MODELLING A SUSTAINABLE ELECTROMOBILITY INFRASTRUCTURE

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Declaration and Approval

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the work contains no material previously published or written by another person except where due reference is made in the work itself.

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17/04/2024

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Abstract

The global transportation sector is undergoing a significant transformation as societies increasingly seek sustainable alternatives to conventional fossil fuelled. Electricity as an alternative for fossil fuels to power mobility in the wake of green transition has gained prominence. Energy inaccessibility due to inadequate availability of a robust infrastructure with reliable and efficient energy provision has become a drawback towards the transition from petroleum powered to electrified mobility. This study aimed to create a model that will foster the uptake of electromobility by formulating a model equation to determine the infrastructural requirements of establishing a sustainable e-mobility charging infrastructure. The study adopts desktop, descriptive and experimental research designs in sourcing for data and simulation of the model. To this end, Westlands region of Nairobi County was selected as an area with a blend of residential and most sought-after office space with capability for modern e-mobility infrastructure. Results depicted that the current EV infrastructural capacity (charging stations, charging station capacity and area coverage) is not sustainable (SI=2.316 (>0.29)) for the given population, energy demand, and coverage area. This is also the case in the short term (5 years) (SI=4.030 (>0.29)), medium term (10 years) (4.828 (>0.29)) as well as long term (15 years) (5.339 (>0.29)). The findings highlight the inadequacy and inflexibility of the current infrastructure to meet the evolving demands of a growing population, increasing energy demand, casting doubt on the viability of Kenya's e-mobility ecosystem in fostering sustainable transportation solutions. To ensure the continued sustainability of the e-mobility infrastructure, policymakers, government agencies, private sector stakeholders and urban planners should prioritize integrated planning and investment strategies in developing a cohesive framework to address current and future demands of e-mobility ecosystem.

Key Words: *Energy Access, Electromobility, Energy Transition, Sustainability*

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Abbreviations and Acronyms

CBD	Central Business District
E-mobility	Electric mobility
EMSA	E-Mobility Systems Architecture
EPRA	Energy and Petroleum Regulatory Authority
ESIF	EcoSystem Innovation Framework
EV	Electric Vehicle
KNBS	Kenya National Bureau of Statistics
MaaS	Mobility as a Service
MATLAB	Matrix Laboratory
MILP	Mixed-Integer Linear Programming
NTSA	National Transport and Safety Authority
OSeMOSYS	Open-Source energy Modelling System
SAEV	Shared Automated Electric Vehicles

Operational Definition Terms

Energy Security	Energy security means a constant, reliable and uninterrupted availability of energy sources at affordable prices.(*Emergency Response and Energy Security - About*, n.d.)
Renewable Energy Access	Energy access means the ability to access and afford use of renewable energy resources.(*Renewable Energy and Energy Access*, n.d.)
Renewable Energy Uptake	Energy uptake means the promotion of renewable energy sources that include wind power, biomass, small hydro, solar, biogas and geothermal. (Environment, 2017)

Chapter 1: Introduction

1.1 Background to the Study

Electricity as an alternative for fossil fuels to power mobility in the wake of green transition has gained prominence. The global transportation sector is undergoing a significant transformation as societies increasingly seek sustainable alternatives to conventional fossil-fuelled vehicles (Kirpes et al., 2019). The rise of electric mobility (e-mobility) offers a promising avenue to mitigate urban congestion, reduce emissions, and enhance energy efficiency within urban environments. As cities strive to create more resilient, accessible, and sustainable transportation systems, the need for a comprehensive model-based framework becomes paramount (Piazza et al., 2023). This calls for a mechanism to address the complexities inherent in designing an e-mobility ecosystem that not only promotes the adoption of electric vehicles but also integrates seamlessly with existing infrastructure, optimizes energy consumption, and contributes to overall urban sustainability.

Smart cities must factor in green transportation in their plan. The concept of e-mobility extends beyond vehicle electrification; it encompasses an ecosystem that includes electric vehicles, charging infrastructure, energy sources, user behaviors, urban planning strategies, and policy frameworks (Roumboutsos et al., 2021). The shift to e-mobility aligns with broader sustainability goals, as it has the potential to significantly reduce greenhouse gas emissions, lower air pollution levels, and decrease dependence on non-renewable energy sources. However, the successful integration of e-mobility within urban contexts requires a holistic understanding of the multifaceted interactions between these components (Nemoto et al., 2021). The interrelation of different features of a suitable, flexible e-mobility ecosystem ought to be considered.

