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Smart and Sustainable Cities in Kenya: A Path to Progress

Martha Naikumi, Humphrey Njogu and Hannah Ngugi

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Abstract

This study explores the journey of four Kenyan cities (Nairobi, Mombasa, Kisumu, and Nakuru) towards achieving smart and sustainable urbanization in alignment with the United Nations' Sustainable Development Goals (SDGs) and the New Urban Agenda. This was achieved by assessing the current state of smart and sustainable urbanization and identifying areas of strength across the various pillars of smart and sustainable cities. The research uses a comprehensive Smart and Sustainable Cities Index (SSCI) framework underpinned by seven pillars: smart people, smart living, smart economy, smart mobility, smart environment, smart infrastructure, and smart governance. The average SSCI score was 0.56, ranging from 0.48 to 0.71, indicating significant progress towards achieving smart and sustainable urbanization. Among the pillars that made up the index, the highest average score was on smart people (0.80) and smart environment (0.69). The lowest were smart mobility (0.37) and smart governance (0.46). The pillars on smart infrastructure (0.56), smart living (0.52) and smart economy (0.52) scored slightly above average. ***Smart people pillar:*** *The dependency ratio performed poorly especially for Nakuru and Kisumu and unrealized universal access to education. In this regard, there is need for demographic and economic planning to anticipate future changes in dependency ratio through resource allocation and infrastructure development and collaborative efforts with development partners focusing on education, technology, and community development to leverage additional resources and expertise.* ***Smart living pillar:*** *The key policy issues include low health insurance coverage uptake, high insecurity, and low expectancy rate. Thus, it is important to enforce policies that enhance affordability and accessibility of health insurance services, especially for low-income residents, and strengthen community policing efforts to enhance safety at the neighbourhood level.* ***Smart economy pillar:*** *There is a weak business environment, low GCP per capita, limited presence of tech hubs, and low adoption of e-commerce. Thus, focus should be on diversifying economic sectors, investing in emerging sectors, and simplifying business registration processes to attract more investors.* ***Smart environment pillar:*** *There was insufficient forest density and waste disposal systems, and low penetration of clean cooking solutions. It is important to prioritize and implement waste reduction and recycling programmes, alongside green building practices, and develop and implement effective clean cooking solutions.* ***Smart mobility pillar:*** *The policy issues include inadequate or outdated road infrastructure and low uptake of e-mobility, thus the need to prioritize investments in cycling infrastructure, promote efficient public transportation, and incentivize electric vehicle adoption.* ***Smart infrastructure pillar:*** *There was limited computer/laptop ownership, low access to electricity, inadequate access to mobile broadband, low Internet connectivity, and low ownership of smartphones. Cities could consider fostering collaboration to expand and upgrade mobile broadband infrastructure. Also, there is need to fast-track the implementation of the National Digital Masterplan and the optic fibre plan to facilitate the development of Internet infrastructure for affordable and accessible Internet services.* ***Smart governance pillar:*** *There was limited women representation in the County Assembly and deficient budget transparency. Thus, priority is to establish data-sharing platforms that promote transparency, engage citizens, and support policy formulation and monitoring. Implementation of gender-inclusive policies will ensure equitable participation and representation of women at all levels of city management.*

Abbreviations and Acronyms

ACAI	Assessment for Certificate of Achievement in ICT
ASCI	Arcadis Sustainable Cities Index
BRT	Bus Rapid Transit
CBEM	County Business Environment for MSEs
CIDP	County Integrated Development Plan
CPI	City Prosperity Index
CPI	City Prosperity Initiative
DTF	Distance to Frontier
ECDE	Early Childhood Development Organization
EV	Electric Vehicle
GCP	Gross County Product
HDI	Human Development Index
ICT	Information Communication Technology
ILO	International Labour Organization
KDHS	Kenya Demographic and Health Survey
KESHP	Kenya Sanitation and Hygiene Programme
KIHBS	Kenya Integrated Household Budget Survey
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
MSE	Micro and Small Enterprises
NMT	Non-Motorized Transport
OSR	Own Source Revenue
PCA	Principal Component Analysis
SDG	Sustainable Development Goals
SGR	Standard Gauge Railway
SSCI	Smart and Sustainable Cities Index
UHC	Universal Health Coverage
USDG	Urban Sustainable Development Goal

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1. Introduction

In line with the United Nation's (UN) Sustainable Development Goals (SDGs), many countries in the world have shown increased interest in making their cities smart and sustainable by ensuring that the cities are inclusive, safe, and resilient (UN-Habitat, 2018). Smart and sustainable cities are associated with numerous benefits, including high level of economies of agglomeration, availability of effective and safe infrastructure and a range of services, such as transportation and communication, and attraction of skilled labour force, which accelerates specialization in the production of various goods and services, and creation of market areas for trading activities where goods are produced using moderate environmental impact technologies, thus boosting economic growth within a country (UN-Habitat, 2011). However, many developing countries, including Kenya, have not yet reaped these benefits. According to Zhang (2016), half of the world's population (seven billion people) resides in cities. Additionally, reports indicate that the share of the world's urban population will increase by two-thirds, since urbanization trends indicate that by the year 2050, an additional 3 billion people will be living in cities (Cohen, 2015).

As urban areas continue to attract huge populations in future, urbanization is accompanied by both opportunities and challenges in equal measure. Urban areas in developing countries are facing numerous challenges in terms of planning, design, and management of public services. The fundamental waste management facilities, water and energy networks, sewage systems, transport systems, and facilities for the drainage of rainwater are all lacking in many settlements in African cities. Urban areas in Africa are generally characterized by congestion, poor living conditions, high levels of poverty, inadequate provision of basic services such as electricity and water, and inadequate housing due to poor planning, thus leading to urban sprawl (Kuddus et al., 2020). Other key issues include poor and inadequate urban infrastructure, leading to poor access to infrastructural services, thus affecting social well-being, economic health, and environmental conditions (Rydin et al., 2012).

Despite numerous obstacles faced by cities in the developing countries, the World Cities Report (2020) reports that cities have a particularly high potential for transformational change due to their concentration of economic activity, potential for social transformation, high levels of infrastructure and building investment, high degree of innovation, ability to reduce eco-footprints by densification, and suitability for systems-based solutions. Moreover, cities can enhance their productive capacities by reforming legal and regulatory frameworks and integrating urban planning and design with measures that provide greater security to workers, particularly those operating in the informal economy.

Urbanization in Africa is taking place at a time when digital technologies are gaining footing in African cities. Digital technologies have potential to address the challenges and thus form a strong foundation for smart and sustainable cities. For instance, digital technologies facilitate easier connections between urban communities and improve the efficiency of the production and distribution of products and services in cities. African cities that struggle with unplanned

settlements have a unique opportunity to integrate digital technologies and change their urban trajectories by using the smart and sustainable city paradigm that is discussed in this study. It is acknowledged that a city becomes smart when digital technologies are effectively incorporated into its institutions, foundations, and legal framework. But the implementation of smart city principles in African cities has long been constrained by the absence of robust legal frameworks and institutions.

The Sustainable Development Goals (SDGs) introduce a range of targets that are important for urban development (Osborn et al., 2015). The SDGs' focus on human development includes "leaving no one behind," the eradication of hunger and extreme poverty, and the elimination of all forms of poverty. The SDGs acknowledge the value of having goals that focus on urban challenges. The Sustainable Development Solutions Network (SDSN) and the Global Taskforce of Local and Regional Governments (GTF) successfully lobbied for the inclusion of a distinct stand-alone goal on sustainable urbanization in the 2030 Agenda. SDG11, which has ten targets covering areas such as housing, transportation, air quality, and waste management, among others, calls on all actors to “make cities and human settlements inclusive, safe, resilient and sustainable”. To ensure maximum social, environmental, and economic well-being, it is crucial to create smart and sustainable cities (Satterthwaite, 2017).

A smart and sustainable city primarily focuses on economy, governance, people, mobility, living, infrastructure and environmental elements (Abubakar and Aina, 2019). A smart and sustainable city is conceived as a sustainable, inclusive, resilient, and prosperous city that promotes a people-centred approach based on economy, governance, people, mobility, living, infrastructure, and environmental components. Further, a smart and sustainable city involves using appropriate technologies to get people involved in daily social, economic, and political activities. According to Kuhlman and Farrington (2010) and Jovovic et al. (2017), smart and sustainable cities can satisfy the needs of the present generation without compromising the needs of the next generation, while maintaining an equal balance between societal, economic, and environmental well-being. If a city can address social, environmental, and economic impacts through proper urban planning and management, it is smart and sustainable (Kuhlman and Farrington, 2010). This can be achieved by incorporating environmentally friendly options into city infrastructure, such as the provision of a reliable public transportation system that takes cars off the road, thus reducing harmful emissions generated daily.

Having a smart and sustainable city entails empowering urban population access services in a sustainable, efficient, and affordable way. Through planned infrastructure, public green spaces, smart waste removal, and more, cities can leave behind a net zero footprint for a more sustainable world (Bibri and Krogstie, 2021). Smart and sustainable cities are known to be inclusive and thus promote growth with equity by accommodating all individuals regardless of their economic status, tribe, race, or religion (Feitosa et al., 2011). Smart and sustainable cities ensure the working poor have access to secure and dignified livelihoods, affordable housing, and basic services such as water/sanitation and electricity supply. Smart

and sustainable cities create an environment that motivates netizens to be more productive in the provision of both skilled and unskilled labour, which leads to large output levels in the country, thus boosting economic growth (Sookhak et al., 2019). For the prosperity of any country, safety is a fundamental factor that should be prioritized by cities (Park, 2016). According to Ismail and Hendrickson (2009), there is a growing body of evidence demonstrating that shortfalls in safety (security) contribute to both poverty and under-development.

According to Schlör et al. (2018), a smart and sustainable city, therefore, is characterized by the ability to address issues that its population face in a sustainable and cost-effective manner, thus accelerating sustainable development and inclusive growth within a country. Kenya has made significant policy efforts in embracing smart and sustainable city applications as demonstrated by provisions embedded in various strategic documents that include the Kenya Vision 2030, National Digital Masterplan, Digital Economy blueprint, and Konza Technopolis project. Although the national and county governments in Kenya have plans outlining pathways to building smart and sustainable cities, achieving the smart and urban sustainability in the country as per the SDGs, the New Urban Agenda, and the Paris Agreement, remains a challenge. Construction of a smart and sustainable city index is a critical tool to assess cities' progress in terms of being smart and sustainable. Unlike Nairobi City, the other three cities (Mombasa, Nakuru, and Kisumu) have not been factored by global indices. For instance, indices such as Arcadis Sustainable Cities Index (ASCI), Cities in Motion Index (CMI), and City Prosperity Initiative (CPI) are constructed in developed countries and only factor in Nairobi City, leaving behind Mombasa, Kisumu and Nakuru cities. Further, while global indices are valuable, they often do not capture the unique challenges and solutions of individual cities. The study will emphasize the development of localized, context-specific strategies for Kenyan cities. Thus, the study aims to contribute to the creation of cities that are not only environmentally sustainable but also economically prosperous and socially inclusive, ultimately improving the lives of all urban residents in the country.

The purpose of this study is to provide a solid understanding of the progress that the four Kenyan cities are making towards being smart and sustainable. Specifically, the study is based on the following objectives:

(i) To assess the current state of smart and sustainable urbanization in Kenyan cities; and

(ii) To identify areas of strength and improvement across various pillars of smart and sustainable cities in Kenyan cities.

The rest of the paper is structured as follows: section two provides the status of urbanization of the four cities, section three details the guiding literature review, including theoretical and empirical literature, section four provides the methodology including theoretical framework, the description of the pillars and their indicators, the data sources, and the steps for index computation. Section five presents the results and discussion of the study while the conclusion and recommendations are presented in section six.

2. Urbanization Status of Kenyan Cities

2.1 Overview

Kenya is undergoing a remarkable urban transformation. As per the 2019 population census, the total population was 47,564,296, with approximately 31.2 per cent of its citizens dwelling in urban centres (KNBS, 2019). As the urban landscape continues to evolve, four of its cities stand as exemplary pillars of this transformation: Nairobi, Mombasa, Kisumu, and Nakuru. These cities are shaping Kenya's socio-economic trajectory, with an urban growth rate of 3.7 per cent fueling their expansion. In this section, the cities' journeys from historical origins to modern urban centres are explored in-depth.

2.2 Urbanization Journey

2.2.1 Nairobi City

Nairobi's journey as a city dates back to 1900 when it was established as a British colonial railway camp along the Mombasa-Uganda railway line. The city's strategic location elevated its significance as a key transportation hub, facilitating trade and connectivity across East Africa.[1] Over the decades, Nairobi's status grew, and it was officially granted city status on 31st October 1954 (KNBS, 2012). This transformation marked a pivotal moment in Nairobi's history, propelling it from a mere railway camp to a thriving urban centre that attracted people from diverse backgrounds seeking economic opportunities.

With a burgeoning urban population of 4,395,749 as of 2019 Population Census, Nairobi stands as the capital city of Kenya (KNBS, 2019). This metropolis encapsulates Kenya's diverse cultures, economic prowess, and innovation. Home to the renowned Kibera, one of Africa's largest informal settlements, Nairobi encapsulates the challenges of rapid urbanization, balancing modern development with the needs of its increasing population (UN-Habitat, 2016).

Further, Nairobi has embarked on key urban transformation projects, including infrastructural, economic, and digital. Notable examples of transformative infrastructure projects include the Nairobi Expressway, the Thika Superhighway, and the Nairobi Bus Rapid Transit (BRT) System. The Thika Superhighway, completed in 2012, was a significant milestone in Nairobi's development. Connecting the city to Thika town, it revolutionized transport connectivity and trade along this vital corridor.[2] Further, the Nairobi Expressway, completed in 2022, has connected Jomo Kenyatta International Airport to the Western Bypass, facilitating smoother traffic flow and reducing travel time. Lastly, the ongoing Nairobi Bus Rapid Transit (BRT) System project, spearheaded by the Nairobi Metropolitan Area Transport Authority (NaMATA), is a pivotal initiative

[1]International Trade Administration (ITA). (2022) Kenya Commercial Profile. https://www.trade.gov/country-commercial-guides/kenya-infrastructure.
[2]AfDB. (2017). AfDB and Kenya - Thika Highway continues to impact Kenyan lives five years on. https://afdb.org/en/news-and-events/afdb-and-kenya-thika-highway-continues-to-impact-kenyan-lives-five-years-on-17519

in Nairobi's urbanization journey. This project aligns with the city's steadfast commitment to mitigate traffic congestion and environmental pollution. Designed as a dedicated network of lanes, the BRT System introduces a novel approach to transportation by deploying specialized buses, marking a transformative step towards enhanced urban mobility, and reduced ecological impact. These infrastructural projects create an enabling environment for economic growth and development.

