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Pathways to Development of Nairobi Towards Gaining a Smart City Status

Mercy Kalondu Peter and Joash Odhiambo Okeyo

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Abstract

Countries worldwide are in a race towards smart city development. Different methods are used to determine the level of smart development in guiding government on priority policy areas. In assessing smart development in Nairobi City, this study adopted the Analytic Hierarchy Process (AHP), which has 38 indicators in six dimensions, including people (7), living (10), mobility (7), economy (6), governance (4), and environment (4). From the results, Nairobi has a normal smart growth with an overall growth of 18.64 per cent. The ranking of the dimensions from the highest to the lowest was as follows: living, people, mobility, economy, governance, and environment. Among the highest ranked indicators in each dimension were as follows: installed learner digital devices in primary schools (People); percentage of households connected to fixed broadband (Mobility); number of hospital facilities per 10,000 population (Living); number of tech hubs (Economy); number of city services that are accessible via web or mobile phone (Governance); and percentage of electricity derived from renewable sources (Environment). All dimensions are very important in achieving smart growth of the city. In addition to improving on all of them, it is necessary that they are interconnected. While leveraging on the highly ranked indicators, there is need to empower human resource; fast-track the progress of the Digital Literacy Programme; improve health infrastructure; enhance digital infrastructure; embrace electric vehicles; encourage youth innovation; promote e-voting technology; and strengthen solid waste management.

Abbreviations and Acronyms

ACC	African Centre for Cities
AHP	Analytic Hierarchy Process
AUAP	Africa Urban Agenda Programme
BBC	British Broadcasting Corporation
CCTV	Closed-Circuit Television
CFI	Cities of the Future Index
CI	Consistency Interval
CIMI	Cities in Motion Ranking
CO2	Carbon Dioxide
CR	Consistency Ratio
CUE	Commission for University Education
DCI	Digital Cities Index
DLP	Digital Literacy Programme
EV	Electric Vehicles
GCI	Global Cities Index
GCP	Gross County Product
GDP	Gross Domestic Product
GPCI	Global Power City Index
ICT	Information Communication Technology
IESE	Instituto de Estudios Superiores de la Empresa
IMD-SUTD	Institute for Management Development (IMD) and the Singapore University of Technology and Design
ISO	International Organization for Standardization
IT	Information Technology
KARA	Kenya Alliance of Resident Association
KHFA	Kenya Harmonized Health Facility Assessment
KHIBS	Kenya Integrated Household Budget Survey
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KNBS	Kenya National Bureau of Statistics
KPLC	Kenya Power and Lighting Company
MCA	Member of County Assembly
MCDA	Multi-Criteria Decision Analysis
MNMD	Ministry of Nairobi Metropolitan Development
NIUPLAN	Nairobi Integrated Urban Development Master Plan
NMS	Nairobi Metropolitan Services
NTSA	National Transport and Safety Authority
NUDP	National Urban Development Policy
NO2	Nitrogen Dioxide
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
SCC	Smart City Council
SDGs	Sustainable Development Goals
SECI	Smart Eco City Index
SGL	Smart Growth Level
SPM	Suspended Particulate Matter
SO2	Sulfur Dioxide
TSC	Teachers Service Commission
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UN	United Nations
UNDESA	United Nations, Department of Economic and Social Affairs

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1. Introduction

The smart city concept has gained popularity over time across the globe, largely attributable to the growing need for quality services in cities and improved efficiency in service delivery by governments for quality life and sustainability of urban settings. Mainly, it entails the utilization of digitization to create sustainable, conducive, and inclusive cities to improve access to services by city dwellers (Lam and Yang, 2020; OECD, 2018; Sedova and Balakina, 2020; UN, 2016).

The scope of a smart city concept, however, is not limited to digitization; it also encompasses other dimensions, including the quality of services, which are categorized into six dimensions: people (education, lifelong learning, qualification level, participation in public life, open-mindedness), mobility (internet connectivity, infrastructure investments, safety in transportation, local accessibility, among others), living (public safety, health conditions, housing quality, cultural facilities, and tourist attractions, among others), environment (waste production reduction, pollution management, emission reduction, energy efficiency, water management, and natural resources), economy (entrepreneurship, productivity, innovative spirit, labour market, and employment creation), and governance (decision-making participation, social and public services, government transparency, and political strategies and perceptions) (Anthopoulos, 2015; Giffinger et al., 2007; SCC, 2012). The dimensions are applicable in modelling the smartness level of medium-sized cities to identify areas of importance for the allocation of resources by city governments. A medium-sized city has a population of between one and five million (UNDESA, 2014). Hence, Nairobi qualifies as a medium-sized city, thus the application of the six dimensions.

Digitization enables sustainable innovations to help with transport, energy, and water challenges. Smart grids for managing energy usage, smart meters for tracking water quality and leakage detection, and sensors for monitoring traffic flow and areas of the city with problems are examples of how digitization might be used (OECD, 2019). Other areas where digitization can play a part are waste disposal payment, digital tracking, remote patient monitoring, digital public transit payment, digital business licensing and permitting, local civic engagement applications for community engagement, provision of opportunity for start-ups, affordable healthcare costs, reduction in travel time, among others. Therefore, utilizing the benefits of urban digitization is crucial to fostering social progress and economic success by finding innovative ways to deliver public services using idle and surplus resources.

Nairobi city county's population was estimated to be 4.4 million in 2019, resulting in a population density of 6,247 people per square kilometre. The population increased by 40% from 2009 (3.1 million). The population increase demonstrates the need for better urban management. Urbanization in Nairobi city has drastically changed the water and sanitation needs, energy consumption patterns, and mobility, among others. Due to the change, the city faces the risk of traffic congestion, air pollution, increased insecurity, and expansion of informal settlements such as slum dwellings, among other problems. Urban areas are necessary for economic growth and prosperity, hence the need for more integrated planning, service delivery, robust financial planning, and strategic policy decisions. Therefore, the main problem hindering Nairobi's transition into a smart city is the disconnection between different infrastructure, both soft and hard systems.

Many researchers have proposed and developed the determination of a city’s smartness for various cities across the globe. However, none of the studies have modelled the smartness of Nairobi. Giffinger et al. (2007), for example, established a comprehensive way of defining cities using the six-dimensional framework. Different researchers have adopted the framework in modelling the smartness of other cities worldwide. For example, Lazaroiu and Roscia (2012) developed an index for smart cities that was applied to distribute funds in the European union 2020 strategic plan.

Different governments and independent agencies have defined the criteria for modelling smartness. For example, the ‘Arcadis Sustainable Cities Index’ 2022 focuses on three pillars planet (environment), profit (economic), and people (social). Toh (2022) defined various indices and criteria for assessing smart development level, including the ‘IMD-SUTD Smart City Index’ (I-SCI), which defines three pillars of technological, economic, and humane aspects. ‘AT Kearney Global Cities Index’ (GCI) uses five criteria, human capital, business activity, political engagement, information exchange, and cultural experience. ‘IESE Cities in Motion Ranking (CIMI)’ has social cohesion, human capital, economy, environment, governance, urban planning, mobility and transportation, technology, and international protection criteria. The ‘Cities of the Future Index (CFI)’ with four criteria, sustainability, digital life, business technology infrastructure, and mobility innovation. The ‘Global Power City Index’ (GPCI) with six criteria; cultural interaction, economy, livability, Research and Development (R&D), accessibility, and environment. ‘Smart Eco City index’ (SECI) with seven criteria: sustainability, transport and mobility, innovation economy, governance, experts’ perception, digitization, and living standard. The ‘Digital Cities Index’ (DCI) 2022 has four key pillars: digital connectivity, services, culture, and sustainability.

Despite, the different methods and indices available for determining a city's smart development level, none comprehensively captures all dimensions. Therefore, using any of the indices to assess Nairobi's level of smart development could result in limiting and inaccurate conclusions that do not account for all the dimensions. Also, the inability of the indices to consider all city dimensions will make it inappropriate to model smartness (Al-Nasrawi et al., 2015). Therefore, using the six-dimensional framework in modelling Nairobi's level of smart development will help policy makers identify the areas that need improvement and establish how the systems can be interconnected.