This resilience extends to factors such as energy supply fluctuations, technological advancements, changes in user demand, and unexpected incidents. Building a robust e-mobility ecosystem necessitates designing a system that can adapt to various disruptions while continuing to provide efficient and accessible transportation services (Kirpes et al., 2019). Moreover, achieving accessibility involves ensuring that e-mobility options are available and viable for diverse user groups, including individuals with different mobility needs, income levels, and geographical locations (Piazza et al., 2023). Thus, the development of a model-based framework must consider these dimensions to create a truly serviceable and accessible e-mobility solution.

The intricate interactions between various elements within the e-mobility ecosystem call for a systematic and integrated approach (Zhou et al., 2023). A model-based framework offers the means to capture the dynamics of these interactions, simulate different scenarios, and evaluate the potential outcomes of different strategies (Kirpes et al., 2019). By harnessing the power of modelling, decision-makers and urban planners can make informed choices that lead to a resilient, accessible, and sustainable e-mobility ecosystem. This framework was grounded in both theoretical insights and empirical evidence to ensure its applicability and effectiveness in real-world contexts.

Within the Kenyan context, the adoption of sustainable transportation solutions presents unique challenges and opportunities. Rapid urbanization, coupled with a growing population, emphasizes the need for efficient and environmentally friendly mobility options (Galuszka et al., 2021). Kenya's commitment to renewable energy further underscores the potential of e-mobility powered by sustainable energy sources. However, to successfully integrate e-mobility into the fabric of Kenyan cities, a tailored approach is required, one that accounts for the country's infrastructure landscape, cultural preferences, and economic realities (Wahab & Jian, 2018). This study thus sought to bridge the gap between global sustainability objectives and the Kenyan context by developing a model-based framework specifically designed to facilitate the adoption of resilient, accessible, and sustainable e-mobility solutions in Kenya.

1.2 Problem Statement

The move towards uptake of e-mobility is coupled with several emerging issues. One major concern is the cure for range anxiety. In general, people tend to be very worried about purchasing an electric car. One of the issues lies on the question of how far they can travel without running out of charge (Hanifah et al., 2015). The lack of exposure to electric vehicle (EV) technology and reliable energy sources evidently affects one’s decision to buy an electric car aside from the initial cost of purchase.

Technological progress has increased the mileage of newer models of EVs but still as a developing country, the infrastructure inadequacy and unreliable energy supply has downplayed the urge to adopt e-mobility. Electric vehicles' increasing demand for electricity must be countered by an increase in supply of zero-carbon electricity for e-mobility to achieve decarbonization (Zhou et al., 2023). Energy inaccessibility due to inadequate availability of a robust technology ecosystem with reliable and efficient energy provision has therefore become a drawback towards the transition from petroleum powered to electrified mobility. To counter this, enhancing the uptake of energy sources and technologies needs to be propelled. The study therefore aimed to develop a model for a sustainable e-mobility infrastructure in Kenya.

1.3 Aim

The research project aims to create a model that will assist in fostering the uptake of electromobility by formulating a model equation to determine the viability of establishing a sustainable e-mobility charging infrastructure.

1.4 Specific Objectives

i). To establish the infrastructural requirements for a sustainable e-mobility ecosystem.

ii). To develop a model to determine the infrastructural requirements for a sustainable e-mobility infrastructure.

iii). To validate the performance of the model

1.4.1 Research Questions

i). What are the infrastructural requirements for a sustainable e-mobility ecosystem?

ii). How can a model be employed to determine the infrastructural requirements for a sustainable e-mobility infrastructure?

iii). Is the performance of the model valid?

1.5 Justification

Driving green growth and climate finance solutions for Africa and the World was a key discussion during the Africa Climate Summit 2023. It was evident that Electric vehicles (EVs) have lower operating costs compared to traditional internal combustion engine vehicles. Additionally, with the high cost of fossil fuels in Kenya, EVs offer a more affordable and sustainable alternative for consumers, businesses, and government fleets. The growing awareness of climate change and the need to reduce greenhouse gas emissions by transitioning to electromobility was identified as a solution towards exploring a sustainable future.

