of South Africa on fossil fuels. Mining and manufacturing are among energy intensive industries in the national economy. The technologies used in green building have decreased energy requirements, yet larger economies are still dependent on electricity generated by coal. This leads to contradictions in policies, with cities promoting renewable power as national energy policy ensures production of coal (Eberhard & Naude, 2016).

Other policy makers fear that tough sustainability policies will drive away investment. Other people claim that green building technologies have the potential to generate new economic activities, including renewable energy, retrofitting, and eco-construction employment (UNEP, 2021). These discussions indicate that the economy and environmental objectives tend to fight each other politically.

5. Discussion

5.1. Interpreting Findings Against Global Best Practices

Results in South Africa reveal that green building technologies are gradually being integrated in smart city planning, albeit the extent of integration is not in tandem with the international benchmark. Green buildings are a component of a broader digital ecosystem in most of the major smart cities like Singapore, Copenhagen, and Barcelona. Cities also tend to implement Internet of Things (IoT), real-time monitoring, smart meters, and high-level automation in buildings to minimize the consumption of energy and water wastage (International Energy Agency, 2021).

There is a global trend in terms of data-driven efficiencies, integration of renewable energy, and full-life-cycle sustainability. Policies in South Africa to improve energy efficiency include policies like the Green Building Council South Africa (GBCSA) rating systems and national policies like SANS 10400-XA guide. Those frameworks are associated with the international standards that encourage the minimization of carbon emissions, passive design, and improved management of resources (GBCSA, 2023). Solar power, efficient insulation, low-energy lighting, and water-saving systems are now provided in many of the buildings in cities like Johannesburg and Cape Town. These characteristics are like international green building practices particularly those ones in emerging economies which have similar resource limitations.

Nevertheless, South Africa continues to use low-technology solutions more as compared to the best practices across the globe. Although the world is shifting towards sensor-based management and predictive energy analytics, and building-level digital twins, the South African cities tend to focus on simple efficiency measures and minimum performance requirements

(UN-Habitat, 2020). This is an indication of a disconnect between policy intentions and technological uptake.

Meanwhile, these less complex interventions are context-specifically applicable, as newer technologies are sometimes costly and demand a set of skills that most of the municipalities are not ready to possess yet. South Africa is also in line with international values of sustainability and requires further incorporation of superior technologies to equal the most developed smart cities. Provided that these gaps are tackled, in particular, in the area of digital innovation, the creation of automation, and data management, the country would be on a path to the standards adopted at the international level.

5.2. Implications for Urban Governance in South Africa

The green building technologies and their combination with the smart city policy should have significant implications on the governance of cities in South Africa. To begin with, city management requires more technical skills. The officials in the municipalities must be aware of energy modelling, passive design, building auditing and green certification. This involves long-term institutional support and continuous training. The National Development Plan (NDP) emphasizes that sustainable development requires the establishment of local government capacity (National Planning Commission, 2012).

In the absence of effective internal capabilities, municipalities will be unable to achieve compliance, performance monitoring, or performance appraisal of building plans. Second, implementation of green building propels the cities to embrace a more collaborative approach of governance. Smart cities rely on systems of government departments, and both private developers, utilities, research centers, and community organizations. The country of South Africa also collaborates with other organizations, including the Council for Scientific and Industrial Research (CSIR) and universities to conduct research on energy efficiency, climate adaptation, and cost-effective green technologies (CSIR, 2022). The partnerships assist the

cities to overcome the challenges related to resource scarcity and technical disjuncture's. Urban governance is thus made more collaborative and knowledgeable.

Third, the systems of governance should respond to financial challenges. Green building technologies have the ability of saving operational expenses; however, their initial investment is normally expensive. Cities must have financial systems that can allow developers to embrace sustainable technologies. As observed in other countries, incentives, including green bonds, tax rebates, and public- private partnerships can be used to boost adoption (World Bank, 2020). South Africa is also starting to use green bonds to finance infrastructure in certain cities, as the case of the water infrastructure bond in Cape Town. Nevertheless, there are still few similar practices on green buildings.

There is a necessity for stronger financial governance with incentives and mechanisms of risk-sharing. Fourth, governance should deal with inequality. The spatial inequality and disproportional municipal capacities in South Africa imply that green building technologies could be in richer regions. Devoid of strategic plans, the development of smart cities can increase the existing gaps. UN-Habitat (2020) notes that fair development of smart cities demands a policy that would promote equity in sharing the benefits of such developments among all communities. Cities should thus have a system of governance that is both innovative and affordable and socially inclusive.

5.3. Policy Rhetoric vs. Implementation Gaps

The results reveal that there is an obvious disconnect between the robust language applied in policy documents and the actual magnitude of implementation in South Africa. Most policies on a national and municipal level outline bold visions, including the net-zero carbon buildings and a smart, sustainable city. The Department of Environment, Forestry and Fisheries and the GBCSA emphasize the significance of climate-resilient development and massive implementation of green building concepts (GBCSA, 2023). The government of South Africa

has also undertaken the goal of cutting down on the emissions as per international laws that are part of the Paris Agreement (Department of Environmental Affairs, 2018).

Notwithstanding these commitments, a lot of cities fail to deliver on the targets of implementation. One of the biggest reasons for this gap is lack of technical capacity. The municipalities may be short of energy professionals and building assessors who can evaluate the proposals of smart technologies, as well as employees.

The findings of research of South Africa Local Government Association (SALGA, 2021) indicate that there are a high number of municipalities with critical shortages of skills, particularly in the fields of engineering and planning. There is also a financial gap. Green technologies do help save money in the long run, but the initial expenses remain a hindrance, particularly in lower-income regions. Developers do not always want to participate in voluntary green certification, and municipalities have no money to renovate old state buildings. Implementation is slow without financial incentives or subsidies. According to the World Bank (2020), developing nations require the availability of funding to help them transition to green cities, and South Africa is not an exception.