The study set to identify areas that need improvement to accelerate the smart development level of Nairobi using the six-dimensional framework and establish the overall index of the city. Specifically, it determined the importance level of the performance indicators across all the dimensions for smart city development and Nairobi city's smart growth level. However, the study is limited to a medium-sized city because it has applied the six-dimensional framework.

The remaining sections are organized as follows: section 2 covers policy and industry developments, section 3 is literature review, section 4 describes the methodology, section 5 is results and discussions, and section 6 covers the conclusion and policy recommendations.

2. Industry and Institutional Framework Developments

2. Industry Developments

The industry developments are assessed based on the status of all six dimensions, and considering all the 38 indicators applicable to Nairobi city, as indicated in Table 2.1. The indicators for each dimension are identified from the literature with the themes of the indicators identified in ISO 37120: 2017 as shown in Table 4.2.

Table 2.1: Status of indicators

Dimension	Indicator	Formulation	Data	Source
People (P)	Number of school age population per 100,000 population (P1)	(Number of children enrolled in both public and private schools/ (population/100,000)	13,326	(MoE, 2019)
	Number of people with complete higher education per 100,000 population (P2)	Number of people with higher education degree/ (population/100,000)	7607	(KNBS, 2019a)
	Number of higher education institutions (P3)	Number of higher education institutions	149	(CUE, 2018)
	Percentage of public primary schools installed with digital devices (P4)	(Number of public primary schools installed with digital devices/total number of primary schools) *100	99.01	(MoE, 2019)
	Number of installed Learner Digital Devices in primary schools (P5)	Number of installed Learner Digital Devices in primary schools	402	(MoE, 2019)
	Number of installed Digital Content Servers and Wireless Routers in primary schools (P6)	Number of installed Digital Content Server and Wireless Routers in primary schools	201	(MoE, 2019)
	Percentage of student enrolment in public universities (P7)	Number of students enrolled/total population	20.59	(MoE, 2019)
Economy (E)	GCP per capita (E1)	Gross County Product/ Total population	596467	(KNBS,2021)
	Companies per 100000 inhabitants (E2)	Total number of companies/ (population/100,000)	7050	(MITED, 2020)

	Unemployment rate (E3)	Rate	43	(KNBSc, 2019)
	The proportion of the population aged 15 years and above using e-commerce (E4)	(Number of people aged 15 years and above using e-commerce/ Total population) * 100	14	(KNBSb, 2019)
	Ease of doing business (E5)	World Bank index	70.31	(World Bank, 2019).
	Number of tech hubs in Nairobi (E6)	Total number of tech hubs	40	(Safaricom Kenya,2022)
Governance (G)	Percentage of voter turnout (G1)	(Total votes cast/Total registered voters) *100	55.96	(IEBC, 2022)
	Percentage of women MCAs (G2)	(Total women MCAs/ Total Wards) * 100	4.7	(Nairobi County Assembly, 2022)
	County budget transparency index (G3)	The county budget transparency index	56	(International Budget Partnership Kenya, 2022)
	Number of city services that are accessible via web or mobile phone (G4)	Total number of city services that can be accessed online	Over 200	(KARA, 2022)
Environment (E)	Total collected city solid waste per capita (in Kg) (N1)	Total collected solid waste (Kilogrammes)/ Total population	0.55	(Nairobi city County, 2022)
	Percentage of recycled waste (N2)	Total recycled waste (tons)/ Total waste produced) * 100	45	(World Bank, 2021)
	Percentage of the population with access to clean drinking water (N3)	(Number of people with access to clean drinking water/ total population) * 100	50	(BBC, 2019)
	Percentage of electricity derived from renewable sources (N4)	(Electricity from renewable sources / total electricity) * 100	92.3	(KNBS, 2022)
Living (L)	Average life expectancy at birth (L1)	total person-years lived beyond the exact age 0/ number of newborns/100,000).	57	(KIPPRA, 2015)
	Percentage of homicides (L2)	(Total number of homicide cases reported/ total crime) * 100	7.87	(National Crime Research Centre, 2018)
	Percentage of the population living in slums (L3)	(Number of slum dwellers/ total population) * 100	36	(KNBSc, 2019)
	Demographic density(L4)	Population per unit area	6247	(KNBSc, 2019)

	Poverty rate (L5)	Multidimensional poverty	16.7	(KNBS, 2020)
	Percentage of the City budget allocated to culture (L6)	(Total budget allocated to culture/ Total County budget) * 100	0.075	(Nairobi city County, 2021)
	Health workforce density per 10,000 population (L7)	Total health workforce/ (total population/10000)	26.3	(Division of Health Sector Monitoring and Evaluation, 2018)
	Health Services Infrastructure Index (L8)	Kenya Harmonized Health Facility Assessment (KHFA)	99	(Division of Health Sector Monitoring and Evaluation, 2018)
	Total number of hospital facilities per 10,000 population (L9)	Total number of hospital facilities/ (total population/10000)	1.6	(Division of Health Sector Monitoring and Evaluation, 2018)
	Number of inpatient beds per 10,000 population (L10)	Total number of inpatient beds/ (total population/10000)	15.4	(Division of Health Sector Monitoring and Evaluation, 2018)
Mobility (M)	Bike path miles per 100,000 inhabitants (M1)	Miles of the bike path/ (total population/100000)	1432.3	(Bikemap, 2022)
	Cars per capita (M2)	Total number of cars/ total population	0.069	(KNBSc, 2019)
	Total transport deaths per 100,000 population (M3)	Total transport deaths/ (total population/100000)	9.85	(NTSA, 2019)
	Percentage of households with computer/laptop/ tablet (M4)	(Total households owning computers/ total population) * 100	22.7	(KNBSb, 2019)
	Percentage of households connected to fixed broadband (M5)	(Total households with fixed broadband/ total households) * 100	13.6	(KNBSb, 2019)
	Number of Electric Vehicles (EV) charging stations (M6)	Total number of EV charging stations	4	(KenGen, 2022)
	Percentage of households connected to mobile broadband (M7)	(Total households with mobile broadband/ total households) * 100	38.5	(KNBSb, 2019)

Source: Author's own compilation

2.2 Development of Institutional Frameworks

The eleventh 'Sustainable Development Goal' (SDG) on "sustainable cities and communities" aims to make cities and human settlements safe, sustainable, inclusive, and resilient, and boost the momentum for smart cities development across the globe. Some of the targets of the goal are to promote safe and affordable housing, sustainable and affordable transport systems, protection of the world's natural and cultural heritage, resource efficiency, and disaster risk reduction, among others (UN, 2022). The goal can be achieved by ensuring that the systems are interconnected.

The Africa Agenda 2063, with the goal of "modern and liveable habitats", aimed at modernizing human settlements, envisions that by 2035, all African cities will be certified as sustainable and smart. Additionally, those with a population of above 2 million will eradicate slums and put a mass rapid transit system in place. The African Centre for Cities (ACC) is at the forefront of urging African governments to adopt the smart city concept to achieve vibrant, sustainable, and just cities (ACC, 2022). Also, the Africa Urban Agenda Programme seeks to improve urbanization as a necessary aspect of African economic development (AUAP, 2022). Various cities in Africa have implemented smart city initiatives toward realizing the agenda. For instance, Cape Town has leveraged real-time data to improve emergency response, law enforcement, and disaster risk management. Also, the city promotes digital inclusion through free wi-fi enabled city buses and remote reading of utility metres, which has helped to reduce water wastage and increase efficiency in energy consumption.