The key economic projects in the city have demonstrated the capability of Nairobi as a major economic hub in East Africa. Some of the notable projects include Nairobi Securities Exchange (NSE), Nairobi Industrial Park, Silicon Savannah, and Nairobi Innovation Week. As East Africa's largest stock exchange, the NSE is a focal point for economic activities, allowing businesses to access capital and investors to participate in the region's financial markets. It is a testament to Nairobi's role as a financial centre in the region. The Nairobi Industrial Park has attracted both local and international investors seeking opportunities in manufacturing and production. It contributes to Nairobi's economic diversification and promotes job creation. Besides, Nairobi's tech ecosystem, often dubbed the "Silicon Savannah," is a breeding ground for startups, tech innovations, and digital entrepreneurship. It has birthed numerous successful companies in fintech, agri-tech, health-tech, and more. The inception of the Nairobi Innovation Week (NIW) in 2015 marked a significant stride towards realizing Nairobi's vision of becoming a vibrant, productive, and sustainable innovation ecosystem. This annual event serves as a powerful platform, not only celebrating local and global innovations, but also playing a pivotal role in nurturing and fortifying the innovation and entrepreneurship ecosystem.

Nairobi's nickname, the "Green City in the Sun," speaks to its efforts to balance urbanization with environmental conservation. Uhuru Park is an iconic park that serves as a green oasis in the heart of Nairobi, offering recreational spaces, serene landscapes, and a breath of fresh air amid the city's hustle and bustle. Karura Forest is one of the largest urban forests in the world, which provides a haven for outdoor activities, environmental education, and conservation efforts within Nairobi (Karura Forest Environmental Education Trust, 2021). Nairobi's push for sustainability is evident in its initiatives to convert waste into energy with planned projects such as Waste-to-Energy Projects such as Dandora Waste-to-Energy Plant and Gikomba Integrated Waste Management Facility. These projects will not only address waste management challenges but also contribute to cleaner energy sources. Additionally, Nairobi has embraced green building standards to promote sustainable architecture and construction practices. These standards encourage energy efficiency, resource conservation, and reduced environmental impact.

Some of the key challenges that Nairobi still grapples with include informal settlements and housing, traffic congestion and mobility, environmental degradation, corruption and governance issues, and climate change vulnerability. Notably, Nairobi's rivers including the Nairobi River, Mathare River, and Ngong River suffer from severe pollution due to uncontrolled dumping of industrial effluents and sewage discharge (Owuor et al., 2011). This has led to high levels

of contaminants including heavy metals, organic pollutants, and pathogenic microbes far exceeding safe limits. The polluted state of Nairobi's rivers threatens aquatic ecosystems, increases water treatment costs, and heightens risks to public health. Addressing these challenges requires a comprehensive approach that involves sustainable urban planning, social equity measures, infrastructure development, improved governance, and community engagement.

2.2.2 Mombasa City

Mombasa's path to becoming a city is woven into its history. It came under British administration in 1895 and played a pivotal role as the capital of the East Africa Protectorate until 1907 (KNBS, 2012). This period marked the city's emergence as a central hub for trade, connectivity, and maritime commerce in the region. The year 1928 is a landmark in Mombasa's trajectory when it officially gained city status, signifying its ascent as an urban centre of significance.

This significant milestone was preceded by other key achievements. Mombasa advanced from a municipality to council status in 1959, further solidifying its administrative and governance structures. Each step of this historical journey reinforced Mombasa's position as a strategic gateway to East Africa and the world, accentuating its influence as a vital maritime and commercial nexus. Mombasa has a population of 1,208,112 (KNBS, 2019) and is the second most populated city from Nairobi, although with a significant difference. Its rich history, characterized by ancient architecture and vibrant markets, coexists with modern urbanization, shaping its unique identity.

Mombasa's urbanization journey is characterized by notable infrastructure projects that have shaped its landscape and improved the city's livability. One key project includes the Mombasa Port expansion. Building upon its historical role as a trading centre, Mombasa's ongoing expansion projects enhance its maritime prowess. These initiatives not only facilitate efficient cargo handling but also underscore Mombasa's enduring importance in global trade networks. The Dongo Kundu Bypass project resonates with Mombasa's legacy as a connector.[3] This modern infrastructure project exemplifies the city's commitment to efficient transportation, augmenting its role as a bridge between Mombasa Island and the mainland. Another key infrastructural project is the Mombasa Urban Regeneration Project. Mombasa's reverence for its cultural heritage finds expression in the Urban Regeneration Project. This endeavour not only beautifies the cityscape but also nurtures tourism, reinforcing Mombasa's historical and contemporary significance.

Notably, the SGR serves as a catalyst for economic growth and development by enhancing trade, efficiency, and mobility between Mombasa and Nairobi. It demonstrates how strategic investments in modern transportation infrastructure can bridge geographical distances, stimulate commerce, and foster closer ties between regions.

[3]State now allocates Ksh 39bn for Dongo Kundu SEZ Project. https://www.constructionkenya.com/11170/dongu-kundu-special-economic-zone/

Notably, Mombasa ECDE Robotics Programme is a great advancement within the city county education system. It introduces technology to learners at a tender age, creating a future digital generation in the Artificial Intelligence (IA) era. Mombasa was also awarded the best county on Digital Innovation and leadership in the Africa CIO-100 Awards 2021, which further cements its commitment to quality education.

The key policy and legal documents that have enhanced urbanization of Mombasa city are Mombasa County Integrated Development Plans (CIDPs and Marine Spatial Planning Framework. The Mombasa CIDPs I, II, and III (current plan) connect Mombasa's history with its aspirations for the future. By guiding sustainable growth and equitable development, it portrays the city's heritage as a centre of convergence and progress. Mombasa's coastal identity is safeguarded through the Marine Spatial Planning Framework. By managing maritime resources, the framework embodies Mombasa's historical resonance as a maritime crossroad.

2.2.3 Kisumu City

Kisumu's journey to attaining city status is deeply rooted in its rich history as a trading hub and regional connector (KNBS, 2012). Founded in 1901 as a small trading post along the shores of Lake Victoria, Kisumu quickly grew into a vital commercial and transportation centre for western Kenya. The completion of the Uganda Railway line to Kisumu in 1901 further fueled the town's growth as an inland port and fishing village. For decades, Kisumu acted as a nexus point for regional trade and commerce, with fishing, agriculture and manufacturing driving its economy.

The year 2001 marked a significant milestone when Kisumu was officially granted city status, affirming its transition into a fully-fledged urban metropolis. Sitting gracefully on the shores of Lake Victoria, Kisumu combines laidback lakeside charm with the energy and prosperity of an emerging regional economic hub.

Boasting a population of 397,957, Kisumu is carving a niche as a burgeoning economic centre, fostering trade and commerce in its lakeside setting (KNBS, 2019). The revamped Kisumu Port aims to reinvigorate maritime trade and commerce on Lake Victoria, while the Kisumu-Mamboleo Bypass is easing traffic congestion. Under the Urban Renewal Initiative, public spaces are being upgraded to accentuate Kisumu's natural and cultural heritage.

In August 2023, the government flagged off Early Childhood Development Education (ECDE) learning materials to all 687 centres within the county to support the early learners. In 2017, the County Government of Kisumu Ministry of Information, Communication and Technology, working in conjunction with the National Government Ministry of ICT, ACAI and Google, conducted a Digital Literacy Training course for 3,000 young people from 4th-6th of April, in Kisumu City-Tom Mboya College (County Government of Kisumu, 2017). The programme debuted in 2016, training over 700 young people across the wards in Kisumu County. The recently launched digital lab in Maseno School demonstrates the County Government's commitment to scaling up digital literacy (County

Government of Kisumu, 2023). This is in line with the Bottom-Up Economic Transformation Agenda to ensure that the youth and other segments of the population at the bottom of the pyramid benefit from the digital infrastructure being put up by the government.

Kisumu is also pioneering the blue economy agenda as part of sustainable development. Stakeholder conferences held in 2018 and 2022 adopted strategies for reducing lake pollution and driving economic growth through aquatic resources. With the gazettement of the Kisumu Lakefront Development Corporation (KLDC) in 2020, rejuvenation of the lakefront into a resort city is also underway through hotels, beaches, and tourism facilities.

Propelled by its strategic location, natural endowments and human capital, Kisumu is solidifying its position as a shining star in Kenya's economic constellation. Its blend of rapid urbanization and maintaining regional heritage makes it one of East Africa's most promising emerging cities. However, Kisumu still faces various urbanization challenges common to rapidly growing cities. The influx of rural migrants has led to mushrooming of slums and informal settlements lacking adequate housing, water, sanitation, and other basic services. Congestion and unemployment are also pressing issues. To improve the living standards, the Kenyan government and development partners have implemented various slum upgrading projects in Kisumu. For instance, the Kenya Slum Upgrading Programme funded by the World Bank has constructed thousands of housing units with water, sewerage, and other amenities across settlements such as Nyalenda, Obunga, and Bandani. Other initiatives such as the Kenya Informal Settlements Improvement Project are also redeveloping slums into liveable neighbourhoods with provision of services and infrastructure such as roads, water pipes and street lighting.

2.2.4 Nakuru City

Nakuru is the fourth and newest city in Kenya, having received its city charter in December 2021. The city's urban population is 570,674 as per the 2019 population census (KNBS, 2019). Nakuru has undergone rapid urbanization and growth over the past century to become the bustling metropolitan area it is today. Founded in 1904 as a small railway outpost during the construction of the Uganda Railway, Nakuru was strategically situated between Nairobi and Uganda. Its location adjacent to the scenic Lake Nakuru, famous for the thousands of pink flamingos that flock its shores, also made it an ideal stopping point. Nakuru's strategic location in the Great Rift Valley underscores its potential for growth and economic advancement. Moreover, Nakuru City borders seven neighbouring counties – Kericho, Narok, Laikipia, Baringo, Bomet, Nyandarua, and Kajiado. This unique geographical placement elevates its status as a central focal point for a range of significant activities across the surrounding counties.

Manufacturing, industry, and tourism emerged as key economic pillars that drove Nakuru's growth from the 1980s onwards. Food processing, grain milling, leather production and vehicle assembly plants provided jobs and diversified the local

economy. Nakuru's strategic location along the transit corridor between Kenya's interior and Uganda also strengthened its economy. Tourism numbers increased as Lake Nakuru National Park gained international popularity for its flamingo spectacle.

The past decade has seen Nakuru cement its position as a major urban centre in Kenya. Designated as the administrative capital of Nakuru County in 2013, the town has benefitted from devolution and investment in local infrastructure and services. The County Government of Nakuru has overseen improvement and expansion of roads, housing projects and health facilities. Real estate, retail and hospitality sectors have all flourished within the thriving cosmopolitan hub.

Nakuru County's education sector zeroes in on provision of ECDE and Vocational Training Centres. The county has put its best foot forward in the recruitment of ECDE teachers and technical trainers, and roll out of the school feeding programme, which has led to increased enrollment at both levels. Further, Nakuru has established seven digital centres in Rongai, Njoro, Kagoto, Shabaab, Kuresoi South, Menengai, and Subukia to promote digital literacy. In addition, the increased number of sites connected with Wide Area Network (WAN)/Local Area Network (LAN) from 3 to 25 has increased access to ICT services.

As indicated by a UN Report of 2011, Nakuru is the swiftest expanding urban centre in Africa and ranks fourth on the global scale for rapid growth (UN-Habitat, 2011). Moreover, Nakuru serves as a hub for diverse retail enterprises, catering to the needs of both the manufacturing and agricultural domains by supplying an array of goods and services. With city status has come more structured urban planning, development controls and governance frameworks. These initiatives aim to turn Nakuru into an organized, modern city that can cope with its rapid growth and address challenges such as traffic congestion, unemployment, and proliferation of informal settlements.

Table 2.1: Urbanization status

Criteria	Nairobi	Mombasa	Nakuru	Kisumu
History to City	Established in 1899 as a railway depot	Established by Arab traders around 900 AD. Capital of East Africa Protectorate until 1907	Incepted as a railway town in 1904 and became a municipality in 1952	Founded in 1901 as a colonial trading post
Upgrading to City	Declared a city on 31st October 1954	Gained city status in 1928	Approved as a city on 3rd June 2021	Received city charter in 2001
Population (KNBS, 2019)	Over 4 million	About 1.2 million	Approximately 570,674	About 397,957
Population Age Structure	0-14 years: 31.4%; 15-64 years: 67.4%; 65+ years: 1.1%	0-14 years: 32.1; 15-64 years: 66.2%; 65+ years: 1.7%	0-14 years: 42.3%; 15-64 years: 53.9%; 65+ years: 3.8%	0-14 years: 42.1%; 15-64 years: 54.6%; 65+ years: 3.1%
Economic Activities	Financial services, trade and commerce, technology, manufacturing, tourism	Maritime trade and commerce, tourism, blue economy, fishing, manufacturing	Agriculture, commerce and trade, tourism, financial services	Fishing, trade and commerce, blue economy, manufacturing

3. Literature Review

3.1 Introduction

This section provides a solid introduction to the concept of city sustainability and outlines the existing theoretical and empirical literature on indicators for sustainable cities, which were reviewed in support of this study.

3.2 Theoretical Review

3.2.1 Concept of urban metabolism

This concept plays a key role in the sustainability of a city through a deeper understanding of how resources flow in and out of a city, city planners and decision-makers can use urban metabolism in building more sustainable cities. It can be used, for instance, to pinpoint the sources of a city's inefficient use of energy, waste production, water use, and pollution. Based on this, strategies can be made on how to minimize pollution, reduce the wastage of water, recycle waste, and consume less energy within a city. It can also help to find the methods to increase the effectiveness of resource utilization in urban areas, such as encouraging and expanding the use of renewable energy sources and putting in place systems for collecting and reusing rainwater. In addition, it can assist in identifying areas for improvement, and tracking the performance of a city's infrastructure over time, thus leading to the building of cities that are sustainable.

3.2.2 Diffusion of Innovations Theory

This theory aims to explain how, why, and how quickly new ideas and technologies spread. Everett Rogers (1962), in his book, *Diffusion of Innovations*, popularized the theory. According to Rogers, the process of diffusion is how an innovation spreads through time among the members of a social system. The diffusion of innovations theory has several different, cross-disciplinary antecedents. The ratio of rural to urban residents in a society, the level of educational attainment in that society, and the degree of industrialization and development are among the factors that influence the rate of innovation diffusion. The rate at which a society's citizens adopt new innovations will probably vary among various societies. Different forms of innovation have varying adoption rates. For instance, a culture might have embraced the Internet more quickly than the automobile because of its affordability, accessibility, and comfort with technological change. This theory is crucial in this study as it is foundational for modern day innovations and how they gain acceptability, including the development of smart cities.