The reliance on electricity by electromobility as a primary energy source, reduces dependence on fossil fuels thus modelling of a sustainable electromobility infrastructure contributes to national energy security by introducing energy diversification and resilience. This greatly informs the future needs, optimizes infrastructure planning and identification of technological innovations to support the adoption of electromobility.

It however remains unexplored in the Kenyan body of knowledge, how a sustainable electromobility infrastructure may be the cure for the lack of effective adoption of EV solutions and interventions. This research will therefore provide insight on how modelling of a sustainable electromobility infrastructure is crucial to policy formulation and interventions towards promoting environmental conservation, enhancing energy security, fostering economic growth, improving public health, and addressing climate change challenges by enhanced EV adoption.

1.6 Significance of the study

The effort of the proposed model is to have a sustainable charging network that is resourceful to a number of stakeholders in the transportation sector. The key factors that hinder the effectiveness of interventions aimed at enhancing EV uptake in Kenya are addressed. This will be resourceful to the County Government, policy makers as they will be informed on how the interventions can be formulated to enable their effective implementation. The outcome will inform the users of sustainable solutions towards EV charging, entrepreneurs, innovators, training institutions and trends in the energy demand. It will eventually deduce solutions on reduction of congestion of charging stations by users.

Additionally, the model will inform potential investors on predictions to profitable approaches towards realization of an EV charging network. This will also serve as a resource for academics and researchers who are considering to conduct research pertinent to the promotion of uptake and adoption of EV technologies.

1.7 Assumptions

The study was conducted under the assumption that the energy supply from the current grid was ample and dependable, thus eliminating it as a barrier to the adoption of e-mobility and that funding for electromobility infrastructure was available. Additionally, the researcher presumed that the secondary data accurately reflected the current situation.

1.8 Scope and Limitations

The study set out to develop a model for a sustainable e-mobility ecosystem. Conceptually, the study confined itself to infrastructural requirements which was operationalized by the projected demand informed by traffic density, charging time, accessibility of proposed locations and energy costs with the aim of promoting e-mobility uptake in urban areas. Methodologically, the study restricted itself to quantitative data obtained from secondary data sources.

The study faced limitations in data availability, specifically regarding primary data on the number of electric vehicles within the study population. Consequently, reliance on secondary data was necessary. During analysis, challenges arose in accessing suitable e-mobility modeling platforms for scenario generation. To overcome this, the researcher opted for simpler tools like spreadsheets for simulating various model scenarios.

Chapter 2: Literature Review

2.1 Introduction

This literature review chapter explored the theoretical underpinnings, empirical insights, and existing conceptual frameworks that collectively contribute to the understanding of a resilient, accessible, and sustainable e-mobility ecosystem. Through a synthesis of theoretical frameworks, empirical studies, and existing models, this review not only addressed current gaps and trends but also provided a solid groundwork for the subsequent development and validation of a model that holistically captures the complexities inherent in achieving a transformative e-mobility paradigm.

2.2 Theoretical Framework

Two theories that could anchor the study aiming to develop a model-based framework for a resilient, accessible, and sustainable e-mobility infrastructure are the Complex Adaptive Systems Theory and the Transition Theory. Both theories offer valuable frameworks for understanding the complexity and dynamics of transitioning towards a resilient, accessible, and sustainable e-mobility ecosystem. They provide lenses through which to analyze interactions, identify critical transition points, and design strategies for successful implementation.

2.2.1 Complex Adaptive Systems Theory

This Complex Adaptive Systems theory is particularly relevant to the present study due to the intricate and dynamic nature of urban transportation systems and their transformation towards e-mobility. Proposed by Buckley (1968), the theory emphasizes that systems, such as urban mobility ecosystems, are composed of interconnected elements that adapt and evolve in response to changing conditions. It can provide a framework for understanding how different components within the e-mobility ecosystem—such as vehicles, charging infrastructure, energy sources, and user behaviors—interact and adapt over time. This theory could guide the development of a model that captures the non-linear relationships, feedback loops, and emergent properties within the e-mobility context.