In Kenya, various policy documents have been developed to transform cities and urban areas into modern and world-class regions to achieve the Kenya Vision 2030, which advocates for sustainable urbanization through an integrated regional and urban planning management framework of Kenyan towns (Government of Kenya, 2007). The plans are the 'National Urban Development Policy (NUDP) of 2016, and the Kenya National Digital Master Plan 2022/2023, which have envisioned secure, sustainable, and well-governed urban areas that also contribute to economic development. Another digitalization strategy is the Kenya Digital Economy Blueprint 2019, which envisions a country where the citizenry is digitally empowered and lives in a digitally enabled society. Also, the country has developed the National Broadband Strategy 2018-2023 to transform the country into a competitive and knowledge-based society enabled by fast, secure, affordable broadband connectivity. These national plans collectively aim to make Kenya's cities and urban areas sustainable through improved management and ICT adoption to enhance service quality and efficiency. However, there is no specific policy in place that outlines the development of Kenyan towns and cities into smart cities.

Different policies have been developed and adopted to transform Nairobi into a world-class modern city. The plans and policies include the Nairobi Metro 2030 strategy of December 2008, whose aim is to transform the city into a world-class and modern African Metropolis by 2030 by building a prosperous, secure, and safe metropolitan (Ministry of Nairobi Metropolitan Development - MNMD, 2008). The second plan is the Nairobi Integrated Urban Development Master Plan - NIUPLAN of 2013, which provided a regulatory framework to realize Nairobi's urban development and operationalize the objectives of the Nairobi Metro 2030 strategy (NCC, 2014). In addition, the ICT transformation roadmap of September 2013 seeks to recognize the role of ICTs in developing cities and towns (NCC, 2018). In general, the plans are aimed at developing, by extension, Kenyan cities into world-class, smart, and modern through fast dissemination of ICT infrastructure and their application in innovations.

3. Literature Review

3.1 Theoretical Literature Review

Modernization theory

Modernization theory became prominent in the 1950s and 1960s. It helps to understand social-economic development issues to create policies that would help poorer countries' social and economic transition. The theory claims urbanization results from introducing new things through societal innovations, information penetration, cultural diffusion, and technology application (Smith, 1996). The world's current development and urbanization are inextricably linked to its original state at the dawn of modernization (Kasarda and Crenshaw, 1991). Several technologically driven developments are products of societies that can boost or increase economic potential, provide surplus food due to improved agricultural systems, and use electronic tools and mechanization to reduce the workload on human labour while increasing speed and efficiency (Lenski and Nolan, 1984; Nolan and Lenski, 1985). However, the theory faces criticism in that it ignores external sources that cause a change in societies. In developing a smart city, the theory is important as it begins with installing electrical systems, layers of advanced telecommunications, mobility systems, and smart buildings as essential foundations for city development.

Systems theory

Systems theory originated in the 1940s, defining systems that are approaching equilibrium. Regarding the smart city, a particular system, energy, transportation, and buildings can be seen as the system (Lom and Pribyl, 2021). The Internet or information relations connect systems in smart cities, and information management is increasingly important. Furthermore, the cyber-physical systems are an area of the systems theory in which the software and hardware worlds are interconnected and operate seamlessly without human interruption; data from the various hardware is sent to the software, where it is analyzed, decoded, and executed.

Smart city theory

The theory proposes a "12345" model for urban renewal, which involves developing a customized proposal for the citizens and the city. It entails setting up a single city management system, two auxiliary safety precautions, three platforms for information infrastructure, four different types of urban management, and five application service systems (Mao et al., 2016). Therefore, the model helps solve the city's problems and promotes all-around city development and access to sustainable development. Due to increased urbanization, the theory is aimed at solving problems in large and medium-sized cities.

Smart growth theory

Zhang (2017) asserts that the smart growth theory is crucial for urban development as it advocates for healthy, people-oriented, and harmonious development. According to Shrivastava and Sharma (2011), smart growth is an urban-generated transportation and planning theory that encourages growth in the city's centre to reduce urban sprawl. The theory also creates transit-oriented, compact, bicycle-friendly land use and walkable city. It also includes complete streets, neighbourhood schools, different housing options, and mixed-use developments. In general, smart growth invests attention, time, and resources in the community, giving cities and older deteriorated areas new life. According to Shen (2017), encouraging smart growth is crucial in transforming a city into a smart and sustainable city.

3.2 Empirical Literature Review

3.2.1 The six-dimensional framework

Giffinger et al. (2007) developed a six-dimensional framework for evaluating medium-sized cities. The dimensions they introduced included people, living, governance, mobility, environment, and economy. The indicators of people are lifelong enthusiasm to learn, open-mindedness, creativity, flexibility in adapting to environmental changes, and participation in public life (Arroub, 2016). Mobility entails different actions meant to improve environmental sustainability and efficiency in cities by incorporating big data that enables the users to have real-time traffic information while the city officials can use the data to improve how the cities are managed and governed (Benevolo et al., 2016; Pinna et al., 2017). Mobility initiatives reduce traffic jams, road carnages, and commuting times and allow road users to modify their journeys (Biyik et al., 2021). Living focuses on inclusive society, social equality and equity, high quality of life, affordable housing, safety, affordable and accessible education and health facilities, and civic and cultural activities, including freedom of speech and citizen participation (Bedi, 2020; Govada et al., 2020). Citizen adoption is an important factor in achieving sustainable smart living, involving intelligence, government role, and cognitive entity (Han and Kim, 2021).

Innovation is a key driver in the economy dimension as it provides an environment to cultivate the entrepreneurial attitude of people within a society (Gupta et al., 2017). The economy dimension facilitates the emergence of new economic sectors that are ICT linked and promoting the growth of existing economic sectors such as information and communication technologies (ICTs), finance, culture, and services. The economy dimension enables the increase of attractiveness of current economic sectors, including finance, ICTs, culture and service, and the occurrence of new economic sectors that are ICT-related (Hollands, 2008; Kazanci, 2022). The economy dimension is composed of mobile commerce, which supports retailers to attract the attention of customers due to improved service delivery (Keegan et al., 2012; Kirimtat et al., 2020).

The environment dimension involves the implementation of smart resource management to create an open space where people, biodiversity, and natural ecology can exist together to provide an exciting environment where people can spend leisure, live, and work (Bhatt et al., 2020; Govada et al., 2020). The urban environment sustainability is analyzed using two ways: energy and prevention of consumption, which includes; green buildings, efficiency, control of pollution and management, technological grids, and renewable energy; the other way is through the management of resources and has a link to the urban grid such as waste management, street lighting, drainage systems, improving the quality of water and management of water resources (Manville et al. 2014; Aletà et al., 2017).

The governance dimension involves the advanced use of ICT to enable people to retrieve information, apply for services, download forms and applications and receive the final products and services through remote-controlled devices and smartphones (Yaghi and Al-Jenaibi, 2017). In addition, ICT is used to improve decision-making through better partnerships among various stakeholders, reflecting public service policies (Pereira et al., 2018; Ryu et al., 2022).

3.2.2 Modelling cities' smart development level

People dimension

Antwi-Afari et al. (2021) used the fuzzy logic procedure to model the smartness of Kumasi city. The indicators considered in the study were good training institutions and schools, level of creativity, dedication to education and willingness to learn, ability to manipulate and use data, usage of computers and understanding, writing and reading skills, good reporting, soft skills availability, and language skills. Good training institutions and schools was the highest-ranked indicator. The study concluded that the people dimension in an urban setting is the most important among all the dimensions.

Nam and Pardo (2011) recognized creativity as an important driver in a smart city, indicating that learning, education, knowledge, and people are the core of a smart city. The people dimension comprises affinity to lifelong learning, open-mindedness, flexibility, creativity, cosmopolitanism, participation in public life, and ethnic and social plurality. The study concluded that social factors (people) apart from smart technologies are necessary for smart cities.

Zhang et al. (2019) used the 'fuzzy Analytic Hierarchy Process' (AHP) to weigh different smart cities in China. The indicators used were per capita (green park area and residential area), social security, employment, popularity rate of mobile phones, medical resources, speed of the urban network, information disclosure, public transport service, equity citizenship quality, and intellectual property protection. The study found that medical resources and social security indicators have the highest demand compared to all other individual indicators.

Hajduk (2021) used the multiple criteria analysis to assess polish cities, focusing on the 'Technique for Order of Preference by Similarity to Ideal Solution' (TOPSIS). The people dimension also referred to as the social capital, had a net enrolment rate (middle schools), graduates of universities, the number of inhabitants per square kilometre, and library outlets as the indicators where net enrolment was highly ranked across all the cities.