3.2.3 Modernization Theory

The modernization theory gained popularity in the 1950s and 1960s. To build policies that will aid the social and economic transition of poorer countries, it

is helpful to comprehend social-economic development challenges. According to the theory, new ideas and innovations are introduced into society through industrialization, information penetration, technological application, and cultural diffusion (Smith, 1996). The initial state of the world's development and urbanization at the start of modernization cannot be separated from it now (Kasarda and Crenshaw, 1991). Technology-driven societies have produced several advancements that can boost or increase economic potential, provide surplus food due to improved agricultural systems, and use mechanization and electronic tools to lessen the workload on human labour while simultaneously enhancing speed and efficiency. The hypothesis is challenged, though, because it disregards outside forces that alter societies. The notion is crucial in creating a smart city, since it starts by putting in place electrical systems, layers of cutting-edge telecommunications, mobility systems, and smart buildings as significant foundations for city development.

3.3 Empirical Review

There are many smart and sustainable city projects around the world. For instance, in Spain, Barcelona City uses the smart city concept to achieve citizen involvement and participation (Capdevila, 2015). In New York City, service delivery is the major benefit of smart cities. In Scotland, the concept is used by the local authorities in Glasgow to enhance safety in urban areas (Janssen and Estevez, 2013). In China, it is urban management activities that are mainly driven by smart technologies, while Hong Kong uses smart cities for people-centric governance model (Joo and Tan, 2020). Evidence shows that Singapore is leading with smart city led programmes (Alleblas and Dorrestijn, 2020), while South Korea is best known for its top-down driven implementation of the smart cities concept (Joo and Tan, 2020).

Smart Cities such as San Diego have also become tech-savvy. For instance, in San Diego, there has been heavy investment in Biotech research, with algae being a very important organism with numerous benefits such as use in cancer treatments, use in food production, and production of biofuels (100% petroleum from underground is algae). There have also been advancements such as growing oil in plants such as gasoline and petrol. This makes it possible to obtain transportation fuel from corn, where it is converted to algae. San Diego has also attracted world-class academic research institutions, world-class investors and attractive places to live for these investors and innovators. Similarly, safeguarding the life and health of the ocean to protect ocean life has been made possible by the research and advancement in medicine that protects marine life (Felger, 2022; Hatem, 2022).

Studies conducted by Moyo et al. (2018) and Balkaran (2019) in South Africa found that the municipal governments had misplaced priorities in terms of meeting their people's needs. According to the National Development Plan (2030), political democracy is hindered when most of the people are poor and lack hope for a better life. Therefore, according to Moyo et al. (2018), South Africa should develop its smart cities in such a way that it does not widen inequality, rather than

easing universal access to services. In a bid to develop smart cities, South Africa Municipal leadership faces challenges such as widening inequality, increased house crisis, water shortages, rampant poverty and unemployment (Balkaran, 2019; Spreen and Vally, 2006).

In a study to determine the prospects and challenges encountered while building smart and sustainable cities in Nigeria, Abubakar and Aina (2019) used secondary data using accessibility to public transportation, safe drinking water, housing, poverty levels, slums, sanitation and cost of electricity. The study depicts that promoting sustainable cities is crucial since, as of 2023, more than half of the world's population lives in cities, and by 2050 that number is expected to rise to 68 per cent. Rapid urbanization is having a significant negative impact on the environment, housing, infrastructure, and fundamental public services in developing nations. In addition, the study indicates that rapid urbanization accelerates poverty levels, crime and violence, social isolation, urban sprawl, and environmental degradation, having a considerable negative impact on public health and way of life, thus inhibiting the establishment of sustainable cities.

Using a confirmatory research method, Salami et al. (2021) did a study to establish the key parameters of sustainability for mixed-use buildings in Lagos City in Nigeria. The study made use of a more integrated sustainability evaluation techniques, which included an economic aspect, a socio-cultural dimension, and an environmental aspect. The study indicates that mixed-use building promotes safety, low crime rate, and ameliorates the living standards of citizens within the city, thus enhancing city sustainability.

Chen and Zhang (2021) denote that city sustainability is a complex interactive system affected by many indicators, and all indicators are not independent of sustainable development. Literature has frequently neglected the connection and interplay between the indicators, nevertheless. Notably, the weight of each indicator depends on more factors than just how evenly it is distributed. In their study, 21 indicators were applied to evaluate the driving factors of city sustainability in 34 cities in Northeast China. The results revealed that the economic dimension, including the per capita GDP, and the proportion of science expenditure rate were the common limiting indicator that hampered sustainability improvement in most cities. In addition, the volume of industrial emissions, industrial soot emissions, and utilization rate of solid wastes belonging to the environmental dimension were the main factors that enhanced city sustainability.

Cities experience pollution, unsustainable land growth, and degradation as a result of urbanization (Brueckner and Helsley, 2011). According to Cobbinah and Amoako (2012), the expansion of an urban area cannot be sustained without government-controlled urban land development and administration. As indicated by low-density physical construction and basic infrastructure, this results in unchecked city growth. Therefore, to address these issues, land-use rules and the promotion of serviced land might be employed (Mahtta et al., 2019). In addition, a report by the World Bank (2016) found that slow development of infrastructure and inadequate resources, along with the growth of urbanization, results in minimal access to basic services, particularly for urban residents. These necessities

include electricity, transport, shelter, clean drinking water, and sanitary facilities. Moreover, as urban residents' living conditions deteriorate, the socio-economic divide widens.

Choon et al. (2011) developed a set of criteria, indicators, and indices for sustainability assessment in major cities in Malaysia. The study focused on the state indicators and an indicator framework that had been developed. After sensitivity analysis, the results revealed that, overall, the major cities in Malaysia have a moderate performance towards the development of a sustainable city. Proper management and environmental services are the major challenges affecting the cities. As cities become more and more economically productive, urbanization trends are likely to lead to even further deterioration of natural resources, aggravation of climate change and other environmental problems, and pose social challenges such as poverty, inequality and segregation, thus making a city not sustainable (Voytenko et al., 2016).

Urban planning evolves as a complex set of ideas that guide both planning decision-making processes and urban outcomes. This is aimed at achieving some social, political, or environmental objectives. It is an activity that can solve many major urban problems and is a significant management tool for dealing with the unprecedented challenges facing 21st-century cities and attaining the goals of sustainable urbanization (UN-Habitat, 2009). In an attempt to evaluate the effectiveness of new town planning as an urbanization strategy in Africa by using the case studies of the new capital cities of Abuja, Dodoma, Gaborone and Lilongwe, a study by Abubakar and Doan (2017) showed that these postcolonial capital cities have not been able to provide adequate housing and basic urban services, but rather place too much emphasis on physical design resulting in implicit segregation of the poor from the wealthy elites and the disruption of the livelihood of the people in the informal sector.

While assessing the pathways for sustainable and inclusive cities in Southern and Eastern Africa, Titz and Chiotha (2019) reveals that cities can be places for creativity, innovation, and efficiency in responding to environmental and social challenges if citizens and local authorities can freely develop their potential. The study further suggests a better understanding of the contested urban life by urban residents and actors in Eastern and Southern Africa. To enhance our knowledge of city dwellers, political and social actors in their roles as citizens who are entitled to appropriate urban space, and to mobilize their rights to access resources to actively promote a meaningful life (Abubakar and Doan, 2017). There is a need to improve scientific understanding of citizens' abilities and opportunities to shape the urban environment and living environments in a participatory way according to their needs, values, and aspirations, and to adapt proactively and creatively to environmental and social challenges, thus leading sustainable cities.

Among the challenges that face the Urban Sustainable Development Goal (USDG) are the complexities that surround the choice of indicators. This is because many indicators serve different purposes and agendas. However, there has not been any clear consensus on methodology or standards for these various systems of indicators. This is partly because they are politically ingrained and serve purposes

other than scientific ones (Moreno Pires et al., 2014). The USDG has the advantage of coming from a consensus of UN member States, but it will still be one indicator system among many in this environment of competing indicator systems. The UN-Habitat is promoting its City Prosperity Index as a sort of consensus tool within the SDG Monitoring Framework to resolve this overlap issue, noting that all of the USDG's targets and indicators are integrated into it (Sminkey and Le Doux, 2016).

The localization of the development goals and agenda has been a major challenge for urban sustainability. The USDG was established by the national governments of UN member States, but the goal and its objectives must be accomplished at the urban/city scale. Thus, in connection to goal implementation and monitoring, the USDG questions the interaction and coordination between cities and other subnational and national governments. This calls for ways of implementing this goal without excluding or disregarding the local conditions. This will help the local adaptation and adoption to be more likely (Simon et al., 2016). Similarly, there lacks the availability of urban data in many cities, particularly in Africa and Asia, where 90 per cent of urban expansion is predicted to occur by 2050 (United Nations, 2014a, 2014b). For instance, high levels of informality in many cities result in the absence of several processes and dynamics from household surveys, which serve as the foundation for national statistics. Additionally, there is a risk that indicators will favour formality while excluding informality, which is prevalent in many cities, leading to skewed statistics. For instance, a large portion or even all the transportation network is rather unorganized and unmapped in many cities in Africa and Asia (Geertman et al., 2015; Klopp et al., 2017).

Kenya is referred to as Africa's Silicon Valley with the Intelligent Community Forum naming Nairobi as Africa's most intelligent city (Nkabinde, 2016). The mobile money concept, which was first popularized in Nairobi in the form of M-Pesa, has enhanced payment of bills for the poorest people and improved their quality of life (Mbassi, 2017). ICT development in Nairobi has seen government services payments made electronically. Similarly, the transport system and waste collection are also digitalized. In the Central Business District (CBD), citizens use electronics services to pay for daily and/or monthly parking fees. The city also introduced the Intelligent Transport System, driven by technology whose objective is to ease traffic congestion. Nairobi has also introduced e-learning tools for the first-time learners in its Early Childhood Education centres. Digital systems have also been installed to improve efficiency of electricity transmission in slums such as Mathare. Automated Teller Machines ATMs are widely installed, water connection applications are done electronically, and water vending machines have been installed in informal settlements (Guma and Monstadt, 2021).

Urban sustainability in Kenya is crucial to achieving the goal of developing the nation's capability to manage urban challenges and to support the Kenya Vision 2030, which calls for Kenya to develop into a middle-income nation by the year 2030. To achieve this, capabilities must be developed so that stakeholders may use them to prevent and lessen the effects of sustainability challenges, build competitive infrastructure, lessen inequality, and construct institutions for urban sustainability (Mutisya and Yarime, 2014). In addition, Yarime et al.

(2014) indicates that problems emanating from economic indicators, governance indicators, environmental indicators, and social indicators may lead to onerous challenges to city sustainability. However, governance remains a crucial dimension of city sustainability more so when dealing with urbanization in developing countries such as Kenya due to high imbalances in social-economic development and high rate of population migration.

Some of the indices which have been used in various studies include the Arcadis Sustainable Cities Index developed in 2015/annually by the Arcadis and the Centre for Economic and Business Research to cover 100 cities in different parts of the world. The tool was developed to measure the urban sustainability that accommodates social, economic, and environmental health of cities. The City Prosperity Initiative (CPI) developed by UN-Habitat in 2012 and 2015 measures the way cities create and distribute socio-economic benefits or prosperity and the overall achievements of the city. The Cities in Motion Index, developed by the Institute of Higher Business Studies (IESE Business School) in 2013/annually, measures the future sustainability of the world's main cities and the quality of life of their residents.

4. Methodology

4.1 Introduction

This section provides a theoretical framework and a detailed description of the pillars used to compute the Smart and Sustainable Cities Index in Kenya, data sources, and the steps for index computation.

4.2 Theoretical Framework

The concept of urban metabolism refers to the study of material and energy flows within urban areas, aiming to understand and optimize resource use and environmental impacts. In the context of enhancing smart and sustainable cities in Kenya, urban metabolism can provide valuable insights into resource efficiency, waste management, and environmental sustainability. The development of smart and sustainable cities in Kenya involves integrating urban information and communication technology (ICT) networks to support connected urban services, efficient management, and sustainable living patterns. Urban metabolism theory can contribute to this by analyzing material and energy flows, identifying opportunities for resource efficiency, and guiding sustainable infrastructure and civic domain development. By leveraging the concept of urban metabolism, Kenya's urban development agenda can optimize city services, promote sustainable living, and respond to the needs of residents, workers, and visitors (Dijst et al., 2018). This approach aligns with the broader goal of creating smart, sustainable, and inclusive African technology cities.

4.3 The Pillars of the Smart and Sustainable Cities Index in Kenya

Smart and sustainable cities are innovative urban environments that leverage technology, data, and sustainable practices to enhance the quality of life for residents while minimizing their environmental impact. These cities aim to create a harmonious and efficient balance between economic development, social well-being, and ecological preservation (Giffinger et al., 2007). The concept of smartness and sustainability in the Kenyan cities of Mombasa, Nakuru, Kisumu, and Nairobi is guided by the Kenya Vision 2030, national policies, and regional and international commitments. The SSCI in Kenyan cities is underpinned by seven pillars drawn from literature (Giffinger et al., 2007; Abubakar and Aina, 2019; Guma and Monstadt, 2021), namely smart people, smart living, smart economy, smart mobility, smart environment, smart infrastructure, and smart governance. Each pillar is characterized by various indicators as described in Table 4.1.

Table 4.1: Description of the SSCI pillars, indicators, and measurement

Pillars	Indicators	Measurement
Smart People	• Education level • Access to digital devices in schools • Demographics (dependency ratio)	• Percentage of the population with some education • Percentage of public primary schools installed with digital devices • Total age dependency ratio
Smart Living	• Life expectancy • Health insurance coverage • Births attended by skilled health personnel • Housing quality • Crime rate	• Life expectancy at birth (years) • Percentage of health insurance coverage • Percentage of births attended by skilled health personnel • Percentage of the population living in modern houses (by roof type) • All offences per 100,000 population
Smart Economy	• GCP per capita • Employment rate • Ease of doing business • Tech hubs • Own source revenue gap • E-commerce	• Gross county product /total population • Percentage of working population aged 15 years and above • CBEM Index Score 2022 • Total number of tech hubs • Percentage of OSR gap • Percentage of population in e-commerce
Smart Environment	• Natural resources • Waste management • Access to improved water • Access to improved sanitation • Access to clean energy for cooking • Access to clean energy for lighting	• Percentage of forest cover • Percentage of households with improved waste disposal • Percentage of households with access to clean drinking water • Percentage of households with access to improved sanitation • Percentage of households using clean energy for cooking • Percentage of households using clean energy for lighting
Smart Mobility	• Miles of bike path • Cars per capita • Electric Vehicle (EV) charging stations	• Miles of bike path per 100,000 population • Total number of cars per total city population • Percentage of charging stations
Smart Infrastructure	• Households with computers/laptops • Access to electricity • Households with mobile broadband • Mobile money subscription • Use of the Internet • Smartphone ownership	• Percentage of households with computer/ laptop • Percentage of households connected to the national grid • Percentage of households with mobile broadband • Percentage of households using mobile money to transact • Percentage of households using the Internet • Percentage of households owning smartphones

Smart Governance	• Voter turnout • Women's representation in the County Assembly • Budget transparency	• Percentage of total votes cast compared to the total registered voters • Percentage of women representation in county assembly • County budget transparency index

4.4 Data Sources

The study used secondary data sources drawn from various national and international sources, including Economic Survey 2022 (KNBS), Kenya Demographic and Health Survey (KDHS) 2022, Kenya integrated Household Budget survey (KIHBS) 2015/16, FinAccess Household Survey Report 2021, National Police Service Report 2021, World Bank, and other national Ministries. The data set used is presented in Appendix II.