2.2.2 Transition Theory

Transition Theory is also well-suited to guide the study's exploration of the shifts required to achieve a sustainable e-mobility ecosystem. This theory was proposed by Davis (1945) and focuses on the processes of societal and technological transitions towards more sustainable modes of operation. It provides insights into how systems, such as transportation, move from one state to another through the interplay of technological innovations, policy changes, and shifts in societal norms. This theory can help explain the barriers and enablers of transitioning to e-mobility, considering the various stages of adoption, the role of key stakeholders, and the institutional changes needed to support the transition.

2.2.3 Electric Mobility Ecosystem

In recent years, electric vehicles (EV) have been gaining importance as an alternative transportation option. However, the EVs' market penetration rate is not very quick because of their limited range, charging time, battery replacement cost, and other limitations related to infrastructure (Miri et al., 2021). EV charging can be achieved either through deploying home, office or public charging infrastructure that need to be cost effective, reliable, and sustainable with limited investment capacity(Metais et al., 2022). A robust public charging infrastructure should be able to give the users a transportation network coverage that is readily accessible to curb range anxiety.

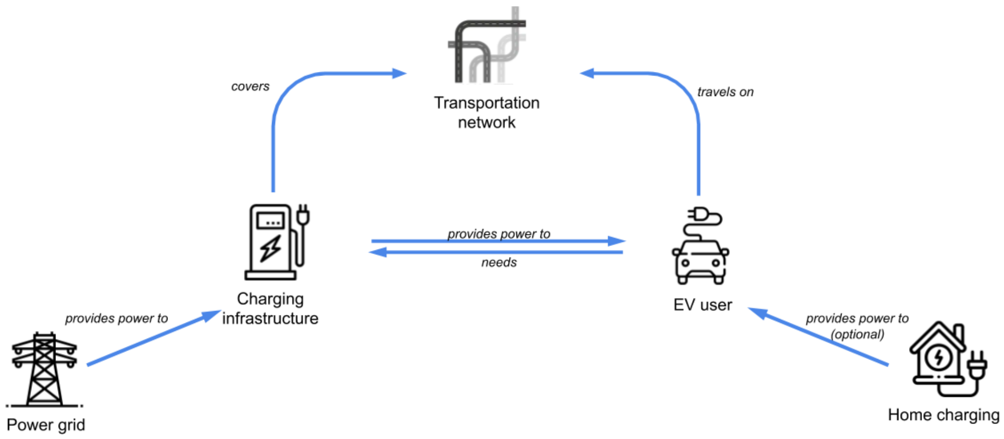

Figure 2-1: Overview of Charging Infrastructure framework (Metais et al., 2022)

A sustainable e-mobility ecosystem needs to address technical issues linked to the technology used and the constraints it places on existing grid infrastructure, assure return on investment due to cost related to charging infrastructure and more importantly respond to user demand.

2.2.4 Charging infrastructure and EV acceptance

Social acceptance of EV mobility is driven by various aspects of the e-mobility ecosystem. Acceptance of this perspective is the extent to which an individual desires to acquire an electric vehicle. According to (Ramachandaramurthy et al., 2023), theories of EV acceptance, include Individual, Community and Institute Acceptance, Socio-Political Acceptance, Community Acceptance and Market Acceptance, Theory of Reasoned Action, Technology Acceptance Model, as well as the purchase intention towards EV. The key drivers towards EV adoption as depicted in Fig.2, tend to revolve around Energy capacity, infrastructure and affordability. Underinvestment in reliable energy supply and cost-effective infrastructure will discourage EV adoption occasioned by insufficient coverage of the charging network.