Mobility dimension

Ameen and Mourshed (2019) used the AHP method to conduct an urban sustainability assessment. The study's "transportation and infrastructure" indicators were among the top three. They concluded that practising transport sustainably enables identification and a detailed understanding of system bottlenecks, and thus helps in developing plans useful in informing and improving decision-making when transport solutions are being implemented. More focus needs to be given to public transport use promotion and diversification of transportation modes.

Antwi-Afari et al. (2021) used the fuzzy logic procedure to model Kumasi city's smartness. The study included the mobility dimension with the following selected indicators: strategies promoting high-speed mobility, integrated mobility, linking areas together (residential to recreational, to workplaces, to transport notes (railway stations, bus, and airports), improved cycling or walkability, seamless mobility for differently-abled people, reduced or no traffic thronging and mass rapid transit system (internationally and locally accessible), road accidents reduction and sustainable transport systems for goods and people. The highly ranked indicator was strategies promoting high-speed mobility, which would make the city sustainable towards becoming smart.

Living dimension

Bruni et al. (2017) developed a smartness audit for assessing a city's smartness through important indicators in medium and small-size cities. The study was applied in three municipalities in northern Italy. The indicators considered were classified into health, fire and emergency response, safety, recreation, innovation, shelter, and telecommunication. The results indicated that health was the most important aspect for the city's inhabitants.

Zou et al. (2022) used the AHP method to analyze Kitakyushu city in Japan. The study used the Analytical Hierarchy Process to weigh different indicators. The indicators considered were the number of hospitals per 1000 population, number of doctors per 1000 population, number of environmental staff per 100,000 population, adult literacy rate, percentage of vehicles with an emission control system, and percentage of industries with emission control systems. The highly weighted indicators were the number of doctors per 1000 population, and the adult literacy rate.

Lotfi and Solaimani (2009) assessed the quality of urban life using the AHP in Northern Iran. The study considered objective indicators (unemployment rate, number of hospitals, green urban spaces, and volume of crime) and subjective indicators (access to health care, green spaces access, jobs access, and urban security). Specifically, the indicators considered include sanitation, green space access, system progress, housing cost, employment rate, crime rate, sports facilities, cultural facilities, educational facilities, health facilities, rate of public transport, quality of the building, and urban political facilities. The study concluded that the indicator with the lowest weighting is where the local planners and authorities can direct more resources as all the indicators are important.

Economy dimension

Zou et al. (2022) applied the AHP to assess smart city development in Japan. Gross city product per capita, Research and Development (R&D) expenditure, use of electricity per GDP, percentage of local government funds allocated for the environment, water use per GDP, and households below the poverty line were among the indicators considered in this dimension. R&D expenditure and use of electricity per GDP were ranked as the most important indicators. At the same time, the household below the poverty line was the indicator with the lowest weight.

Hsu et al. (2021) formulated an index to measure the smartness of Jiangsu city in China. The study used the fuzzy AHP method, and the economy dimension had the highest weight. The study concluded that an improved economy indicates that the city's level of smartness is high. The indicators considered included expenditures on science and technology, GDP per capita, and technological innovation state, with GDP per capita as the highly ranked indicator.

Antwi-Afari et al. (2021) used the fuzzy logic procedure to model the smartness of Kumasi city. The indicators considered for the economy dimension were: innovative ability and the spirit of entrepreneurship, labour market flexibility and high productivity, transformative ability to international market, foreign and domestic direct investment, the transformation from an urban economy to a smart economy, tourism, and high standard of living. The highly ranked indicator was the innovative ability and the spirit of entrepreneurship.

Environment dimension

Hsu et al. (2021) developed an index to evaluate Jiangsu city's smartness level using the AHP. In the environment dimension, the indicators considered were the percentage of treated urban refuse, domestic refuse treatment rate, green area coverage, and the total amount of urban domestic refuse generated. The green coverage in built-up areas was the most important indicator reflecting the environmental protection state of a city.

Joel et al. (2019) used the AHP to identify the most appropriate strategy for solid waste management in Yaoundé (Cameroon). The indicators considered were polluter pays principle, sustainable development, eco-friendly products use, reuse of waste materials, waste treatment technology, and waste service quality. The study concluded that waste service quality and sustainable development are the focus areas for achieving a smart environment.

Ozkaya and Erdin (2020) assessed forty-four smart and sustainable cities using the AHP and TOPSIS techniques. From the results, London, Tokyo, and New York were in the top three in the overall ranking. But none of these cities was among the top five in the environment dimension. The indicators considered were sunshine hours annually, natural conditions attractivity, the share of public green space, pollution index, environmental performance index, water use per GDP, water use efficiency, environment index, sustainable resource management, renewable energy rate, commitment to climate action, CO_2 emissions, waste recycle rate,

NO_2 and SO_2 density, and SPM density. The public green urban space share was highly weighted across the countries.

Milutinović et al. (2014) used the AHP to assess different sustainability scenarios of waste treatment in Niš. The scenarios considered were landfilling waste, recourses preservation, energy recovery, organic waste composting using anaerobic digestion, inorganic waste recycling, and waste incineration. The study concluded that the best sustainable waste management scenario includes energy recovery through organic waste composting and inorganic waste recycling.

Maharika et al. (2021) assessed the smartness of Kampung city using the AHP to understand Kampung's smart environment residents' preferences. Different criteria were used, which include availability of green space, macro-climate information, natural energy utilization, waste management, water quality, air quality, nature protection efforts, soil quality, disaster management information, sharing disaster management information, water efficiency, electricity efficiency, energy conservation, rainwater management, drinking water quality, drinking water supply, and well water quality. The highly weighted indicators were water quality and natural energy utilization.

Governance dimension

Sultan et al. (2012) used the AHP to determine the most important project that can be implemented for successful e-government projects in developing countries. The indicators considered were e-administration, e-service, and e-mail. The study concluded that the decision-maker should focus on the ICT skill base compared to culture, leadership, and technology, which were sub-indicators of the study for e-government success.

Hassan and Lee (2015) developed a framework that can help determine the most important indicators to help policy makers in Pakistan. The indicators used were legal and regulatory framework, ICT policies, top management support, managerial strategy and collaboration, region, structure, and autonomy, telecom technology, portal technology, security and privacy, funding, expertise and training, education and skills, digital divide, and trust, income, cost, and benefits. The study concluded that managerial strategy, political stability, ICT policies, and funding are the most important factors that affect the e-Government success in Pakistan.

Feng (2016) constructed a smart city evaluation index to assess China's development level using the AHP method. It considered six factors: economy, population, environment, governance, mobility, and living. For the governance dimension, the indicators considered were information disclosure index, rate of the emergency system, social security penetration, building digital energy saving rate, natural disaster warning release, and environmental quality automation monitoring rate. The study concluded that developing a smart city is a systematic process that requires the combination of the city's subsystems. Also, the city should include soft and hard systems and develop new ways of applying smart city projects.

Zou et al. (2022) assessed the smart-level development for the Kitakyushu of Japan using the AHP method. The indicators considered for the governance dimension included the fight against corruption, bureaucracy transparency, civil participation, monitoring of environmental performance, female city representatives per (1000) residents, city representatives per resident, and environmental decision-making public participation. Bureaucracy transparency emerged as the most important indicator, with female city representatives per (1000) residents being the least important.

3.3 Overview

The literature outlines various theories and empirical literature that explain the emergence of smart cities. The theories explored include modernization theory, which explains the emergence of new things through innovation in a city and technology use in a smart city. Secondly, the systems theory forms the basis for the composition of a city; that is, different sub-systems within a city are interconnected to form the major system (smart city). The third concept is the smart city theory, which proposes a model of urban renewal by explaining the application of ICT to improve existing problems and help decision-making within a city. Finally, the smart growth theory advocates for healthy, people-oriented, and harmonious development and proposes a model for urban renewal. The smart growth theory also explains an urban-generated transportation and planning theory that informs growth within the city to reduce urban sprawl.