4.5 Steps for Computing the Smart and Sustainable Cities Index (SSCI)

(i) Identification and categorization of SSCI indicators

The initial step encompassed converting raw data from various sources into standardized percentages that could be compared across different pillars.

(ii) Distance-to-Frontier Approach

The Smart and Sustainable Cities Index (SSCI) framework used the World Bank's Distance to Frontier (DTF) approach in its computation (World Bank, 2018). The analytical process followed a two-step methodology. Initially, the indicators were transformed into percentages and rates to facilitate comparability among the four cities. Subsequently, these indicators were converted into a normalized index value on a scale of zero (0) to one (1) using the DTF approach. The selection of indicators for inclusion in the index was guided by literature, government commitments, and alignment with the Sustainable Development Goals (SDGs).

To ensure the credibility and significance of the chosen indicators, their reliability and relevance were confirmed through Principal Component Analysis (PCA) and the Cronbach alpha test. Furthermore, the responses for each indicator were analyzed and categorized into best and worst performances. In the calculation of the SSCI, the top-performing result for an indicator set the benchmark, referred to as the frontier. Conversely, the poorest performance for an indicator represented the lowest point. Equation 1 illustrates the calculation process for indicator scores.

$$\text{Score} = ((\text{Worst} - y))/((\text{Worst-frontier})) \quad (1)$$

(World Bank, 2018)

Where y is the data point for each indicator, Worst represents the worst performance and frontier indicates the target/best practice/benchmark. The scoring spans

from zero (0) to one (1). Equation 1 provides the score corresponding to each value within the dataset. This approach provided insight into the extent to which each city deviates from the best practice. Table 4.2 provides detailed information on the criteria for indicator scores as per the national, regional, and global aspirations.

Table 4.2: Criteria for the computation of the indicators' scores

Pillars	Indicators	Scoring of the indicators
Smart People	Education	Kenya seeks to attain 100% accessible education to all through the Kenya Vision 2030. The worst is when the percentage of education rate is 0% and the frontier is 100%
	Digital devices	The Ministry of Information, Communication and Digital Economy envisions all the primary public schools to have access to digital devices. The worst is when the percentage of public primary schools without digital device is 0% and the frontier is a 100% (benchmark)
	Demographics	The study on Youth Unemployment and Political Instability in Selected Developing Countries, Working Paper Series No. 171 African Development Bank, South-East Asian countries (for example Malaysia, Thailand, South Korea) has an average dependency ratio of 46 dependents per 100 in the working ages and Kenya is in a critical rate of 77 per 100 working ages
Smart Living	Life expectancy	The global aspiration of 85 years and a minimum of 20 years as used in World Bank HDI was considered in the computation of the index as the frontier and worst, respectively. Worst would be 20 years, and the frontier is 85 years
	Health insurance coverage	Kenya Universal Health Coverage Policy 2020-2030 requires the Kenyan Government to provide medical insurance coverage for every Kenyan. Thus, the best practice would be 100% while the worst is 0%
	Births attended by skilled health personnel	In alignment to UN SDG Goal 3, the country has an aspiration to achieve a 100% delivery under a skilled birth attendant to improve maternal and child health outcomes. Zero (0%) is the worst situation while 100% is the frontier
	Housing quality	Housing quality is in line with target 1 of SDG 11 on access to adequate, safe and affordable housing and basic services and upgrading of slums. The best scenario then was taken as 100% and worst as 0%
	Crime rate	The benchmark is Copenhagen, which has the least crime rate of 25.86. The frontier will be 25.86 and the worst Caracas which has the highest crime rate globally (250.77)
Smart Economy	GCP per capita	The targets for GDP per capita are US$ 1,035 to US$ 4,045 for lower-middle income countries (World Bank, 2018). The worst GCP per capita is 147,280.50 and the frontier is 575,603.50

	Employment rate	The benchmark is the expected employment rate in Sub-Saharan Africa by ILO where the 2023 employment rate target was 63.2%. The worst is 0 and the frontier is 63.2
	Ease of doing business	Based on Micro Small Enterprises on the County Business Environment for MSEs (CBEM) 2022, a score of 100% on County Business Environment for MSEs was the set benchmark
	Tech hubs	The best practice in this case is Nairobi City, which belongs to the first Tier of 20-40 tech hubs according to the GSMA report (2019)
	Own source revenue gap	The target for counties' own source of revenue is 94 for worst and 35 for frontier (World Bank Report, 2018)
	E-commerce	In Zurich, at least 90% use the Internet for shopping. This is the benchmark. The frontier is 90% and 0% the worst scenario
Smart Environment	Natural resources	The Kenya Vision 2030 aims at attaining 10% of forest cover by 2030. The target is 10%, implying that it is the frontier, while 0% represents the worst scenario for the cities
	Waste management	The Kenya Vision 2030 envisions Kenya to become a country where its people reside in a clean, safe, and sustainable environment, resulting in a significant reduction, by half, of all diseases related to the environment. Further, the National Sustainable Waste Management Policy 2021 aims at advancing Kenya towards a more sustainable and circular, green economy. Thus, the best practice would be 100% while the worst would be 0% waste disposal.
	Access to improved water	In line with the Kenya Vision 2030 and SDG6, Kenya is working towards all the households that have access to improved water by 2030. Therefore, the worst is when the percentage of households with access to improved water is 0%, and the frontier is 100%
	Access to improved sanitation	As per Kenya Sanitation and Hygiene Programme (KESHP), the goal is to ensure universal access to improved sanitation for all households in Kenya by 2030. The scale ranges from 0% (worst scenario) indicating no households with improved sanitation to 100% (the frontier), indicating all households have access to improved sanitation
	Access to clean energy for cooking	Kenya seeks to achieve a target of 100% use of clean energy by 2030 as per the Kenya Vision 2030. The worst is when the percentage of transition rate is 0% and the frontier is 100 %
	Access to clean energy for lighting	Through the Kenya Vision 2030, Kenya seeks to achieve a target of 100% use of clean energy by 2030. The worst is when the percentage of transition rate is 0% and the frontier is 100%

Smart Mobility	Miles of bike path per 100000 inhabitants	The Kenya Roads Act of 2007 mandates the inclusion of dedicated lanes or tracks for non-motorized transportation modes on all public roads. The frontier in this case is the city with the highest miles of bike path while the worst is the city with the least
	Cars per capita	UN SDG 11 provides a guideline which promotes sustainable, inclusive, and resilient cities, including the expansion of safe and accessible public transportation systems and the reduction of the environmental impact of urban transportation. In this quest, the frontier is the city with the lowest cars per capita and the worst is one with the highest
	EVs charging stations	By the year 2030, the National Energy Efficiency and Conservation Strategy (2020) aims to have electric-powered vehicles account for 5% of all registered vehicles in Kenya. In this indicator, the frontier was taken as the city with the highest number of charging stations and the worst scenario to be the city with the least
Smart Infrastructure	Households with computer/laptop	The frontier is the best performance in the data set and worst scenario is the worst performance in the data set
	Access to electricity	Kenya aims to have 100% access to electricity, which forms the benchmark (frontier), and the SDG 7 aims for countries to attain universal access to electricity. The worst scenario is where the city has 0% of the population with access to electricity
	Households with mobile broadband	The Kenya Vision 2030 envisages for the country to become a globally competitive knowledge-based society enabled by secure and fast broadband connectivity. Therefore, the benchmark is 100% and the worst scenario is 0%
	Mobile money subscription	The National Financial Inclusion Strategy, developed by the Central Bank of Kenya (CBK), outlines the government's commitment to increasing access to financial services for all Kenyan citizens. The benchmark is to attain 100% mobile money subscriptions and the worst scenario is 0%
	Use of the Internet	The Kenya Digital Master Plan 2022-2023 requires Kenya to have universal access to the Internet; 100% being the frontier and 0 indicating the worst scenario
	Smartphone ownership	Through the National ICT Policy, 2019, the government of Kenya seeks to ensure every Kenyan can afford a device that they can use to access the Internet. The frontier is 100% smartphone ownership and 0% is the worst scenario
Smart Governance	Voter turnout	The IEBC intends that voters' turnout is 100% (frontier); thus, the worst is 0% and best practice is 100%
	Women representation in County Assembly	The Kenya's Constitution 2010 stipulates for a two-third gender rule for elective and appointment positions. In this case, the worst scenario would be less than a third and the best scenario (frontier) would a third and above

	Budget transparency	The County Budget Transparency Survey (CBTS) stands out as a notable and inclusive transparency project that takes place annually and offers impartial and comparative assessments of the information shared by all of Kenya's sub-national units, known as counties. The survey's purpose is to ensure compliance with the Public Finance Management Act (PFM Act) of 2012 and its associated regulations in terms of providing essential financial information. The frontier is 100% while the worst is 0%

(iii) Calculation of Smart and Sustainable Cities Index

The calculation of the comprehensive SSCI score involved amalgamating seven distinct pillars: smart people, smart living, smart economy, smart environment, smart mobility, smart infrastructure, and smart governance. Each pillar is characterized by specific key indicators that are employed to formulate a pillar-specific index. Consequently, the collective SSCI is derived by computing the arithmetic mean of the individual pillar scores. This weighting approach is adopted to mitigate potential criticism, consistent with principles of index number theory, which posits that assigning weights can sometimes be arbitrary and subject to manipulation, potentially leading to biased target outcomes. Therefore, the following formula is used to calculate the composite SSCI using equal weights:

$$SSCI = 1/7\ (Smart\ People + Smart\ Living + Smart\ Economy + Smart\ Environment + Smart\ Mobility + Smart\ Infrastructure + Smart\ Governance) \quad (2)$$

4.6 Robustness of Composite Indicators

Two reliability tests were performed during the calculation of the SSCI: the Cronbach's alpha test and the Principal Component Analysis (PCA). These tests played a crucial role in determining whether the indicators used in constructing the index met the criteria for statistical reliability and consistency. The results show that the indicators are statistically reliable and consistent to be used for measuring the various pillars under study. More details are provided in Appendices I and II (Tables 12-19).

5. Key Findings and Discussion

5.1 Introduction

This section presents data analysis and discussion of results. Section 5.2 outlines the study's descriptive statistics for the key variables, which are categorized into seven pillars as the key explanatory variables on smart and sustainable cities.

5.2 Smart and Sustainable Cities Index Computation

The Smart and Sustainable Cities Index (SSCI) was measured using seven pillars, namely: smart people, smart living, smart economy, smart environment, smart mobility, smart infrastructure, and smart governance. Each pillar represents a vital aspect of a city's overall performance and readiness to embrace the challenges of urbanization while ensuring a high quality of life for its residents.

5.2.1 SSCI scores

As shown in Figure 5.1, on average the SSCI score for Kenyan cities is 0.56. This reveals that Kenya's cities are on the right trajectory to attaining smartness and sustainability for its cities. Nairobi City has the highest index score of 0.71, which is above average, Mombasa ranked second, Kisumu third, and Nakuru fourth with scores of 0.54, 0.52, and 0.48, respectively. Nairobi stands out as a frontrunner in the journey toward becoming a smart and sustainable city. Its comprehensive strategy is evidenced by notable strengths across multiple pillars, including smart people, smart living, smart economy, smart environment, and smart infrastructure. Mombasa's index score places it as the second-ranking city, highlighting commendable progress in its pursuit of a smart and sustainable future. Kisumu ranked third with an overall score of 0.52, which is slightly above average. The city performed quite well in the smart mobility pillar, indicating efforts to enhance smart and sustainable transport. Nakuru ranked fourth with a score slightly below average (0.48). Despite being Kenya's newest city, Nakuru has proved to be committed to smart and sustainable urban development. From Table 5.1, Nakuru's ascent to prominence becomes especially evident in the pillar of smart governance, where the city has a score of 0.51, which is above average. This achievement underscores Nakuru's commitment to transparent, efficient, and responsive governance practices. Despite its young age, Nakuru has embraced innovative approaches to administration, setting an example for other cities to follow in effective policy implementation and citizen engagement. The results for the pillars are presented in tables with heat maps to enhance the visualization of the scores for the cities with three colours: green for frontier score (1), yellow for average score (0.5), and red for worst score (0).

Figure 5.1: SSCI scores for Kenyan cities

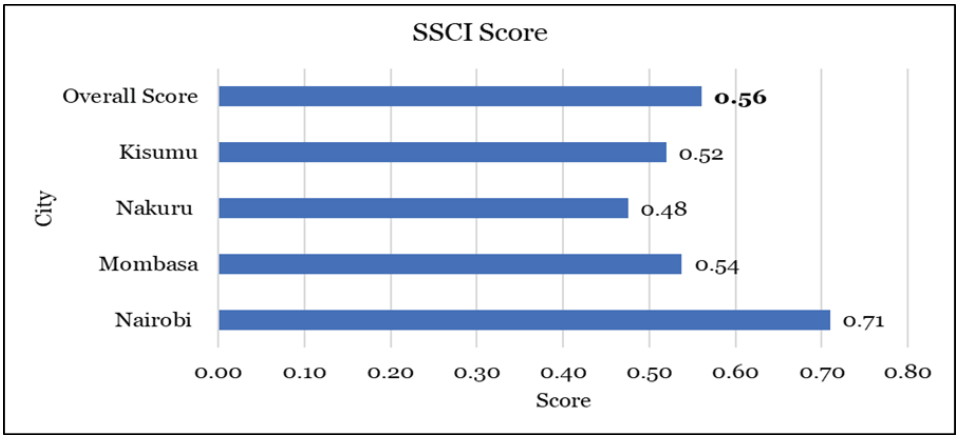

Table 5.1: City performance across pillars

Pillar	Nairobi	Mombasa	Nakuru	Kisumu	Overall Score
Smart People	0.97	0.94	0.64	0.66	**0.80**
Smart Living	0.57	0.52	0.51	0.48	**0.52**
Smart Economy	0.74	0.49	0.42	0.42	**0.52**
Smart Environment	0.88	0.69	0.71	0.50	**0.69**
Smart Mobility	0.61	0.11	0.08	0.67	**0.37**
Smart Infrastructure	0.77	0.58	0.46	0.42	**0.56**
Smart Governance	0.42	0.44	0.51	0.49	**0.46**
SSCI Score per City	**0.71**	**0.54**	**0.48**	**0.52**	**0.56**
Ranking	**1**	**2**	**4**	**3**	

5.2.2 Smart people pillar

The smart people pillar is a key measure of the smartness of a city. It indicates the importance of human capital and aims to empower its residents through education, access to information, technology, and opportunities for innovation. This pillar was measured by three indicators, namely: access to education, access to digital devices, and dependency rate. The scores were computed by taking the average of the total scores for the three indicators. From Table 5.2, Nairobi ranked first at 0.97, Mombasa second at 0.94, Kisumu third at 0.66 and lastly Nakuru at 0.64. Kisumu and Nakuru have potential for improvement in this key pillar.