Fragmented policy coordination at levels of governments is another factor. Smart city plans, climate policies, municipal by-laws, and energy rules do not necessarily coincide. As an illustration, the national building standards might not be entirely adequate to support municipal climate plans, and the municipalities might understand national regulations differently. This incompatibility undermines execution and delays.

Lastly, the discourse of smart cities tends to focus on hi-tech innovation, but numerous cities implement simple green solutions. The lack of integrated data systems, smart grids and advanced building automation is evidence of the lack of correspondence between policy

language and operational capacity. This gap depicts that there is a necessity of more realistic policy formulation, better coordination, and an enhanced support mechanism.

5.4. Positioning South Africa in the Global Smart Cities Discourse

The place of South Africa in the global discussion of smart cities is determined by its advantages as well as its weaknesses. Sustainable urban development is evident in the country, and it has embraced the idea of green buildings, an indication that the emergent economies can actively contribute in the transition of the world towards low-carbon cities. Engaging in projects like C40 Cities and world climate deals, South African cities put themselves in the global networks promoting environmental innovation (C40 Cities, 2021). The ability to emphasize on cost-effective, context-appropriate technologies is one of the strengths of South Africa. Although the rich nations can opt to use costly automation systems, passive design, solar energy, and effective water systems are favored by South Africa. Such solutions apply to most developing nations that have comparable limitations.

A study conducted by UN-Habitat (2020) postulates that emerging city economies need to concentrate on the low-cost innovations that enhance fundamental services when it comes to smart cities instead of the costly ones. The South African approach represents such an attitude and provides an example to be followed by the other nations in which cost-effectiveness and rudimentary infrastructure are the central concerns. Nevertheless, another significant problem concerns South Africa as well that can affect its global standings.

Red tape in implementation, non-existent municipal capacities and constraints in infrastructures slow down the pace of improvement. South African cities cannot implement sophisticated technologies on a large scale as compared to other cities in the world like Singapore or Amsterdam. The instability in power supply, the old infrastructure, and the lack of funds are also significant obstacles. Nevertheless, South Africa can also teach valuable lessons to the

world. It shows how intelligent cities can reconcile environmental objectives with socio-economic facts and that sustainability should be associated with equity. Experience has shown that it requires flexible approaches, effective collaboration, and advanced policies. Through the outlined advantages, South Africa can go on to influence discourses about smart and sustainable development in the emerging economies.

6. Conclusion and Recommendations

6.1. Summary of Key Findings

The results indicate that South Africa is enjoying significant gains in applying green building technologies into the smart city policy, but the progress is also uneven. GBCSA certifications and national frameworks assist in the alignment of the local practices with world sustainability objectives. South African cities have generally started to include energy-efficient design, renewable power systems and water saving technologies. They are in line with the best practices in the world that emphasize fewer emissions and resource efficiency. Meanwhile, there exist apparent boundaries. The practice usually lags behind the policy objectives due to technical incompetence, lack of funds, and effective coordination mechanisms of the municipalities.

Although international smart cities apply high-performance technologies, including automation and IoT, in South Africa, the primary concern is the efficiency of low costs. This is a suitable strategy in domestic settings but not in full accord with international standards of intelligent innovation. All in all, South Africa demonstrates the interest, development, and opportunities, yet the country requires enhanced institutional resources, improved financing processes, and policy coordination to achieve the full potential of smart city and green building agenda.

6.2 Policy Recommendations

6.*2.1. Stronger Policy Alignment and Integration*

To ensure there are no duplications or confusion, policies at the national, provincial and municipal levels should be synchronized. Municipal climate targets should be supported by national standards of building and the national sustainability goals should be evident in the municipal by-laws. Accountability is enhanced and implementation is enhanced through clear

alignment. Inter-governmental joint planning platforms ought to be established to promote similarity in the way regulations are interpreted.

6.2.2. Capacity Building for Municipalities

Natural green building evaluation, energy modelling, and smart-technology evaluation should be trained in the long run-in municipalities. Municipalities can come up with technical support units to undertake the related evaluations pertaining to sustainability. Professional development can be supported by collaborating with CSIR, universities, and GBCSA. The local authorities are to be trained in how to plan their buildings and monitor systems financially to be green as well.

6.2.3. Financing Mechanisms for Green Technologies

The barrier of finances should be overcome to make it more widespread. Tax deductions, low-interest loans, retrofit subsidies, and grants on energy-efficient government buildings are some of the incentives that governments can also introduce. Green bonds must be increased to finance projects in building. Such collaboration as a partnership between the government and businesses can be useful in distributing risks and making municipalities less overburdened. With the affordable financing models, green technologies become affordable to the developers and public institutions.

6.2.4. Strengthened Intergovernmental Coordination

Better communication and coordination at government level is needed. It should establish a national platform of smart city and green building coordination. This platform may lead to alignment of policy, sharing of best practices and tracking progress across the municipalities. Enhanced coordination will contribute to uniform implementation, less duplication and resource utilization.

6.3 Future Research Directions

Long-term performance of green buildings in South Africa needs to be studied in future. Research must monitor utility consumption, water conservation, comfort of occupants, and expenditure. Knowledge of these outcomes can be used to help in designing better policies. It is also possible to conduct comparative analysis of various cities and reveal the reasons why certain municipalities are doing better than others.

To have equitable development of smart cities, research on affordable smart technologies that can be used in low-income regions should be carried out. Lastly, the research should be expanded in the future by looking at the community attitudes on smart city projects in order to know how the community feels about the changes as well as how the benefits can be distributed more broadly.

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