Giffinger et al. (2007) introduced six dimensions: people, governance, environment, living, mobility, and economy, which are applicable in assessing the smart development level of a medium-sized city. Different authors measure different indicators in each dimension to assess the smartness level of a city. The differences are attributed to the geographical location of a city by choosing only indicators that apply to the city. On the people dimension, Antwi-Afari et al. (2021) found that good institutions and schools was the most important indicator. The "transport and infrastructure" indicator was among the top three under mobility (Ameen and Mourshed, 2019). On the living dimension, "the adult literacy rate" and "the number of doctors per 1000 population" were the highly ranked indicators

(Zou et al., 2022). Antwi-Afari et al. (2021) highly ranked innovative ability and the spirit of entrepreneurship under the economy dimension. Joel et al. (2019) identified waste service quality and sustainable development as the focus areas to achieve a smart environment. Bureaucracy transparency was the most important indicator under smart governance, while female city representatives per 1000 residents was the least important (Zou et al., 2022).

The present study focuses on Nairobi city as no study has been able to establish the smart development level of Nairobi and identify the most important indicators to accelerate towards smartness. The study has considered 38 indicators with people (7), living (10), economy (6), governance (4), environment (4), and mobility (7). It uses the AHP method to establish each indicator's importance level to help city planners in decision-making by identifying the indicators with the highest weight in terms of their relevance. All the indicators are important to achieve smartness and sustainability; only the importance level matter. The overall smartness level is established, and the Smart Growth Level (SGL) of Nairobi is determined by a scale used by Min et al. (2018) in determining the SGL of cities in China. The scale has four grades; terrible - the development model has threatened and limited further city development; the normal - the city is yet to realize smart growth; good - some smart growth success in the city; and outstanding - great smart growth success in the city.

4. Methodology

4.1 Theoretical Framework

The systems theory best explains the smart city concept. The theory is applicable in problem-solving in real-world situations, which are divided into both soft and hard systems. In the smart city, hard and soft systems are applicable for operation and efficiency. The hard systems encompass the buildings where ICT devices are housed; that is, sensors which are soft systems, are installed to allow for data collection. Therefore, the different systems in a smart city are engaged in a complex relationship with interaction and integration at the core of providing enhanced service delivery.

In smart cities, therefore, systems interconnected by information relations or energy and information management are increasingly important. Cyber-physical systems are of major focus in systems theory, where soft and hard systems are interconnected. Data from hardware are sent to the software, where they are analyzed, and the city officials can identify areas with problems. Thus, the sub-systems are the components of the smart city that are then connected to make the larger system (smart city).

In addition, the smart growth theory supports the study in evaluating the development level of Nairobi's city towards becoming a smart city. The theory is important in urban development as it advocates for healthy, people-oriented, and harmonious development. Smart growth encourages growth in the city's centre to reduce urban sprawl. The theory also creates transit-oriented, compact, bicycle-friendly land use and walkable city. It also includes complete streets, neighbourhood schools, different housing options, and mixed-use developments. In general, smart growth invests attention, time, and resources in the community, giving cities and older deteriorated areas new life.

4.2 Analytical Framework

The study uses Multiple Criteria Decision Analysis (MCDA) with a focus on the AHP. MCDA is a valuable tool applicable in complex decision-making in urban planning, transport planning, energy demand forecasting, and economic development planning, among many others (Ameen and Mourshed, 2019; Saaty, 1990). It helps solve problems characterized as a choice among alternatives by focusing on what is important, consistent, and logical.

4.2.1 Introduction of the AHP

The AHP is used for complex problem solving and is organized in a hierarchical structure with the goal at the top, criteria (sub-criteria) at the second level, and alternatives at the third level. The method's application can be broken down into four steps.

1. The development of a hierarchical problem model, with the goal at the top, criteria (sub-criteria) at the second level, and alternatives at the third level.
2. At the third level of the hierarchy, a pairwise comparison of alternatives is performed, with the Saaty scale of relative importance used to assign weights.
3. The relative importance of all the alternatives is assessed using linear algebra to calculate the weights for each alternative from the pairwise comparison matrix. Also, the weights for each dimension are calculated where in this study, the dimensions are the criteria. Finally, the overall development (goal), which indicates the smartness level is calculated.
4. The consistency test of the pairwise comparison matrix is then done to determine how consistent the comparisons are.

4.2.2 Mathematical model of the AHP

If the matrix compares n elements, the comparison results create a matrix of form B with dimensions *nxm*.

$$B = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nm} \end{bmatrix} \quad 4.1$$

The ratio between the compared criteria of the matrix is expressed as:

$$b_{ij} = w_i/w_j, \quad 4.2$$

for *i* the row element and *j* the column element.

The matrix elements are calculated to obtain the normalized matrix (C).

$$C_{ij} = b_{ij}/(\sum(i=1)nb_{ij}) \quad 4.3$$

4.2.3 Consistency test of the pairwise comparison matrix

A quantifiable measure for comparison matrix B is developed to determine the consistency of the pairwise comparison matrix.

a) Eigenvector calculation (the n^{th} root of the $\overline{m}$ of the pairwise comparison matrix)

$$\overline{\omega} = \sqrt[n]{\prod_j^n I_{aij}} \quad i = 1,2, \ldots, n \qquad 4.4$$

b) Normalized weights

Get $\overline{w} = Y[(\overline{w})1, (\overline{w})2, \ldots, (\overline{w})n]^T$ normalize $\overline{\omega}$, calculate:

$$\sum_{j=1}^{n}((\overline{w})_j) = j = 1,2, \ldots, n \qquad 4.5$$

Hence, $Y_{\overline{\omega}} = Y_{\omega 1, \omega 2, \ldots\ldots, \omega n}\ Y^T$, which is the feature vector's approximate value.

c) Computing λmax which is the maximum eigenvalue

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(B\overline{w})_i}{n\overline{\omega}_i} \qquad 4.6$$

d) Calculating the Consistency Index (CI)

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad 4.7$$

e) Consistency test

$$C.R = {}^{C.I}/_{R.I} \qquad 4.8$$

The smaller the C.I value (close to zero), the better the consistency of the pairwise comparison matrix. The consistent error and the C.I value requirements are different for different pairwise matrices. The average Random Consistency (R.I) is also introduced to help in calculating the satisfactory consistency with values as shown in Table 4.1.

Table 4.1: Standard R.I table

Order	2	3	4	5	6	7	8	9	10
R. I	0	0.52	0.89	1.12	1.26	1.36	1.41	1.45	1.49

Source: Chiroli et al. (2022)

From the calculation, the relative weight of the matrix is determined, and the priority ranking of the indicators is done based on the weight. The consistency level of each pairwise comparison matrix is determined, with the acceptable level defined as the one where 0.1<CR<0.2, depending on the size of the matrix (Subramanian and Ramanathan, 2019).

4.3 Indicators Criteria and Themes Definition

The European Smart Cities 4.0 (2015) model is used to define the criteria (mobility, people, living, economy, governance, and environment). The criteria were developed using the European model, with the themes of the indicators identified in ISO 37120: 2017. Table 4.2 provides a summary of the criteria considered.

Table 4.2: ISO 37120: 2017 criteria and themes

Dimension	Criteria	Sub-criteria
Governance	Government Social public services	Transparency in government Social and public service
Environment	Water and energy Environment	Protection of the environment Natural conditions attractiveness Natural resource management
Living	Quality of housing Health Public safety	Public safety Health conditions Cultural facilities Housing quality Tourist attractions Social cohesion
People	Public life participation Education	Diversity Level of qualification Public life participation
Mobility	Innovation	ICT infrastructure Accessibility Sustainability Innovation Transportation safety

Economy	Economy	Productivity Entrepreneurship Labour market Innovative spirit

Source: Chiroli et al. (2022)

4.4 Indicators for Nairobi city

A total of 38 indicators, as shown in Table 2.1, are used to determine Nairobi's smartness level. The people dimension (7), living dimension (10), mobility (7), economy (6), environment (4), and governance (4). The choice of dimensions is supported by Giffinger et al. (2007), as they defined the dimensions to be applied when assessing the smart development level of a medium size city.