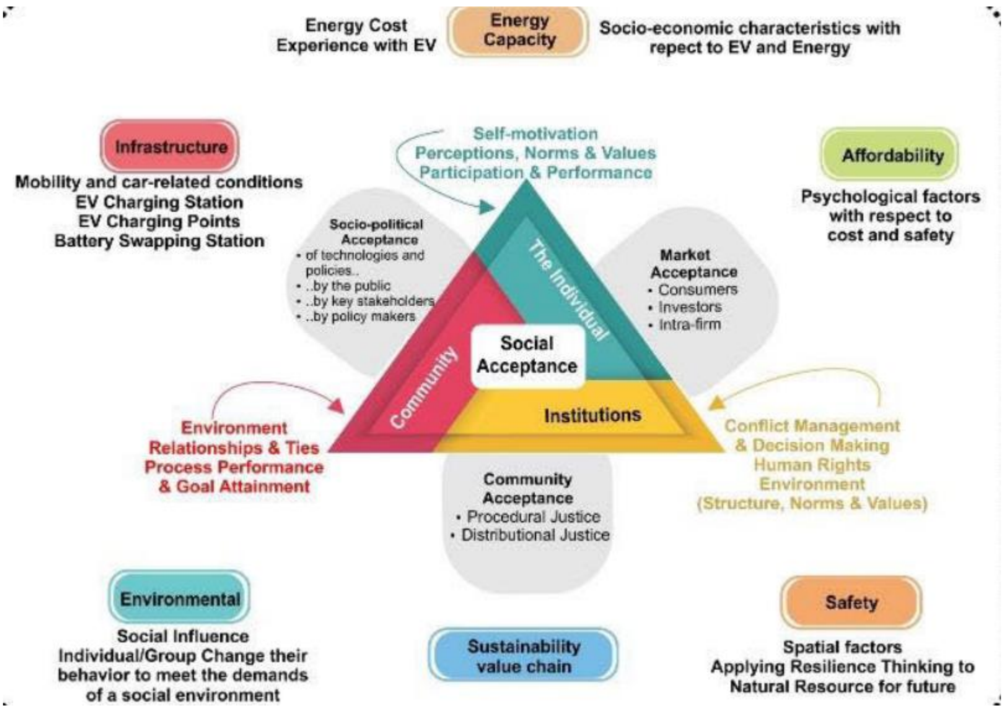

Figure 2-2: Factors Influencing EV Acceptance(Ramachandaramurthy et al., 2023)

EV acceptance and adoption is limited due to various factors that are influenced by political, economic, social, environmental and technological concerns. Technology Acceptance Model studies the adoption of innovation and customer behaviour in technological context by establishing perceived usefulness and perceived ease of use (Özdemir-Öztürk & Barutçu, 2022). In this context, the perceived usefulness relates to the social beliefs in the improvement that can be achieved by new technology such as electrified transportation. The perceived ease of use is defined as the social opinions in the difficulties to implement this new technology. It is noted that the social acceptance of EV revolves around a number of factors such as driving range, charging challenges and cost implications. Table 1 describes the obstacles and challenges identified by related studies.

Source: Based on literature by **(Ramachandaramurthy et al., 2023)**

Table 2.1: Factors Influencing EV adoption.

Perceived Influencing Factor	**Illustration**
Driving Range	EV has a lower driving range. Consumers who want to go great distances cannot currently be served by the present EV driving range.
Charging Location	Users have their own routine and preference as to where and when to charge therefore determination of location influences the users.
Charging time	EV takes hours to recharge. This has an adverse impact for it increases range anxiety
Charger Type	Quick charge capability makes Fast chargers higher in demand. However, this technology is costly and requires high electricity rate. It is also noted that fast charging has a significant health impact to EV battery.
Charging Rate	Increase of EV charging demand can cause power congestion to the electric grid. The strategy is to encourage the EV users to charge their EV during off-peak hours.
Environmental Factor	The environmental impact caused by mining and manufacturing Lithium-ion batteries has raised concerns.

To have a sustainable and reliable e-mobility ecosystem, these factors need to inform the model under development.

2.3 Empirical Framework

2.3.1 Approaches for sustainable electromobility

Multiple scientific and mathematical methodologies are used to develop approaches towards sustainable electromobility. Nigro et al., 2021 in a study propose a modelling framework that can be useful to evaluate short-term and medium to long-term measures to avoid energy congestion in urban areas with the aim to simulate multimodality between EVs and public transport (Park and Ride), as well as to estimate energy demand requested by EVs as a function of the land use of the city these are moving to. The modeling framework after being incorporated into an EV simulator, will be useful to local governments to promote a sustainable development of electromobility in partnership with mobility planners and energy providers.

The increasing popularity of EVs in cities presents new infrastructure challenges related to charging, encompassing a wide range of transportation patterns and requirements. From an energy perspective, a proper simulation of a short-term solution, like encouraging multimodality between EVs and public transportation in Park and Ride locations scattered around the city's suburbs, envisions two objectives. First, compared to the demand derived from regular commuter trips using only private EVs, energy demand can be shifted differently in space and time. Moreover, it would encourage effective charging management through a vehicle-to-grid approach in which the EVs act as "demand peak stabilizers" in the parking lots (Nigro et al., 2021). On the other hand, estimation of energy demand as a function of land use helps in the medium to long term toward an energy saving approach. Due to the impact on the electricity grid, infrastructure improvements need to be made to optimize EV charging operations and to ensure a smooth integration with renewables-based energy generation.