Table 5.2: Smart people performance per city

Indicator/City	Nairobi	Mombasa	Nakuru	Kisumu
Education	0.92	0.90	0.91	0.90
Digital Devices	0.99	0.98	1.00	1.00
Demographics	1.00	0.93	0.01	0.08
Average	**0.97**	**0.94**	**0.64**	**0.66**
Rank	**1**	**2**	**4**	**3**

Education: The Kenya Vision 2030 envisages for Kenya to achieve 100 per cent access to education for all. From Table 5.2, Nairobi's score of 0.92 in education indicates its strong emphasis on providing quality education opportunities. The city's role as the capital and a major economic centre contributes to its availability of educational institutions and resources. Mombasa closely follows with a score of 0.90, highlighting its commitment to educational development as a key coastal city. Notably, Mombasa ECDE Robotics Programme is a great advancement within the city county education system. It introduces technology to learners at a tender age, creating a future digital generation in the Artificial Intelligence era. Nakuru and Kisumu also exhibit competitive scores of 0.91 and 0.90, respectively, suggesting they are making substantial efforts to offer quality education to their residents. The good performance by the cities is largely attributed to the free primary education policy in Kenya, which aims at reducing illiteracy levels by 80 per cent and improved access to education.

Digital devices: Access to digital devices in schools was computed as: = (0-y) / (0-100), where the worst is the percentage of public primary schools without digital devices is 0%, and the frontier is 100% where all the primary public schools have digital devices as indicated by the Ministry of Information, Communication and Digital Economy. From Table 5.2, Nakuru and Kisumu cities scored the best at 1.00 each, signifying their proactive approach to embracing digital technologies. In Nakuru, it can be attributed to the establishment of seven digital centres and the increased number of sites connected with WAN/LAN from 3 to 25. In 2017, the County Government of Kisumu conducted a Digital Literacy Training course for 3,000 young people in Kisumu City-Tom Mboya College. These achievements position Nakuru and Kisumu cities as digitally enabled cities poised for further advancements. Nairobi and Mombasa also scored well in this indicator at 0.99 and 0.98, respectively. Notably, Mombasa ECDE Robotics Programme introduces technology to learners at a tender age creating a future digital generation in the Artificial Intelligence era.

Dependency ratio: The indicator assessed the percentage of dependency across the cities. According to Youth Unemployment and Political Instability in Selected Developing Countries, Working Paper Series No. 171 African Development Bank, South-East Asian countries (for example, Malaysia, Thailand, and South Korea) have an average dependency ratio of 46 dependents per 100 in the working ages, and Kenya is in a critical rate of 77 per 100 working ages. Table 5.2 reveals Nairobi's

perfect score of 1.00 in demographics, reflecting its diverse and economically active populations. Mombasa scored relatively well with a score of 0.93. This agrees with Mombasa's age structure where 32.1 per cent are between 0-14 years and 1.7 per cent are aged 65 years and above. Nairobi and Mombasa cities have the percentage of working population at 67.4 and 66.2 per cent, respectively. While Nakuru and Kisumu exhibit lower scores of 0.01 and 0.08, respectively, indicating a significantly higher total dependency ratio. Nakuru and Kisumu cities' age structures of below 15 years is 42.3 and 42.1 per cent and above 65 years is 3.8 and 3.1 per cent (Table 2.1), respectively. The scores can further be attributed to the fact that Kisumu and Nakuru have rural areas which, according to the KIHBS report 2015/16, have higher dependency ratio as compared to urban areas.

5.2.3 Smart living pillar

The smart living pillar was measured using five indicators, namely: life expectancy, health insurance coverage, births attended by skilled personnel, housing quality and crime rate. The average score for this pillar for each city was Nairobi (0.57), Mombasa (0.52), Nakuru (0.51) and Kisumu (0.48). As illuminated by the results presented in Table 5.3, each of the studied cities has demonstrated commendable efforts to enhance the quality of life for their inhabitants, reflected by scores that all surpass the average except for Kisumu that scored slightly below average.

Table 5.3: Smart living performance per city

Indicator/City	Nairobi	Mombasa	Nakuru	Kisumu
Life Expectancy	0.68	0.74	0.67	0.59
Health Insurance Coverage	0.46	0.29	0.33	0.21
Births attended by skilled health personnel	0.99	0.96	0.93	0.98
Housing Quality	0.91	0.94	0.94	0.96
Crime rate	0.39	0.16	0.15	0.15
Average	**0.57**	**0.52**	**0.51**	**0.48**
Ranking	**1**	**2**	**3**	**4**

Life expectancy: The life expectancy indicator for smart living serves as a critical barometer of a city's public health and well-being. The global aspiration of 85 years and a minimum of 20 years as used in World Bank Human Development Index (HDI) was considered in the computation of the scores. The Kenyan cities performed above average in this indicator with Mombasa ranking first at 0.74, Nairobi second at 0.68, Nakuru third at 0.67 and Kisumu fourth at 0.59 (Table 5.3). The high performance of life expectancy in Mombasa indicates a higher score for life expectancy. This is in support of the Kenya Economic Survey Report 2022 that puts the coastal city highest in life expectancy both for male and female at 77.7 and 80 years, respectively (KNBS, 2022). For Nakuru, the score for this

indicator is 0.68, indicating a good performance but there may be potential for improvement through targeted health interventions and enhanced healthcare access. Kisumu's relatively lower score highlights the importance of focusing on public health efforts to improve life expectancy.

Health insurance coverage: Health insurance coverage as a measure of smart living reflects a city's commitment to the well-being of its residents and the establishment of a comprehensive and sustainable healthcare system. It aligns with the principles of equitable access to healthcare, financial protection, and proactive health management. According to Kenya Universal Health Coverage Policy 2020-2030, the Kenyan Government aims to provide medical insurance coverage for every Kenyan. From Table 5.3, Kenyan cities performed below average in this indicator with Nairobi leading at 0.46 followed by Nakuru (0.33), Mombasa (0.29) and Kisumu (0.21). In 2018, a motion was moved in Nairobi County Assembly urging the County Executive to investigate ways of establishing a County Public Health Insurance Policy targeted at cushioning the most vulnerable and ensuring access to basic healthcare for the County's uninsured low-income residents. This motion was adopted. However, health insurance uptake is intriguingly low. This points to limiting factors such as shortage of formal employment, scarcity of information, social, and demographic factors such as a young and healthy population, which may consider health insurance as a tertiary requirement among others. The performance of Nakuru city is also notably low. The recent partnership between Nakuru County Government and Thinkwell Kenya Ltd aims to improve health financing in the county to make primary health care as affordable as possible. This is a very promising development. It is worth noting that Kisumu (one of the universal health coverage pilot counties) is taking a step in the right direction. The Kikuyu Solidarity Health Insurance Scheme alias 'Marwa' is a digitally enabled health insurance scheme under the umbrella of UHC whose aim is to ensure access to quality and affordable healthcare (County Government of Kisumu, 2021). It is an initiative of PharmAccess Foundation and Kisumu County Government that is underwritten by the National Hospital Health Insurance Fund. The initiatives notwithstanding, the cities' lower scores indicate that a significant portion of the population may lack health insurance coverage, potentially limiting access to medical services. The policies to increase health insurance accessibility and affordability could help improve smart living conditions across the cities' populations by reducing incidences of catastrophic health expenditures.

Births attended by skilled health personnel: Several obstetric complications could be avoided or managed if women had access to skilled birth attendance. This measure embodies the essence of proactive and preventive health practices, guaranteeing that expectant mothers receive expert medical care, guidance, and support throughout the critical moments of childbirth. According to SDG 3 – good health and well-being, Kenya has an aspiration to achieve a 100 per cent delivery under a skilled birth attendant to improve maternal and child health outcomes. Nairobi's high score indicates that a significant percentage of births are attended by skilled health personnel, contributing to safer childbirth experiences and better maternal and infant health outcomes. Kisumu's strong score (0.98)

reflects a positive trend in births attended by skilled health personnel. Mombasa and Nakuru performed well with 0.96 and 0.93, respectively. This points to the availability of hospitals and clinics where skilled birth attendance is available. In addition, initiatives such as the National Health Insurance Fund and Linda Mama have also made maternal healthcare quite affordable.

Housing quality: This indicator is in line with target 1 of SDG 11 on access to adequate, safe, and affordable housing and basic services and upgrading of slums. The indicator measured the quality of houses by the roof type. From Table 6, Kisumu ranked first (0.96), Nakuru and Mombasa tied at 0.94 and Nairobi was fourth with 0.91. Nakuru County has partnered with the World Bank in a project dubbed developing partnerships to deliver affordable housing in addition to the domestication of the national programme for slum upgrading. Nairobi County has the housing and urban renewal sub-sector whose functions include housing development, estates management, urban renewal and building designs and implementation services. The four cities are doing relatively well in this indicator, implying efforts to achieve adequate and safe housing.

Crime rate: Crime rate refers to the number of reported criminal incidents or offenses that occur within a specific population or geographic area over a given period. It is a key indicator used to assess the prevalence and level of criminal activity within a society. Crime rates are often expressed as a ratio or a percentage of crimes per unit of 100, 0000 population. The data was retrieved from the National Police Service Report 2021. The information encompassed the rate of all offences, including sexual gender-based violence (SGBV). From Table 5.3, Nairobi ranked first with 0.39, followed by Mombasa with 0.16 and lastly, Kisumu and Nakuru ranked third with an equal score of 0.15. The cities are still quite far from the frontier score (1), and there is a need for interventions to reduce crime rates across the cities. Some of the contributing factors include but are not limited to high unemployment rates, poverty and inequality, urbanization, drug and substance abuse, and inadequate urban housing and planning.

5.2.4 Smart economy pillar

The smart economy pillar is a key measure of the smartness and sustainability of cities as it reflects their economic vibrancy, innovation, and adaptability. The smart economy pillar was measured using six indicators: GCP per capita, employment rate, ease of doing business, tech hubs, own source revenue gap, and e-commerce. From Table 5.4, Nairobi ranked first with 0.74, Mombasa ranked second with 0.49, and Nakuru and Kisumu scored 0.42. This reflects Nairobi's status as the economic hub of the country, where various industries and economic activities thrive. The other cities were below average and can borrow a leaf from Nairobi City to enhance their performance.

Table 5.4: Economic pillar performance per city

Indicator/City	Nairobi	Mombasa	Nakuru	Kisumu
GCP per capita	1.00	0.58	0.15	0.14
Employment Rate	1.00	1.00	1.00	1.00
Ease of Doing Business	0.37	0.30	0.29	0.32
Tech Hubs	1.00	0.03	0.05	0.03
Own Source Revenue	1.00	1.00	1.00	1.00
E-commerce	0.07	0.02	0.04	0.05
Average	0.74	0.49	0.42	0.42
Ranking	1	2	3	4

GCP per capita: It provides a comprehensive insight into the economic output generated by a city per resident, offering a nuanced understanding of its economic efficiency, productivity, and prosperity. The indicator is computed by dividing the total economic output (GCP) of a county by its population, given that cities are under county governments (The Urban Areas and Cities (Amendment) Act, 2019), and most importantly Nairobi and Mombasa are city counties. As shown in Table 5.4, Nairobi shines with a perfect score, indicating its high economic output per resident. It is partly because of its status as the country's economic hub, hosting diverse industries and businesses. Mombasa ranked second with a score of 0.58, which is above average, indicating its capacity to improve further with focused policy initiatives. Mombasa is a major trade hub and home to the largest port in East Africa. Equally, the city's tourism industry, including its beautiful coastline and historical sites, attracts visitors from around the world. However, the major challenge could be that the economic benefits of these activities are not evenly distributed across the population. Nakuru has a low score (0.15), indicating the need for utilization of the city's economic activities. Some of these economic activities include floriculture, livestock farming, tourism and hospitality, livestock farming, and retail and trade. Kisumu also performed low on this indicator (0.14). Kisumu has potential of improving its performance in the areas of infrastructure and connectivity, which are enablers for economic growth and development.

Employment rate: In this indicator, the best practice is the expected employment rate in Sub-Saharan Africa by ILO–the 2023 employment rate target is 63.2 per cent. The employment rate is a key component for a city's economic growth and development. Kenya has put in place policies to help her achieve its goal of becoming "a newly-industrializing, middle income country" enshrined in the Kenya Vision 2030. Other aspirations are envisaged in these key policy documents, including the Sessional Paper No. 4 of 2013 on Employment Policy and Strategy, the State Department of Labour Strategic Plan 2018-2022, the Third Medium-Term Plan 2018-2022, and the Youth Development Policy 2019. From Table 5.4, all the cities performed well in this indicator as per the benchmark, with a best score of one. A perfect employment rate performance not only reflects a healthy labour market, but also underscores the effectiveness of the policies aimed at supporting job creation.

Ease of doing business: The measurement of ease of doing business focused on evaluating the business environment for Micro Small Enterprises (MSEs), using the CBEM scores for 2022. The benchmark for this assessment was established as a 100 per cent on the County Business Environment for MSEs. In the pursuit of smart and sustainable cities in Kenya, the Ease of Doing Business indicator is as a vital gauge of a city's economic vitality and attractiveness to investors. This measure sheds light on the efficiency of administrative processes and bureaucratic hurdles that can impact the ease of establishing and operating businesses. All the cities scored below average: Nairobi (0.37), Kisumu (0.32), Mombasa (0.30), and Nakuru (0.29) (Table 5.4). This indicates that the cities are yet to establish an enabling environment for the growth of the private sector.

Tech hubs: Within the realm of smart economies, the presence and vitality of tech hubs stand as a pivotal indicator, underlining a city's readiness to embrace innovation, harness technology, and foster economic growth. The scores were computed using the best practice as Nairobi City (40) as it emerged among leading cities in Africa with high number of tech hubs where best is regarded as 20-40. Nairobi's perfect score in tech hubs firmly cements its position as Kenya's premier tech hub and a beacon of innovation. The cities of Mombasa, Nakuru, and Kisumu scored low in this indicator. These cities can foster an environment that encourages tech innovation by harnessing the power of digitalization.

Own source revenue gap: In the World Bank Report (2018) on "Own-Source Revenue Potential and Tax Gap Study of Kenya's County Governments", the worse scenario for own source revenue (OSR) gap is 94 per cent while the best practice is 35 per cent. Reducing the OSR gaps holds profound importance as cities strive for smart and sustainable transformation. In this indicator, the four cities achieved a perfect score of one. This demonstrates the counties' commitment to empower themselves with greater financial resilience, enabling them to finance critical infrastructure projects, providing essential services, and investing in initiatives that enhance livability and prosperity.