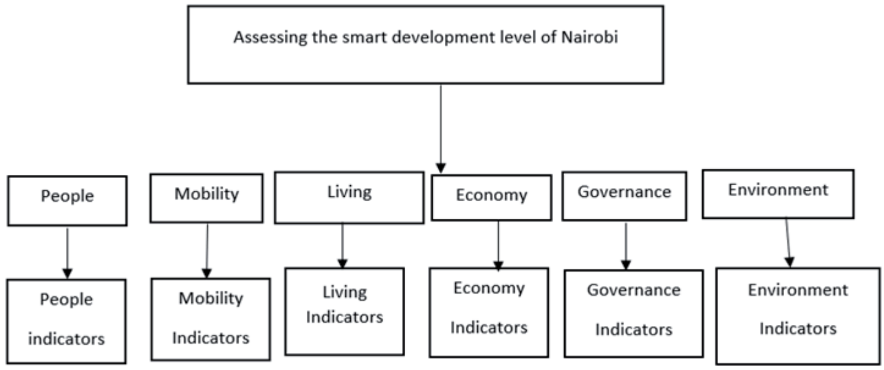
4.5 Index Weight Calculation

The weights of the evaluation index are calculated using the AHP method. In the first step, a hierarchical structure is constructed, and then scores as defined by Saaty are used to construct the pairwise comparison matrix where the weights for each indicator are calculated. Consistency is checked for each matrix. The weights for each dimension are then calculated and the overall weight. Finally, rankings are done based on the weights to determine the highest and least ranked in terms of relative importance.

4.5. Developing the hierarchical structure

A hierarchical structure is required in problem solving because it helps to determine the effectiveness of the analysis results. It also gives a graphical picture of the goal, sub-criteria and alternatives. Therefore, the hierarchical structure is in Figure 4.2.

Figure 4.1: Hierarchical structure



Source: Own creation

4.5.2 Creating a pairwise comparison matrix

Each smart city component is used to construct the matrix. Scoring of the indicators is done based on the relative importance of each city component indicator. The relative importance is determined using a rating scale in which two indicators are compared and assigned specific values. In defining the alternatives (indicators) weights, an importance scale of 1 to 5 is used, as indicated in Table 4.3.

Table 4.3: Scale of relative importance

Score	Level of Importance	Description
1	Equal importance	The two indicators have equal importance
2	Small importance	The first indicator is a little bit more important than the second indicator
3	Medium importance	The first indicator is medially important than the second indicator
4	Strong importance	The first indicator is strongly more important than the second indicator
5	Extreme importance	The first indicator is extremely more important than the second indicator
Inverse comparison		
½	Small less importance	The first indicator is a little bit less important than the second indicator

1/3	Medium less importance	The first indicator is medially less important than the second indicator
¼	Strong less importance	The first indicator is strongly less important than the second indicator
1/5	Extreme less importance	The first indicator is extremely less important than the second indicator

Source: Source: Saaty (1990) and Chiroli et al. (2022)

4.6 Determining the Weighting for Each Dimension

The weighting for each dimension is obtained by taking the mean of each pairwise comparison matrix. The total mean is calculated by adding the mean for each dimension from the pairwise comparison matrix. The weighting is then calculated by dividing each dimension's mean by the total mean for all the dimensions.

$$\text{Dimension weight} = M_i/(\sum M_i) \qquad 4.9$$

Where, M_i= mean of each dimension and $\sum M_i$= Sum of each dimension mean.

4.7 Determining the Smart Growth Level

To determine the overall smart development level for Nairobi, the average weightings of all the dimensions are calculated. It is obtained by multiplying each dimension weighting by the total number of indicators for each dimension. The sum is then divided by the total of all the indicators (38).

$$\text{Overall weighting} = \sum M_i/\sum M_i * N_i/N_i \qquad 4.10$$

where $M_i/\sum M_i$ is the weighting for each dimension, N_i is the number of indicators for the specific dimension, and $\sum N_i$ is the total number of indicators.

The Smart Growth Level (SGL) of Nairobi is determined by a scale used by Min et al. (2018) to determine the SGL of cities in China. The scale has four grades: terrible, normal, good and outstanding. Therefore, the standard SGL is detailed in Table 4.4.

Table 4.4: The standard growth level

The standard of Smart Growth Level Grade	Description	Smart Growth Level
Terrible	The development model has threatened and limited further city development	0 - 0.175
Normal	The city is yet to realize smart growth	0.175 - 0.252
Good	Some smart growth success in the city	0.252 - 0.435
Outstanding	Great smart growth success in the city	0.435 - 1

Source: Min et al. (2018)

5. Results and Discussion

5.1 Importance Level of the Performance Indicators

Table 5.1: People dimension

People (P)	P1	P2	P3	P4	P5	P6	P7
P1	1	0.33	0.33	0.25	0.25	0.25	1
P2	3	1	1	0.33	0.33	0.33	1
P3	3	1	1	0.33	0.33	0.33	1
P4	4	3	3	1	1	1	0.33
P5	4	3	3	1	1	1	4
P6	4	3	3	1	1	1	3
P7	1	1	1	3	0.25	0.33	1
Weights (%)	4.96	8.65	8.65	19.10	23.72	22.46	12.46
Rankings	6	5	5	3	1	2	4

Source: Own computation

According to Table 5.1, there are seven indicators, so the RI = 1.36, λ_max = 7.820563, C.I = 0.136761, and C.R = 0.100559<0.15, which demonstrates that the pairwise comparison matrix is consistent.

In the people dimension, "installed learner digital devices in primary schools (P5)" and "installed digital content server and wireless routers in primary schools (P6)" indicators are ranked the highest. This is attributable to the initiation of the Digital Literacy Programme (DLP) by the Ministry of ICT, Innovation, and Youth Affairs in 2016, which was aimed at distributing digital devices to public primary schools and training teachers in the delivery of digital learning content. Other components of DLP include creating content for the learners and electrification of schools in collaboration with the Kenya Power and Lighting Company (KPLC). The least ranked indicator is the "school-age population" (P1). This could be attributed to the overall notion that what matters most is the number of those with completed education or literacy level. The people dimension in an urban setting is the most important among all the dimensions (Antwi-Afari et al., 2021). Therefore, policies of smart city development should focus more on the people dimension. Smart cities should be people-centric; industries and governments should design people-centric service intelligence to ensure improved quality of life, sustainability, and better development (Xu and Geng, 2019).

Table 5.2: Mobility dimension

Mobility (M)	M1	M2	M3	M4	M5	M6	M7
M1	1	3	2	0.5	1	0.25	1
M2	0.33	1	2	0.33	0.25	1	0.33
M3	0.5	0.5	1	0.5	0.25	0.5	0.25
M4	2	3	2	1	1	2	1
M5	1	4	4	1	1	4	1
M6	4	1	2	0.5	0.25	1	0.25
M7	1	3	4	1	1	4	1
Weights (%)	13.62	6.91	5.56	18.52	21.91	12.51	20.98
Rankings	4	6	7	3	1	5	2

Source: Own computation

According to Table 5.2, there are seven indicators, so the RI = 1.36, λ_ max=7.851091407, C.I=0.141848568, and C.R=0.104300418<0.15, which demonstrates that the pairwise comparison matrix is consistent.