The figure 2-3 is the methodological illustration of the two different approaches as depicted in the study. An aggregated approach where both dependent variable and explanatory variables are aggregated variables at zonal level and a disaggregated approach where the decision of each user is simulated as a function of several explanatory variables related to both individual features and zonal ones.

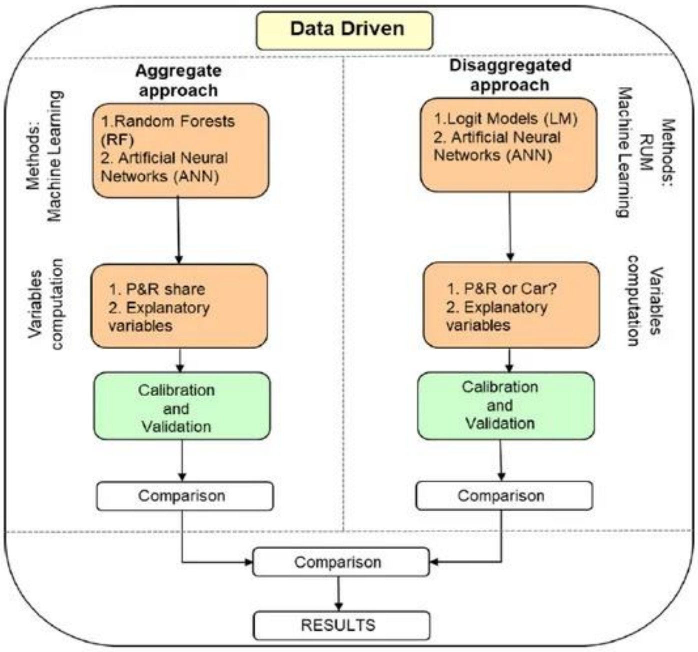

Figure 2-3: Methodological framework of multimodality models (Nigro et al., 2021)

Formulation of the Park and Ride models according to Nigro, starting from the aggregated approach, the model must be able to represent multimodal choice behaviours, thus assessing the share of the private EVs that can be moved onto public transport by using Park and Ride sites. The model assumes the following structure:

$$(G_O^{Park}/G_O)\,|_{Dt} = f\,(x_1, x_2, \ldots, x_n) \qquad \textbf{Equation 2.0-1}$$

where G_O^{Park}/GO is the share of generated trips from the traffic zone O that would make P&R in the time interval Dt. The explanatory variables x1, x2, …, xn are mainly related to the accessibility of the park and Ride sites, impedances due to the travel times on the public transport, the location and occupancy of the P&R sites, and characteristics related to the activity system in the starting point of the trip. First, the suggested explanatory variables have to be laid out. One notable variable that has been used is one that is dependent on the time interval where the dummy variable x10 equals 1 if the journey starts inside the morning peak (between 6:00 and 11:00 a.m. for school trips taken by public transportation), and 0 otherwise.

$$x_1 = \left(\sum_{P \in O} t_{OP} f_{OP}\right) / \left(\sum_{P \in O} f_{OP}\right) = \left(\sum_{P \in O} t_{OP} f_{OP}\right) / G_O^{Park}$$

$$x_2 = \left(\sum_{P \in O} f_{OP} \left(\frac{\sum_D t_{PD}{}^{TP} A^D}{\sum_D A^D} \right) / \left(\sum_{P \in O} f_{OP} \right) = \left(\sum_{P \in O} f_{OP} \left(\frac{\sum_D t_{PD}{}^{TP} A^D}{\sum_D A^D} \right) \right) / G_O{}^{Park} \right.$$

$$x_3 = \left(\sum_D f_{OD} A_D \left(\left(\sum_{P \in O} t_{PD}\right)/n_{P \in O}\right)/\left(\left(\sum_D f_{OD}\right)\left(\sum_D A_D\right)\right)\right)$$

$$x_4 = \sum_D A_D \left(t_{OD} - \left(\sum_{P \in O} (t_{OP} + t_{PD})/n_{P \in O}\right)\right)/\sum_D A_D$$

$$x_5 = \left(\sum_{P \in O} r_P\right)/n_{P \in O}$$

where:

t_{OP} = travel time by car from the origin/starting traffic zone O to the P&R site P;

f_{OP} = vehicle flow from the origin/starting traffic zone O to the P&R site P;