E-commerce: The e-commerce indicator performance for the cities is a crucial aspect of understanding their readiness and capacity for digital commerce. Challenges such as customer reluctancy and infrastructure gaps remain a major impediment to the growth of e-commerce across the four cities. These challenges are fueled by the existence of scammers and loss of customer trust due to unmet value for money. Table 5.4 shows that Nairobi leads in e-commerce (0.07) readiness due to its strong economic base, tech ecosystem, and workforce. Kisumu follows (0.05), with potential for growth in e-commerce infrastructure. Nakuru and Mombasa are promising but need focused efforts to enhance their e-commerce capabilities, including improving the business environment and fostering technology-driven innovation.

5.2.5 Smart environmental pillar

This pillar evaluates how effectively a city is in managing its natural resources, reducing pollution, and ensuring access to basic services that contribute to a

healthier and more sustainable urban environment. The pillar was measured using six indicators: forest cover, waste management, access to improved water, access to improved sanitation, access to clean energy for cooking, and access to clean energy for lighting. Nairobi ranked first with 0.88, followed by Nakuru with 0.71, Mombasa 0.69 and lastly Kisumu with 0.50 (Table 5.5). The low score by Kisumu has been affected by its poor score on forest cover that is almost 0. More effort needs to be put by the county to enhance its performance in enhancing forest cover to meet the current target of 10 per cent as aimed nationally through the Kenya Vision 2030.

Table 5.5: Smart environment pillar performance per city

Indicator/City	Nairobi	Mombasa	Nakuru	Kisumu
Forest Cover	0.78	0.51	0.93	0.04
Waste Management	0.80	0.76	0.59	0.48
Access to improved water	0.99	0.52	0.73	0.72
Access to improved sanitation	0.94	0.95	0.75	0.69
Access to clean energy for cooking	0.82	0.43	0.28	0.15
Access to clean energy for lighting	0.97	0.94	0.97	0.91
Average	**0.88**	**0.69**	**0.71**	**0.50**
Ranking	**1**	**3**	**2**	**4**

Forest cover: Through the Kenya Vision 2030, Kenya aims at attaining 10 per cent of forest cover by 2030. The scores for this indicator were computed using this threshold. The indicator assesses the extent of green spaces and the preservation of natural habitats within each city. A higher score signifies a better-preserved environment. Table 5.5 shows that Nakuru stands out with the highest score (0.93), indicating robust efforts in maintaining green areas. Nakuru's 0.09 per cent landmass is its gazetted forest area comprising mostly the Mau and Donduri forests. There are also six non-gazetted forests in the county. Mombasa County has the Water, Sanitation and Natural Resources Department, which manages forests. Nairobi County Green Nairobi Sector through the environment sub-sector implements specific policies on natural resources and environmental conservation. Conversely, Kisumu's low (0.04) score highlights a need for more focus on preserving its forested landscapes. In this regard, the government in collaboration with African Guarantee Fund (AGF) on 19th May 2023 rolled out the Kisumu Greening Initiative with a view to boosting forest cover in the county.

Waste management: According to the Kenya Vision 2030, Kenya's aim is to become a country where its people reside in a clean, safe, and sustainable environment, resulting in a significant reduction, by half, of all diseases related to the environment. Further, the National Sustainable Waste Management Policy 2021 aims at advancing Kenya towards a more sustainable and circular, green economy. Effective waste management is crucial for preventing pollution and maintaining a clean environment. From Table 5.5, Nairobi ranks first with 0.80, indicating a well-established system. Mombasa and Nakuru also performed

well, while Kisumu could enhance waste disposal strategies to improve its score. The Kisumu Urban Programmes (KUP) was launched in 2012 with the aim of procuring various waste management equipment to improve waste management in the city. Nakuru's main dumpsite, Gioto, has become an eyesore to the neighbouring communities, and this needs to be investigated. Nairobi City County Waste Management Act (No. 5 of 2015) makes provision for waste management in the city. Mombasa County Sessional Paper No. 01 of 2019 provides a policy and legal framework on solid waste management.

Access to improved water: Access to clean water is fundamental for public health and well-being. According to the Kenya Vision 2030 and SDG 6, Kenya is working towards all households having access to improved water by 2030. The indicator was computed using 100 per cent as the frontier and 0 per cent as the worst scenario. The Kenyan cities have a mandate to ensure this is achieved by ensuring they implement policies that will enhance access to clean water to their residents. Table 5.5 shows that Nairobi ranked first (0.99), Nakuru second (0.73), Kisumu third (0.72), and lastly Mombasa (0.52). Nairobi demonstrates strong performance in providing improved water sources and ensuring a higher quality of life. Nakuru, Kisumu and Mombasa could invest more in water infrastructure to enhance access for their residents. Although Nakuru has several natural water resources such as Rivers Malewa, Njoro, Molo, and Igwamiti, some residents still cover about six kilometres to get to the nearest water points while others take 1-4 minutes. The KDHS 2022 ranked Nairobi as the county with the highest number of households with at least basic service for drinking water.

Access to improved sanitation: Proper sanitation facilities are vital for preventing disease and maintaining a hygienic environment. As per the Kenya Sanitation and Hygiene Programme (KESHP), the goal is to ensure universal access to improved sanitation for all households in Kenya by 2030. The SDG 6, indicator 6.2, aims to monitor access to equitable and adequate sanitation and hygiene for everyone and put an end to open defecation by 2030. As shown in Table 5.5, the Kenyan cities are doing well in this quest, with all of them scoring more than 0.90. Mombasa topped the list with a 0.95 score and closely followed by Nairobi (0.94) while Nakuru ranked third (0.75) and Kisumu fourth (0.69). Despite the current efforts to ensure improved sanitation services, the key is for the cities to ensure sustainability of their sanitation services.

Access to clean energy for cooking: Clean energy for cooking reduces indoor air pollution and reliance on non-renewable energy sources. The Kenya Vision 2030 envisions universal access to clean cooking by 2030. Further, the National Climate Change Action Plan (NCCAP) 2018-2022 highlights the shift towards adopting cleaner cooking methods as a priority for climate action. So far, the country has made significant progress in this indicator. However, the proportion of clean energy for cooking has not been fully utilized. This is partly due to the high costs of cleaner cooking sources such as Liquefied Petroleum Gas (LPG). From Table 5.5, Nairobi leads (0.82) with a relatively high score, while Mombasa (0.43), Nakuru (0.28), and Kisumu (0.15) have opportunities to promote cleaner cooking technologies. Some of the reasons for Nairobi's success in this indicator include a well-established infrastructure and availability of clean energy sources

for cooking, effective awareness campaigns and education programmes, and focused government initiatives such as tax incentives and subsidies. The other cities could adopt these techniques for them to enhance adoption of clean cooking technologies. A report by Modern Energy Cooking Services (MECS) on Nakuru County Electricity Access and Clean Cooking Profile highlights top opportunities for e-Cooking in Nakuru County, such as investment in Menengai Geothermal Power Station to tackle deforestation in Mau Forest. The Mombasa Environment, Waste Management and Energy Department promotes clean and safe energy for the residents of the county, underscoring the importance of green energy production. According to the Population and Household Census (KPHC) 2019, the use of traditional energy sources in Kisumu County is predominantly biomass, with 79.6 per cent of households still using unclean energy sources.

Access to clean energy for lighting: The indicator reveals the extent to which residents in each city could use clean and sustainable energy sources for lighting purposes. The Kenya Vision 2030 and SDG 7 aims to ensure access to clean and affordable energy by 2030. By promoting the transition to clean energy sources such as electricity or solar power for lighting, the cities seek to achieve improved air quality, reduced greenhouse gas emissions, and enhanced energy efficiency. Table 5.5 shows that all the four cities demonstrate commendable performance in this category, indicating a positive shift towards adopting sustainable lighting solutions. The scores were 0.97 for both Nakuru and Nairobi, 0.94 for Mombasa and 0.91 for Kisumu. Mombasa County Climate Change Policy 2021 aims to promote investments in renewable energies, such as wind and solar. This is a step in the right direction. The Nakuru County Energy Plan 2022-2027 outlines the importance of clean energy for lighting for all households. Kisumu County undertook an indispensable move to join the International Council for Local Environment Initiatives (ICLEI)'s 100 per cent renewable initiatives, meaning it will receive all the necessary support to develop its roadmap to reach 100 per cent renewable energy use by 2050.

5.2.6 Smart mobility pillar

Smart mobility is integral to creating resilient, eco-friendly, and efficient cities. Emphasizing cycling infrastructure, managing car ownership, and promoting electric vehicle adoption align with global sustainability goals. By investing in smart mobility, cities can alleviate traffic congestion, reduce emissions, and enhance the quality of life for residents, ultimately fostering more vibrant and sustainable urban environments. In this pillar, three indicators were used: miles of bike path, cars per capita, and EV charging stations. From Table 5.6, Kisumu ranked first with 0.67, Nairobi second with 0.61, Mombasa third with 0.11, and Nakuru fourth with 0.08. To foster smart mobility and align with global sustainability objectives, Mombasa and Nakuru have substantial room for improvement across all key indicators. Their lower scores have been due to low uptake of electric charging stations. Also, the two cities have less miles of bikes per path, indicating a need for efforts by stakeholders to adopt these technologies towards sustainable urban mobility. Nairobi, on the other hand, has remarkable performance for electric

charging stations with more transport firms adopting electric buses for public transport.

Table 5.6: Smart mobility performance per city

Indicator/City	Nairobi	Mombas	Nakuru	Kisumu
Miles of Bike Path	0.72	0.00	0.24	1.00
Cars per Capita	0.11	0.17	0.00	1.00
EV Charging Statio	1.00	0.17	0.00	0.00
Average	0.61	0.11	0.08	0.67
Rank	2	3	4	1

Miles of bike path: Bike paths encourage eco-friendly transportation options, reduce traffic congestion, and promote healthier lifestyles. The Kenya Roads Act of 2007 mandates the inclusion of dedicated lanes or tracks for non-motorized transportation modes on all public roads. Table 5.6 shows that Kisumu takes the lead with a perfect score (1), indicating a robust commitment to cycling infrastructure. This performance can be attributed to the County government's efforts to achieve fair and inclusive transportation within the city through the development of the Kisumu Sustainable Mobility Plan (KSMP) in 2021. Further, KSMP is a significant leap towards equitable urban mobility with the reconstruction of 1.5 kilometres of pedestrian walkways along Oginga Odinga Street, Ang'awa Avenue, and Jomo Kenyatta Highway being a pivotal component. Nairobi scores reasonably well with a score of 0.72, reflecting a growing commitment to sustainable and eco-friendly transportation options. The city, in conjunction with the Nairobi Metropolitan Area Transport Authority (NaMATA), is actively working on improving the public transport system in the Nairobi Metropolitan Area (NMA) through the implementation of a comprehensive Mass Rapid Transit System (MRTS). This transformative initiative includes the development of a Bus Rapid Transit System (BRT), a Commuter Rail System, and a Non-Motorized Transport System (NMT), all of which complement the city's dedication to promoting alternative and sustainable transportation modes. However, Nakuru and Mombasa have room for improvement in promoting cycling as a sustainable mode of transport. Nakuru has embarked on redesigning public transport routes and the construction of non-motorized transport (NMT) corridors on Kenyatta Avenue and the city's main road. Further, Nakuru and Mombasa could benchmark Kisumu and Nairobi in adopting focused initiatives towards attainment of non-motorized transportation modes on their roads.

Cars per capita: High car ownership per capita often leads to congestion, air pollution, and increased carbon emissions. Nairobi and Mombasa exhibit relatively low scores (0.11 and 0.17), suggesting a significant presence of cars. Nakuru's lowest performance raises concerns about potential traffic-related challenges. Kisumu's high score (1) indicates a more balanced approach with

reduced car dependence, aligning with sustainable mobility objectives in line with UN SDG 11, which promotes sustainable, inclusive, and resilient cities, including the expansion of safe and accessible public transportation systems and the reduction of the environmental impact of urban transportation. Private car ownership has been on the rise in the country. In the quest for reducing this trend, the government and other stakeholders could invest more on improving the efficiency of public transportation.

Electric vehicles (EV) charging stations: By 2030, the National Energy Efficiency and Conservation Strategy (2020) aims to have electric-powered vehicles account for 5.0 per cent of all registered vehicles in Kenya. This indicator is aimed at determining the presence of electric vehicles in the cities. Electric vehicle (EV) charging infrastructure is crucial for promoting electric mobility and reducing fossil fuel consumption. The scores were computed using Nairobi's score, which is the highest in the data set, and the worst scenario was the least of zero (0) per cent for Kisumu and Nakuru. Nairobi's perfect score indicates a proactive approach to supporting EV adoption, contributing to cleaner urban air quality. Mombasa, while making some progress, could invest more in EV charging stations. Nakuru and Kisumu have opportunities to develop such infrastructure to incentivize sustainable transportation alternatives. Besides, there is high potential for the growth of electric vehicles in the country given the progress made in renewable energy penetration of above 85 per cent.

5.2.7 Smart infrastructure pillar

Smart infrastructure empowers cities with connectivity, data-driven decision-making, and improved service delivery. The smart infrastructure pillar was measured using six indicators: computer or laptop ownership, access to electricity, households with mobile broadband, mobile money subscriptions, use of Internet, and smartphone ownership. Table 5.7 shows that Nairobi ranked first with 0.77, Mombasa second with 0.58, Nakuru third with 0.46, and Kisumu fourth with 0.42. Nairobi's success in this pillar can be attributed to several factors. First, as the capital city, it serves as the country's political, economic, and technological hub, attracting investments and talent. Second, Nairobi has earned a reputation as the "Silicon Valley" of Africa due to its thriving tech ecosystem and numerous tech startups, fostering innovation and digital adoption. Third, the city's robust infrastructure development initiatives, including the expansion of the electricity grid and promotion of digital literacy, have contributed to increased computer and Internet access, further boosting its smart infrastructure capabilities.

Table 5.7: Smart infrastructure performance per city

Indicator/City	Nairobi	Mombasa	Nakuru	Kisumu
Computer/Laptop	1.00	0.30	0.00	0.04
Access to Electricity	0.97	0.86	0.64	0.53
Households with mobile broadband	0.63	0.56	0.48	0.45
Mobile Money Subscription	0.94	0.89	0.86	0.87
Use of Internet	0.52	0.39	0.27	0.24
Smartphone Ownership	0.57	0.51	0.52	0.42
Average	**0.77**	**0.58**	**0.46**	**0.42**
Ranking	**1**	**2**	**3**	**4**

Computer/laptop ownership: Computer and laptop ownership reflects digital literacy and access to information. Nairobi's perfect score (1.00) indicates widespread use of computer, relatively high connectivity and education, due to initiatives such as the Digital Literacy Programme, Connected Kenya, ICT in education policies and the recently launched Smart Nairobi Programme. Mombasa scores low (0.30), reflecting a reasonable level of digital access. However, Nakuru and Kisumu have room for improvement in digital accessibility, as evidenced by their lower scores. Nakuru has a score of zero, signifying the need for enhanced efforts in promoting computer ownership and digital inclusion, given that it performed poorly in this indicator. The Digital Literacy Programme and ICT in education policies have played a vital role in shaping the digital landscape in Kenya's urban centres.