The percentage of households connected to fixed broadband (M5) ranked the highest at 21.91 per cent, followed by the percentage of households connected to mobile broadband (M7) at 20.98 per cent. The high ranking of these indicators could be partly ascribed to various national broadband strategies by the government. For instance, the National Broadband Strategy 2018-2023 aims at transforming Kenya into a knowledge-based competitive society facilitated by fast, secure and affordable broadband connectivity. The high ranking implies that these two indicators are the most important in implementing smart city initiatives. It is strongly supported by the theory and application of smart city initiatives as far as ICT infrastructure is concerned. Both hard and software ICT infrastructure are prerequisites and enablers for developing a smart city. With robust Internet connectivity, solutions to the smart city concept can be implemented (Hugbo, 2019). Kenya's Internet quality ranks fifth in Africa, although the speed is a bit low. Therefore, there is need to improve the quality of the Internet in the country. Broadband will allow for connections to pave way for smart solutions and help transform Nairobi city inhabitants' lives, creativity, and development of business ideas despite their location to allow for economic and societal benefits for the realization of digital transformation. Also, it will contribute towards increasing digital literacy in schools and the workforce and address the digital divide among city residents. The results are in tandem with Antwi-Afari et al. (2021), who found that the strategies for promoting high-speed mobility is the highly ranked indicator. The city management needs to also focus on the least ranked indicators, such as miles of bike paths within the city and the number of electric vehicles (EVs) charging stations. Currently, they are four in the city (KenGen, 2022). When these two aspects are improved, clean mobility will be attained. For instance, increasing the number of EV charging stations, will encourage the importation of electric vehicles and reduce the use of petrol and diesel-powered vehicles, which account for a quarter of greenhouse gas emissions globally.

Table 5.3 Living dimension

Living (L)	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
L1	1	0.5	0.33	2	0.25	3	0.5	0.25	0.2	0.25
L2	2	1	2	3	2	4	0.5	0.5	0.5	0.33
L3	3	0.5	1	4	2	4	0.25	0.25	0.25	0.33
L4	0.5	0.33	0.25	1	0.25	0.5	0.25	0.25	0.25	0.25
L5	4	0.5	0.5	4	1	4	0.25	0.25	0.25	0.25
L6	0.33	0.25	0.25	2	0.25	1	0.25	0.25	0.25	0.25
L7	2	2	4	4	4	4	1	0.33	0.33	3
L8	4	2	4	4	4	4	3	1	0.25	0.25
L9	5	2	4	4	4	4	3	4	1	3
L10	4	3	3	4	4	4	0.33	4	0.33	1
Weights (%)	4.23	8.47	7.05	2.64	6.63	2.98	14.47	14.68	22.94	15.90
Rankings	8	5	6	10	7	9	4	3	1	2

Source: Own computation

According to Table 5.3, there are ten indicators, so the RI = 1.49, λ_max = 11.1458, C.I = 0.127311, and C.R = 0.085443<0.15, which demonstrates that the pairwise comparison matrix is consistent.

The living dimension has total number of hospital facilities per 10,000 population (L9) ranking first at 22.94 per cent, followed by number of inpatient beds per 10,000 population (L10) at 15.90 per cent. These two indicators together account for 38.8 per cent of this dimension. Health infrastructure is one of the most critical areas for a city to be smart, since it contributes to improving other indicators such as average life expectancy at birth, health workforce density, and the health services infrastructure index. Greater access to quality health services will also lead to increased life expectancy at birth. These findings are in tandem with Bruni et al. (2017), who found that health is the most important aspect of city inhabitants. Also, Zou et al. (2022) highly weighted the number of doctors per 100000 population as the most important indicator. While hospital facilities will contribute to the overall quality of life, culture is equally important since it will promote a sense of appreciation and belonging to people’s way of life and act as a tourist attraction. Culture is also a symbol of unity and brings city dwellers together for the common purpose of economic growth. The indicator with the lowest weight, demographic density (L4), is the least important for assessing the smartness level of a city. The issue of demographic density is evident in many smart cities across the world, which are equally densely populated despite being sustainable.

Table 5.4: Economy dimension

Economy (E)	E1	E2	E3	E4	E5	E6
E1	1	0.33	0.33	0.5	0.25	0.5
E2	3	1	4	0.5	1	0.5
E3	3	0.25	1	0.33	0.25	0.5
E4	2	2	3	1	1	0.33
E5	4	1	4	1	1	0.33
E6	2	2	2	3	3	1
Weights (%)	6.93	17.04	9.28	17.71	18.57	30.48
Rankings	6	4	5	3	2	1

Source: Own computation

According to Table 5.4, there are six indicators, so the RI = 1.26, λ_max = 6.720969, C.I = 0.144194, and C.R = 0.11444 <0.15, which demonstrates that the pairwise comparison matrix is consistent.

The number of tech hubs (E6) is ranked first at 30.48 per cent, followed by ease of doing business (E5) and proportion of population aged 15 years and above using e-commerce (E4) at 18.57 and 17.71 per cent, respectively. Among the smart city indicators, the number of tech hubs is among the most important indicators. A smart city is the incorporation of technology in the delivery of services, though not limited to it. By increasing the number of tech hubs in a city, indicators such as companies per 100,000 inhabitants (E2) and unemployment rate (E3) would possibly be improved. Tech hubs indicator will contribute to innovation and creativity within the city. The results align with Antwi-Afari et al. (2021) findings, which found that innovative ability and the spirit of entrepreneurship are highly ranked. The Kenya digital economy blueprint has identified digital business as one of the pillars of Kenya's digital economy. E-commerce is one of the indicators. Full implementation of the blueprint will lead to realization of an innovative economy and put Nairobi on the right path towards achieving smart city status. To promote e-commerce while at the same time protecting consumers, there is a need to develop policies on promoting e-commerce growth.

The indicators regarded as the least important towards establishing a smart city include Gross County Product (GCP) per capita, unemployment rate, and companies per 100,000 inhabitants. The low ranking of GCP per capita could be because it is not the best indicator for measuring the well-being of city inhabitants. The GCP could be high while income is unequally distributed. Since ease of doing business was ranked among the most important indicators, establishing more companies within the city can be achieved. When the number of companies increases, more employment opportunities will be created, thus reducing the unemployment rate.

Table 5.5: Environment dimension

Environment (N)	N1	N2	N3	N4
N1	1	1	1	0.25
N2	1	1	0.33	0.25
N3	1	3	1	0.25
N4	4	4	4	1
Weight (%)	13.87	11.22	19.43	55.48
Rankings	3	4	2	1

Source: Own computation

According to Table 5.5, there are four indicators, so the RI = 0.89, λ_max=4.155893, C.I=0.051964, and C.R=0.058387<0.15, which demonstrates that the pairwise comparison matrix is consistent.

The percentage of electricity derived from renewable sources (N4) and percentage of the population with access to clean drinking water (N3) with 55.5 per cent and 19.4 per cent, respectively, were ranked as the most important indicators. It is because energy is the number one enabler to achieving smart growth, as most soft systems will need the power to share information with others. The city derives most of its energy from renewable sources, which explains why it is highly ranked. Water is important in achieving smart growth as it enables people to feel included. Currently, the percentage of people with access to clean drinking water is at 50 per cent, which implies that city officials have a lot to do in the provision of drinking water. To increase the percentage of those with access to clean drinking water, the county government can invest in drilling wells, increasing capacity to harvest rainwater, and maintaining the existing sewer lines to ensure water use efficiency. The two least weighted indicators include percentage of recycled waste (N2), which accounts for 11.22 per cent, and total collected solid waste per capita at 13.87 per cent. If well-managed, the amount of waste collected in a city may not be among the most important indicators. The city has traditionally faced the challenge of waste collection and management despite a waste management policy calling for active implementation of the existing waste management act to ensure compliance by residential building owners. Water service quality and sustainable development should be the areas of focus to achieve a smart environment (Joel et al., 2019).

Table 5.6: Governance dimension

Governance (G)	G1	G2	G3	G4
G1	1	4	0.33	0.2
G2	0.25	1	0.25	0.2
G3	3	4	1	1
G4	5	5	1	1
Weight (%)	15.13	6.97	35.36	42.55
Rankings	3	4	2	1

Source: Own computation

According to Table 5.6, there are four indicators, so the RI = 0.89, λ_max=4.227878, C.I=0.075959, and C.R=0.085347<0.15, which demonstrates that the pairwise comparison matrix is consistent.

For the governance dimension, the number of city services that are accessible via web or mobile phone (G4) was ranked at the top with 42.55 per cent compared to the percentage of women Members of County Assembly (MCAs) (G2), which was ranked last at 6.97 per cent. Female city representatives per 1000 residents are the least important indicator of smart governance (Zou et al., 2022). Nairobi is a cosmopolitan with mixed cultures; the perception of city residents could be based on the culture of some communities that women are not fit to hold leadership positions, thus the low percentage of elected women MCAs. The high ranking of the top indicator is because smart growth has an aspect of adopting ICT, which helps improve service delivery. The city has digitized over 200 services, including single business permit applications, e-Jiji pay, land service application, county halls and grounds hire, and health certificates (KARA, 2022). Also, digitizing city services reduces the time one spends queuing to access services from physical offices. Governments worldwide are enabling and embracing web and mobile-based service delivery. Government citizen-centricity is the new standard expected by citizens, business firms, and other government entities. Accurate data and timely and high-quality services are required and must be provided securely, safely, accountably, and transparently. Although digitizing services increases efficiency, women's representation within the city is also important in addressing gender equity. From the indices, it is notable that the deviation is quite large, ranging from 7.0 to 45.5 per cent, indicating that there is no close similarity in terms of prioritization of these indicators; hence focus should be on the highly ranked indicator until it is fully achieved.

5.2 Overall Smart City Development Level Index- The Dimensional Weights

Table 5.7: Overall smart city development level index

Dimension	Weights (%)	Ranking
People (P)	17.12	2
Mobility (M)	16.69	3
Living (L)	29.66	1
Economy (E)	14.54	4
Environment (N)	10.12	6
Governance (G)	11.86	5

Source: Own computation

The deviation across the dimensions is small as it ranges between 10 to 30 per cent, which indicates that focus should be put across all the dimensions to improve the smart development level of Nairobi. This is attributable to the systems theory where, for a city to become smart, all the systems within the city must be interconnected to allow for the sharing of information and identification of areas with problems for improved service delivery (Kasarda and Crenshaw, 1991). The living dimension was highly ranked and weighted at 29.66 per cent. Giffinger et al. (2007) opined that the living dimension is a key pillar that could lead to understanding the overall smartness of cities. This is because the living dimension measures the well-being of city inhabitants. The people dimension ranks second with a weighting of 17.12 per cent followed closely by the mobility dimension at third rank with a weight of 16.69 per cent. The people dimension has received a major boost from government policies. For instance, the 100 per cent transition from primary to secondary school has seen the enrolment rate in secondary schools hit a record high. Also, the revision of university entry cut-off points to a minimum grade of C+ has seen high university enrolment rates. The government has also chartered several universities into a fully-fledged status, leading to an increased number of higher learning institutions. Also, the government currently admits government-sponsored students in both private and public universities. The environment dimension is ranked last with a weight of 10.12 per cent. Despite having a solid waste management act in place, Nairobi city has faced challenges in waste management. It calls for active policy enforcement to ensure effective waste management within the city. Also, there is need to develop a policy on waste recycling to ensure a reduction in air and water pollution. The city has a problem with waste collection, and the percentage of people with access to clean drinking water is 50 per cent (BBC, 2019). Policies should lean towards providing clean piped water, sewerage services, and waste management.

The governance dimension was ranked fifth among the six dimensions. Emphasis needs to be given to this dimension as well. For instance, government services such as application documents in line with Chapter Six of the Constitution requirements on leadership and integrity should all be availed online to avoid the long queues in physical offices. The economy dimension has an overall rating of 14.54 per cent, which is attributed to the number of tech hubs. However, the dimension needs much attention, especially in innovations, to enhance smartness.

The overall smart city development index for Nairobi is 18.64 per cent, which indicates the city is at a normal rate of smart growth, as Min et al. (2018) opined in realizing the smart city initiatives. Therefore, it gives an overall understanding that Nairobi city has the necessary infrastructure and facilities required and can be advanced to cover the entire city population. This can be done by interconnecting different systems within the city to allow for monitoring and improvement of service delivery. It calls for multiple stakeholder initiatives to fast-track the growth by focusing on all the dimensions as they are equally important.

6. Conclusion and Policy Recommendations

6.2 Conclusion

The world is currently amid a rapid and continual trend towards urbanization. Determining tailor-made solutions for problems faced by urban dwellers is the responsibility of policy makers, community developers, scholars, and urban planners, among other stakeholders. Smart cities play an important role in urban transformation towards enhancing service delivery. They improve resilience, sustainability, workability, and livability. To achieve the status of a smart city, the main step is to interconnect all the systems within the city and allow urban planners to monitor activities. Through the smart city concept, the research has concluded a conceptual framework that shows the common features that a smart city should have. The six dimensions' main contents include hard (infrastructure, mobility, energy, and environment) and soft systems (governance, people, living, and economy) where all the systems must be interconnected to achieve the smart city status.

The research draws from existing literature to construct a smart city index to determine the smart development for Nairobi city, the capital of Kenya. The AHP method is also applied to calculate the weights for all 38 indicators identified for Nairobi city. The six dimensions considered include economy, people, governance, mobility, living and environment. It emerges from the analysis that the deviation on the importance level across all the dimensions is not huge as it ranges from 10.12 to 29.66 per cent, which indicates that all the dimensions are important in achieving the smart growth of a city, hence all the systems within the dimensions should be interconnected. The overall smart city development index for Nairobi city is 18.64 per cent, which implies that Nairobi has the potential of becoming a smart city if each is improved and they are interconnected. Among the components making up the index, the highest average scores were on living and people dimensions, scoring 29.66 and 17.12 per cent, respectively, while the lowest average score was on the environment component with 10.12 per cent. Out of the 38 indicators, the percentage of electricity derived from renewable sources is the single indicator that scored the highest. Other indicators that scored highly include the percentage of city services accessible online via web or mobile, number of tech hubs, number of hospital facilities per 10,000 population, percentage of households connected to fixed broadband and those connected to mobile broadband, number of installed learner digital devices in primary schools and number of installed digital content server and wireless routers in primary schools. Since these are the indicators where Nairobi has the strength, policy makers and city developers need to leverage these indicators to realize the city's full potential in becoming smart.

6.2 Policy Recommendations

6.2.1 General recommendation

In addition to improving the indicators that are of higher importance across all the dimensions, Nairobi city planners will also need to consider interconnecting, social, IT, physical and business infrastructure facilities within the city (waste, water, housing, traffic, among others) to allow for data availability in real-time to monitor inefficiencies in service delivery and improve liveability.

6.2.2 Specific recommendations

People

- Empowering human resource development through education and digital access to improve the people's dimension.
- Fast-track the progress with Digital Literacy Programme (DLP) through monitoring and evaluation to identify the gaps and ensure seamless implementation of the programme to improve the people's dimension.

Living

- Strengthen the project of building additional health centres in the slum areas initiated by the Nairobi Metropolitan Services (NMS), which will improve the health infrastructure indicator. These hospitals need to be equipped with drugs, inpatient beds, and maternity facilities, and pharmaceuticals. Also, there is need to employ additional health officers.

Mobility

- Expand the ICT infrastructure by fast-tracking implementation of the National Broadband Strategy 2018-2023 to increase the speed of Internet within the country, which is a prerequisite.
- Fast-track the implementation of the Kenya National Digital Masterplan's flagship programmes anchored on four pillars: digital infrastructure; digital government services, product, and data management; digital skills; digital innovation, enterprise, and digital business to allow for increased digital technologies adoption.
- Increase the electric vehicle charging stations to encourage importation of electric vehicles and thus reduce the use of petrol and diesel-powered transport, which accounts for a quarter of greenhouse gas emissions globally, thus improving the mobility dimension.

Economy

- Create more tech hubs by developing and implementing policy and legal framework to allow more young people to innovate and start their entrepreneurial journey.
- Encourage public-private partnerships to enhance investment, create employment opportunities, to reduce unemployment rate.
- Governance
- Encourage a transparent governance system with enabling technologies to promote e-voting to improve on voter turnout.

Environment

- The Nairobi City County to fast-track the implementation of the Solid Waste Management Act of 2015 to improve the environment dimension, especially the waste aspect.
- Enhance waste recycling by developing and implementing a policy on waste recycling. Recycling waste will lead to energy conservation, reduced water and air pollution, and reduced greenhouse gases.

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