Access to electricity: Access to electricity is fundamental for smart infrastructure. In computing the scores for this indicator, Kenya aims to have 100 per cent access to electricity by 2030, aligning with its commitment to achieving Sustainable Development Goal 7 on affordable and clean energy. This national goal serves as the benchmark (frontier) for measuring progress towards universal electricity access. Relatively high scores across cities imply significant advancements in aligning with this national objective, but gaps in access and connectivity persist. Nairobi leads (0.97), enabling a conducive environment for technological integration. Mombasa (0.86), Nakuru (0.64), and Kisumu's (0.53) scores highlight ongoing efforts to improve access and connectivity. The scores for Nakuru and Kisumu could be attributed to the fact that the data used was for the counties, other than for specific cities.

Households with mobile broadband: Mobile broadband empowers citizens with Internet access. The Kenya Vision 2030 envisages a globally competitive knowledge-based society enabled by secure and fast broadband connectivity. From Table 5.7, Nairobi leads with a moderate score (0.63), fostering digital inclusion. Mombasa (0.56), Nakuru (0.48), and Kisumu's (0.45) scores suggest a growing but evolving digital landscape, underscoring the importance of equitable access. Recently, Safaricom, a digital lifestyle enabler, increased its 5G network to 21 counties, Mombasa, Kisumu, Nakuru and Nairobi being among them. This will spur economic growth and enable people to access important services such as

healthcare. Safaricom in partnership with Huawei set up 5G experience centres in Safaricom's Village market, the Hub and Buruburu shops in Nairobi, which are showcasing smart capabilities for homes and businesses.

Mobile money subscription: It is an important metric for evaluating the impact of mobile technology on urban development and the well-being of residents. Mobile money has significantly transformed financial services and daily transactions in Kenya. The country is renowned for its pioneering mobile money platform, M-Pesa, which was launched by Safaricom in 2007 and has since become a global success story. Higher mobile money subscription rates can indicate a more active and vibrant economy, as it suggests a higher level of financial activity, trade, and business transactions within the city. The cities performed relatively well in this indicator as per Table 5.7: Nairobi (0.94), Mombasa (0.89), Nakuru (0.86), and Kisumu (0.87) denoting a vibrant digital economy, promoting ease of transactions, and reducing barriers to financial services.

Use of Internet: Internet usage reflects digital engagement and information sharing, key components of smart infrastructure. Kenya's commitment to achieving universal Internet access, as articulated in the Kenya Vision 2030 economic development strategy and the National Broadband Strategy (NBS), sets a strong policy foundation for digital inclusion. Nairobi's leading score of 0.52 can be attributed to its central role as Kenya's technology epicentre, resembling a Silicon Valley in East Africa. The city has actively fostered an environment conducive to tech innovation and digital entrepreneurship. In contrast, Mombasa (0.39), Nakuru (0.27), and Kisumu (0.24) demonstrate room for improvement in digital connectivity and engagement. These cities can further benefit from targeted policies that promote digital literacy, invest in Internet infrastructure, and encourage the growth of local tech ecosystems to enhance their smart infrastructure capabilities and digital inclusion. In 2016, the Nairobi City County Assembly developed an ICT policy to govern the usage of ICT infrastructure with its various departments. This underscores the city's commitment to integrate ICT to its daily businesses. Kisumu City has an ICT policy in place to facilitate effective service delivery though a robust ICT infrastructure. Mombasa City County was awarded the Best County on Digital Innovation and leadership in the Africa CIO100 Awards 2021. This clearly shows the cities are making concerted efforts to spur innovation and economic growth through integration of ICT in their daily activities.

Smartphone ownership: It signifies mobile connectivity and access to services. Based on the most recent data provided by the Communications Authority of Kenya (CA) (2023), it is evident that feature phones maintained a significant presence in the mobile market, with an astonishing 33,618,061 million units actively in use between October and December of 2022. This substantial figure represents 68.1 per cent of all subscriptions for such devices. These statistics shed light on the comparatively lower penetration of smartphones across Kenyan cities, as reflected in Table 5.7: Nairobi (0.57), Mombasa (0.51), Nakuru (0.52), and Kisumu (0.42). The data underscores the prevalence of feature phones, implying that a considerable portion of the population still relies on non-smartphone devices for mobile communication and access to digital services.

5.2.8 Smart governance pillar

Smart governance establishes the framework for a transparent, participatory, and responsive city administration. The country's long-term development plan emphasizes the importance of technology and innovation in achieving social, economic, and political objectives. By integrating technology into governance processes, cities can amplify citizen voices, ensure equitable representation, and promote data-driven decision-making. Measuring smart governance through three critical indicators—voter turnout, women's representation in the county assembly, and budget transparency—offers insights into each city's unique governance journey. The cities scored as follows: Nakuru (0.51), Kisumu (0.49), Mombasa (0.44), and Nairobi (0.42) as shown in Table 5.8. Nakuru (0.51) leads, driven by a commitment towards good governance.

Table 5.8: Smart governance performance per city

Indicator/City	Nairobi	Mombasa	Nakuru	Kisumu
Voter's Turnout	0.56	0.44	0.66	0.71
Women Representation	0.14	0.60	0.44	0.51
Budget Transparency	0.56	0.28	0.44	0.23
Average	0.42	0.44	0.51	0.49
Rank	4	3	1	2

Voter turnout: It refers to the percentage or proportion of eligible voters who participate in a specific election or voting event by casting their ballots. It is a measure of the level of civic engagement and active participation of the electorate in the democratic process. Kisumu leads with a score of 0.71 and Nakuru ranks second with 0.66, indicating active citizen involvement in the democratic process. Nairobi (0.56) and Mombasa (0.44) have room for improvement, suggesting potential areas for initiatives that encourage voter engagement.

Women representation in the County Assembly: The indicator highlights inclusivity and gender equality in governance. The Constitution of Kenya, 2010, enshrines the principle of gender equity and requires that not more than two-thirds of the members of elective and appointive public bodies be of the same gender. Further, devolution in Kenya has created opportunities for women's representation in county governments. Each county is required to ensure that at least one-third of its members of the county assembly are of the opposite gender. Mombasa and Kisumu demonstrate relatively above average scores, indicating efforts to empower women's participation in decision-making. From the 2022 general elections, Nairobi had only five elected women MCAs out of 85 indicating the need for concerted efforts for the city county to increase women representation in positions of power.

Budget transparency: Budget transparency enhances public trust and accountability. Nairobi's relatively high score (0.63) suggests efforts to provide accessible budget information. Transparent budgeting fosters trust between citizens and local governments. When residents have access to clear and comprehensive budget information, it promotes confidence in the city's financial management practices. The Public Finance Management Act (2012) aims to ensure prudent and transparent management of public finances, including the preparation and implementation of budgets at the national and county levels. Mombasa (0.56), Nakuru (0.48), and Kisumu (0.45) could enhance transparency further, ensuring citizens have a clear understanding of resource allocation and expenditure.

6. Conclusion and Policy Recommendations

6.1 Conclusion

The study aimed at assessing the current state of smart and sustainable urbanization in Kenyan cities. Also, it sought to identify areas of strength and improvement across various pillars of smart and sustainable cities in Kenyan cities. The results revealed that Nairobi had the highest index score of 0.71 – an intriguing score relative to the other three cities. Mombasa and Kisumu scored slightly above average with scores of 0.54 and 0.52, respectively. Nakuru scored slightly below average with a score of 0.48. These SSCI results illuminate the diversity of approaches each city is adopting in their journey towards smart and sustainable urbanization. Notably, Nairobi takes lead in the journey towards becoming a smart and sustainable city having ranked first in five of the seven pillars. The findings underscore the significance of a multi-dimensional approach, as cities strive to balance economic growth, citizen well-being, governance effectiveness, and environmental stewardship. The assessment serves as a valuable resource for policy makers, offering a nuanced understanding of each city's strengths and areas for enhancement. It is through such insights that Kenyan cities can chart their path to a smart, sustainable, and prosperous future. The SSCI encompassed seven pillars, namely smart people, smart living, smart economy, smart environment, smart mobility, smart infrastructure, and smart governance as discussed below.

Smart people

The smart people pillar's findings hold valuable implications for urban policy makers. The rankings offer a clear window into each city's efforts to empower its citizens, facilitate access to knowledge, and embrace technological progress. Nairobi and Mombasa are tending to a perfect index score of one. However, more interventions are needed to fast-track Kisumu and Nakuru cities' performance towards enhancing the smartness of their people, especially on the life expectancy indicator and enhance the realization of universal education for all. As these cities continue to evolve, there exists a dynamic opportunity for them to learn from one another's practices and experiences, thereby collaboratively advancing their smartness and sustainability agendas.

Smart living

Each of the studied cities has demonstrated commendable efforts to enhance the quality of life for their residents, reflected by scores that were slightly above average. However, they all need to double their efforts to improve the living standards of their people. Focusing on healthcare accessibility, skilled childbirth attendance, housing quality, and effective crime management can have a transformative impact on the quality of life for residents in each city.

Smart economy

The smart economy pillar stands as a critical determinant of the smartness and sustainability of cities, showcasing their economic dynamism, innovation, and adaptability. While Nairobi's top rank underscores its economic prowess, other cities could leverage their unique strengths to foster economic vibrancy. Besides,

Mombasa, Nakuru, and Kisumu could borrow a leaf from Nairobi. By enacting targeted policies and fostering a conducive economic environment, cities can build smart economies that drive sustainable growth, innovation, and improved quality of life for their residents.

Smart environment

The smart environment pillar serves as a crucial benchmark for evaluating a city's management of natural resources, pollution reduction, and the provision of essential services that contribute to a healthier and more sustainable urban ecosystem. Kisumu scored below average while Nairobi, Mombasa and Nakuru all performed above average. Nairobi's top ranking showcases its commitment towards attaining a smart environment. Other cities have the potential to strengthen their environmental performance.

Smart mobility

The smart mobility pillar emerges as a pivotal component in the creation of resilient, environmentally conscious, and efficient cities. Kisumu and Nairobi performed exceptionally well relative to the other cities. Consequently, Nairobi serves as the benchmark for Mombasa, Nakuru, and Kisumu in adoption of electric vehicles. Focusing on key aspects such as cycling infrastructure, car ownership management, and the promotion of electric vehicle adoption, Kenyan cities can align their efforts with global sustainability objectives. Smart mobility investments hold the promise of alleviating traffic congestion, curbing emissions, and enriching residents' quality of life, thereby contributing to the establishment of vibrant and sustainable urban landscapes.

Smart infrastructure

The smart infrastructure findings depict the evolving landscape of technology-enabled urbanization. While Nairobi's top ranking showcases its tech-driven advancements, the progress of other cities highlights the potential for smart infrastructure to uplift societies and create a more connected and prosperous future. Through strategic policy interventions and investments, cities can amplify the benefits of smart infrastructure, fostering growth, inclusivity, and a vibrant urban environment.

Smart governance

The smart governance pillar serves as a key component in the journey towards smart and sustainable urbanization. Conspicuously, the cities performed below average in this pillar, with only Nakuru scoring slightly above average. Therefore, cities need to put more effort in embracing technology to create inclusive, transparent, participatory, and responsive governance. By fostering these qualities, cities can ensure that policies and decisions align with the needs of citizens, driving progress towards a smart, inclusive, and prosperous future.

6.2 Policy Recommendations

Based on the study's findings, Kenyan cities could consider the following recommendations to accelerate their ambitions to become smart and sustainable cities.

Smart people

1. The boards of cities in collaboration with county finance and planning departments to consider long-term demographic and economic planning to anticipate future changes in dependency ratio through resource allocation and infrastructure development.
2. County governments to collaborate with Non-Governmental Organizations (NGOs) and Community-Based Organizations (CBOs) on education, technology, and community development to leverage additional resources and expertise.

Smart living

1. County governments through the departments of health to enhance accessibility of health insurance coverage to enhance access to health services.
2. Full operationalization of the Urban Areas and Cities Act, 2019 – the Boards of the cities need to establish a framework to smoothly coordinate implementation of national and county government security initiatives.

Smart economy

1. The boards of the cities need to focus on diversifying the cities' economic sectors to drive growth and increase GCP per capita. Investing in emerging sectors such as technology, renewable energy, and creative industries can enhance economic resilience and raise income levels.
2. The boards of the cities to invest in skills development and vocational training programmes that align with emerging industries to help reduce unemployment by creating a workforce with relevant and marketable skills.
3. The boards of the cities consider simplifying and digitizing business registration, licensing, and permit processes to significantly improve the ease of doing business and attract more investors.
4. Mombasa, Kisumu, and Nakuru cities to benchmark with Nairobi to develop advanced technology infrastructure and build skilled technology talent to enhance the presence of tech hubs.
5. The Ministry of Information, Communication and Digital Economy fast-track the implementation of a National Addressing System that aims to provide an integrated addressing solution to enhance the uptake and growth of e-commerce.

Smart environment

1. The boards of cities in collaboration with the Ministry of Energy and Petroleum to focus on incentivizing and adopting renewable energy sources to reduce reliance on fossil fuels.
2. The boards of cities and County Governments (departments of environment and solid waste) to prioritize and implement waste reduction and recycling programmes, alongside green building practices, to minimize environmental impact and promote a healthier urban environment.
3. Kisumu City Board in collaboration with Kenya Forest Service and development partners to fast-track the county government's commitment to plant 10 million tree seedlings by 2025 to increase its forest cover.

Smart mobility

1. The county's transport and infrastructure departments in collaboration with the Ministry of Roads and Transport prioritize investments in cycling infrastructure, promote efficient public transportation, and incentivize electric vehicle adoption.
2. The Ministry of Roads and Transport needs to consider enacting policies that reduce car dependence, enhance connectivity, and support eco-friendly modes of transportation to create vibrant, accessible, and environmentally conscious urban environments.

Smart infrastructure

1. County governments to foster collaboration between the government and private sector through public-private partnerships. These partnerships can accelerate infrastructure development and service expansion.
2. County governments in conjunction with the Ministry of Information, Communication and Digital Economy to provide incentives for private sector investments in expanding and upgrading mobile broadband (5G deployment) infrastructure in cities.
3. County governments in collaboration with the Ministry of Information, Communication and Digital Economy to consider putting incentives to encourage mobile network operators to offer affordable data plans to enhance the use of Internet across the cities' population.
4. National government to consider introducing subsidies or tax incentives to reduce the cost of smartphones for low-income individuals to bridge the affordability gap.

Smart governance

1. Boards of the cities and county governments to strengthen smart governance by leveraging on artificial intelligence and data analytics for evidence-based decision-making.

2. The Independent Electoral and Boundaries Commission to adopt e-voting where citizens can vote electronically to enhance voter turnout.
3. The Board of the cities in collaboration with citizen fora to establish data-sharing platforms that promote transparency, engage citizens, and support policy formulation and monitoring.
4. Board of the cities to acknowledge the critical role of women's representation in city governance and decision-making to comply with the two-thirds gender rule highlighted in the Constitution of Kenya, 2010. Further, there is need to implement and enforce gender-inclusive policies that ensure equitable participation and representation of women at all levels of city management.

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Appendix

Appendix I: Cronbach's Alpha

The Cronbach alpha results range between 0 and 1 in giving out the overall assessment of a measure's reliability (Appendix Table 1). Generally, the higher the Cronbach's alpha, the more intercorrelated the indicators are among themselves. For this case, the rule of thumb is that:

- Alpha values close to 0 indicate uncorrelated indicators or share no covariance.
- Alpha values close to 1 indicate highly correlated indicators.
- Negative alpha values indicate negatively correlated indictors.
- Alpha values of below 0.50 are unacceptable.

Alpha values between 0.65 and 0.80 (or higher in many cases), indicate a good coefficient (Pallant, 2020).

Appendix Table 1: Cronbach's alpha test results

Pillars	Indicators	Cronbach's Alpha	Decision
Smart People	• Education level • Access to digital devices in schools • Demographics	• Scale reliability coefficient: 0.6385 • Average interitem covariance: 0.3706 • Number of items in the scale: 3	A Cronbach's Alpha coefficient of 0.6385 suggests some level of internal consistency, but it is not very high. This indicates that the items in the scale are related to each other, thus the three indicators are considered for analysis
Smart Living	• Life expectancy • Health insurance coverage • Births attended by skilled health personnel • Housing quality • Crime rate	• Scale reliability coefficient: 0.8033 • Average interitem correlation: 0.4496 • Number of items in the scale: 5	The Cronbach's Alpha coefficient of 0.8033 suggests a good level of internal consistency among the items in the scale. This indicates that the items are measuring the same underlying construct in a reliable manner
Smart Economy	• GCP per capita • Employment rate • Ease of doing business • Tech hubs • Own source revenue gap • E-commerce	• Scale reliability coefficient: 0.9299 • Average interitem correlation: 0.7683 • Number of items in the scale: 6	The Cronbach's Alpha of 0.9299 is very high and suggests an excellent level of internal consistency among the items in the scale. This means that the items are measuring the same underlying construct reliably

Smart Environment	• Natural resources • Waste management • Access to improved water • Access to improved sanitation • Access to clean energy for cooking • Access to clean energy for lighting	• Scale reliability coefficient: 0.8719 • Average interitem covariance: 0.5314 • Number of items in the scale: 6	A Cronbach's Alpha coefficient of 0.8719 indicates high internal consistency. Thus, the indicators are measuring the smart environment pillar reliably
Smart Mobility	• Miles of bike path • Cars per capita • EV charging stations	• Scale reliability coefficient: 0.5454 • Average interitem covariance: 0.2857 • Number of items in the scale: 3	With a Cronbach's Alpha coefficient of 0.5454 falls within the range of 0.50 to 0.65. While it might not be very high, it is not "unacceptable" as per the above rule of thumb. Thus, the indicators are measuring the construct reliably
Smart Infrastructure	• Households with computers/laptops • Access to electricity • Households with mobile broadband • Mobile money subscription • Use of Internet • Smartphone ownership	• Scale reliability coefficient: 0.9804 • Average interitem covariance: 0.8929 • Number of items in the scale: 6	The Cronbach's Alpha coefficient of 0.9804, which is close to 1, suggests that the scale has a very high level of internal consistency and reliability. The items in the scale are measuring the same underlying construct consistently
Smart Governance	• Voter turnout • Women's representation in the County Assembly • Budget transparency	• Scale reliability coefficient: 0.6278 • Average interitem covariance: 0.3018 • Number of items in the scale: 3	The Cronbach's Alpha coefficient of 0.6278 is below the recommended range for good reliability. This indicates that there might be room for improvement in terms of the internal consistency of the scale

Appendix II: Principal Component Analysis

Principal Component Analysis (PCA) is a statistical technique used for dimensionality reduction and data transformation in a dataset. Its main purpose is to simplify the complexity of the data while preserving as much of the original information as possible. PCA accomplishes this by creating new variables, known as principal components, that are linear combinations of the original variables. The key outputs for the analysis include the eigenvalues, the proportion of the variance that the component explains, the coefficient and the eigenvectors. The rule of thumb is that the larger the absolute value (regardless of the direction, whether positive or negative), the more important the corresponding variable is in calculating the component. The results of PCA for each pillar are discussed below.

Smart people

The results in Appendix Table 2 show that components one and two have eigenvalues greater than 1. These two components explain 99.0 per cent of the variations in the data. The first principal component (Comp1) has a large positive relationship with demographics and a large negative relationship with digital devices. The second component has a large positive relationship with education. Therefore, all the indicators are considered for index computation.

Appendix Table 2: Principal Component Analysis - Smart people

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	1.910	0.637	Education	0.187	0.938	-0.293
Comp2	1.059	0.990	Digital devices	-0.673	0.340	0.657
Comp3	0.031	1.000	Demographics	0.716	0.074	0.694

Smart living

The results in Appendix Table 3 show that components one and two have eigenvalues greater than 1. These two components explain 89.8 per cent of the variations in the data. The first principal component has a large positive relationship with people living in modern houses and crime rate; it has a large negative relationship with health insurance coverage. The second principal component has a large positive relationship with average life expectancy and a large negative relationship with births attended by skilled health personnel. Therefore, all the indicators are suitable for index computation.

Appendix Table 3: Principal Component Analysis - Smart living

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	3.155	0.631	Average life expectancy	-0.242	0.681	0.621
Comp2	1.333	0.898	Health insurance coverage	-0.555	0.070	-0.211
Comp3	0.511	1.000	Births attended by skilled health personnel	-0.193	-0.695	0.684
Comp4	0	1.000	People living in modern houses	0.561	-0.074	-0.007
Comp5	0	1.000	Crime rate	0.531	0.209	0.319

Smart economy

Appendix Table 4 indicates that components one and two have eigenvalues greater than 1. These two components explain 97.9 per cent of the variations in the data. The first principal component has a large positive relationship with ease of doing business, tech hubs, and e-commerce. The second principal component has a large negative relationship with GCP per capita, and a large positive relationship with employment rate. The third component has a large negative relationship with own source revenue gap. Therefore, all the six indicators are fit for index computation.

Appendix Table 4: Principal Component Analysis - Smart economy

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	3.761	0.627	GCP per capita	0.371	-0.483	0.120
Comp2	2.062	0.971	Employment rate	0.027	0.690	0.299
Comp3	0.176	1.000	Ease of going business	0.501	-0.086	-0.479
Comp4	0	1.000	Tech hubs	0.495	-0.164	0.363
Comp5	0	1.000	Own source revenue gap	0.380	0.441	-0.561
Comp6	0	1.000	E-commerce	0.471	0.249	0.469

Smart environment

Appendix Table 5 indicates that components one and two have eigenvalues greater than 1. These two components explain 91.9 per cent of the variations in the data. The first principal component has a large positive relationship with waste management, access to clean water and access to clean energy for lighting. The second principal component has a large positive relationship with access to sanitation. The third component has a large negative relationship with natural resources and a large positive relationship with access to clean energy for cooking. Therefore, all the six indicators are fit for index computation.

Appendix Table 5: Principal Component Analysis - Smart environment

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	3.190	0.638	Natural resources	0.412	0.357	-0.531
Comp2	1.405	0.919	Waste management	0.455	-0.345	-0.075
Comp3	0.404	1.000	Access to improved water	0.429	-0.413	0.113

Comp4	0	1.000	Access to improved sanitation	0.160	0.663	0.590
Comp5	0	1.000	Access to clean energy for cooking	0.466	-0.155	0.516
Comp6	0	1.000	Access to clean energy for lighting	0.444	0.345	-0.292

Smart mobility

Appendix Table 6 shows that components one and two have eigenvalues greater than 1. These two components explain 97.1 per cent of the variations in the data. The first principal component (Comp1) has a large negative relationship with miles of bike path and a large positive relationship with cars per capita. The second component has a large positive relationship with EV charging stations. Therefore, all the indicators are suitable for index computation.

Appendix Table 6: Principal Component Analysis - Smart mobility

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	1.739	0.580	Miles of bike path per 100000 inhabitants	-0.669	0.399	0.627
Comp2	1.174	0.971	Cars per capita	0.728	0.184	0.660
Comp3	0.087	1.000	EV charging stations	0.148	0.898	-0.414

Smart infrastructure

The results in Appendix Table 7 indicate that component one has eigenvalues greater than 1. The first component explains 91.3 per cent of the variations in the data. The first principal component has a large positive relationship with households with mobile broadband and use of Internet. The second principal component has a large positive relationship with smartphone ownership and a large negative relationship with mobile money subscription. The third component has a large negative relationship with access to electricity and a large positive relationship with households with computer/laptop. Therefore, all the six indicators are suitable for index computation.

Appendix Table 7: Principal Component Analysis - Smart infrastructure

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	5.479	0.913	Households with computer/ laptop	0.411	-0.356	0.442
Comp2	0.407	0.981	Access to electricity	0.415	0.182	-0.625
Comp3	0.115	1.000	Households with mobile broadband	0.425	0.022	-0.311
Comp4	0	1.000	Mobile money subscription	0.407	-0.461	0.248
Comp5	0	1.000	Use of the Internet	0.426	-0.085	-0.155
Comp6	0	1.000	Smartphone ownership	0.363	0.787	0.481

Smart governance

Appendix Table 8 indicates that components one and two have eigenvalues greater than 1. These two components explain 96.9 per cent of the variations in the data. The first principal component (Comp1) has a large negative relationship with women representation in the County Assembly and a large positive relationship with budget transparency. The second component (Comp2) has a large positive relationship with voter turnout. Therefore, all the indicators are suitable for index computation.

Appendix Table 8: Principal Component Analysis - Smart governance

Principal components (Correlation)			Principal components (Eigenvectors)			
Component	Eigenvalue	Cumulative	Indicator	Comp1	Comp2	Comp3
Comp1	1.893	0.631	Voter turnout	0.010	0.992	0.129
Comp2	1.015	0.969	Women representation in County Assembly	-0.708	-0.084	0.702
Comp3	0.092	1.000	Budget transparency	0.707	-0.099	0.701

Appendix III: Dataset

Appendix Table 9: Dataset for computing SSCI for Kenya cities

Pillars	Indicators	Formulation	Nairobi	Mombasa	Nakuru	Kisumu	Source
Smart People	Education (literacy level)	Percentage of the population with some education	92.26	90.3	91.0	89.76	(KNBS, 2019)
	Number of public primary schools installed with digital devices/ total no. of public primary schools Percentage of public primary schools installed with digital devices		99.01	97.92	99.71	100.00	(MoE, 2019)
	Demographics	Dependency ratio	48.3	51	85.5	82.9	(KIBHS, 2015/2016)
Smart Living	Average life expectancy	Total person-years lived beyond the exact age 0	63.9	68.4	63.7	58.6	(KNBS, 2019)
	Health insurance coverage	Percentage of health insurance coverage	46.0	29.0	33.0	21.0	(KDHS, 2022)
	Births attended by skilled health personnel	Percentage of births attended by skilled health personnel	99.4	95.5	93.4	97.9	(KDHS, 2022)
	People living in modern houses	Percentage of the population living in modern houses (by roof type)	90.7	93.9	94.0	96.0	(KNBS, 2019)
	Crime rate	All offenses per 100, 000 population	164	214	216	218	(NPS, 2021)
Smart Economy	GCP per capita	Gross county product/total population	596467	394281	213502	206446	(KNBS, 2019)
	Employment rate	Percentage of working population aged 15 years and above	81.12	74.91	81.00	77.34	(KNBS, 2019)
	Ease of doing business	CBEM Index	37.04	30.46	29.07	32.10	(CBEM, 2022)
	Number of Tech hubs	Total number of tech hubs	40	1	2	1	(Safaricom Kenya, 2022)
	County own source of revenue gap	Revenue gap	24	24	9	15	(CORA, 2022)
	E-commerce	Percentage of population in e-commerce	7.2	1.7	4.4	4.9	(KNBS, 2019)
Smart Environment	Natural resources	Percentage of forest cover	7.78	5.12	9.29	0.44	(NEMA, 2021)
	Waste management	Percentage of households with improved waste disposal	80.35	75.9	59.25	47.55	(KNBS, 2019)
	Access to clean drinking water	Percentage of households with access to clean drinking water	98.6	52.4	72.6	71.5	(KDHS, 2022)

	Access to improved sanitation	Percentage of households with access to improved sanitation	94.3	94.7	75.1	68.8	(KDHS, 2022)
	Access to clean energy for cooking	Percentage of households using renewable energy for cooking	81.7	43.3	28.2	15.0	(KDHS, 2022)
	Access to clean energy for lighting	Percentage of households using clean energy for lighting	96.7	93.6	97.4	91.2	(KDHS, 2022)
Smart Mobility	Miles of bike path per 100000 inhabitants	Miles of the bike path/ (total population/100000)	1432.3	71.58	517.36	1958.419	(Bikemap, 2022)
	Cars per capita	Total number of cars/ total population	6.9	6.8	7.1	5.3	(KNBS, 2019)
	EV's charging stations	Percentage of charging stations (Number of charging stations/ Total number of EV charging stations in the country) *100	85.71	14.29	0	0	(Electromap, 2023)
Smart Infrastructure	Households with computer/laptop	Total households owning computers/ total population) *100	25.3	14.6	10.0	10.6	(KNBS, 2019)
	Access to electricity	Percentage of households connected to the national grid	96.5	85.9	64.4	52.6	(KNBS, 2019)
	Percentage of households with mobile broadband	(Total households with mobile broadband/total households) *100	63	56	48	45	(KNBS, 2019)
	Mobile money transaction	Percentage of households using mobile money to transact	93.9	88.6	85.9	86.5	(FinAccess Household Survey, 2022)
	Use of Internet	Percentage of population using Internet	52.4	39.2	26.8	23.9	(KNBS, 2019)
	Smartphone ownership	Percentage of household ownership of smartphones	57.20	50.79	51.92	41.93	(Kenya digital economy, 2020)
Smart Governance	Voters' turnout	Percentage of total votes cast/total registered voters) *100	55.98	44	65.5	71.4	(IEBC, 2022)
	Women representation in County Assembly	(Total women MCA's/ total wards) *100	4.7	20	14.5	17.1	(County Assembly, 2022)
	Budget transparency	County budget transparency index	56	28	44	23	(International budget partnership Kenya, 2022)

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