$G_O{}^{Park}$ = generated trips from the origin/starting traffic zone O making P&R;

$tP \to {}^*TP$ = average travel time on public transport to reach all the destinations of the city from the P&R site P;

f_{OD} = vehicle flow from the origin/starting traffic zone O to the final destination D;

t_{PD} = travel time by public transport from the P&R site P to the final destination D;

$nP \in O \in$ = number of P&R sites belonging to the catchment area of the origin/starting traffic zone O;

G_O = generated trips from the origin/starting traffic zone O

t_{OD} = travel time by private transport from the origin/starting traffic zone O to the final destination D;

A_D = attractiveness of the destination zone D;

rP = occupancy of the P&R site P.

When adopting the disaggregated approach, each user's decision between Park and Ride or a car is the model's output, and the explanatory variables include both aggregated and disaggregated data. Since these are a function of the trip's starting zone, we refer to the zonal variables outlined for the aggregated approach when addressing the aggregated ones. The disaggregated model has been calibrated considering just those trips connected to the morning peak hours, hence the only variable not adopted from the aggregated set is the dummy variable x10. Six additional factors have been added to the disaggregated ones in order to better characterize the behaviour of each unique user that includes the travelled distance by Park and Ride, the total P&R travel time, number of transfers by public transport, average waiting time by public transport, travelled distance by car and the travel time by car.

The energy demand is computed as follows:

$$E_{zkh}[kWh]=f\times\sum_{i=HB,\ NHB} Trips_{zki,h}*\ ParkingTime_{zki,h}*\ Power\ col_{\ i|HB,NHB}\ \forall\ zk,\ \forall\ h$$

where:

f = recharge frequency computed as a function of distance travelled and battery life before charging.

Trips = number of trips of type

Parking Time = parking time of trips

The pressure of combating the climate crisis has given rise to exponential technological advancements and a plethora of creative solutions in the fields of energy and automotives as well as urban infrastructure and construction, including smart roads and highways, mobility-as-a-service (MaaS), photovoltaic solar energy conversion, photovoltaic system battery storage, smart grids, smart buildings, and smart homes, among many others. An editorial commentary by (Yigitcanlar, 2022) notes that it is a unique strategy to introduce sustainability into urban transport networks through electrification powered by renewable energy sources. However, electrification of vehicles is merely the starting point. Electromobility requires more than just an electric car. System thinking is also key towards realizing electromobility in the context of sustainable urban transportation. This does not limit to the infrastructure, power systems, renewable sources, and user behaviour. It goes beyond as is depicted in Figure 2-4 below.

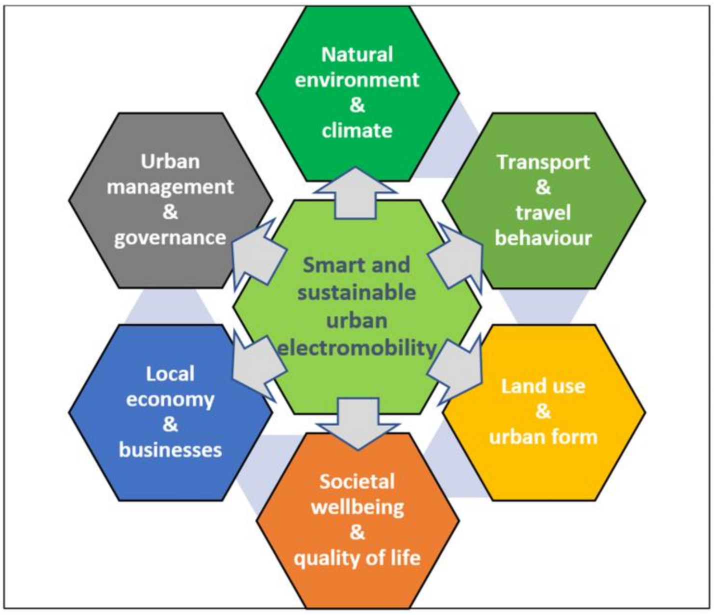

Figure 2-4: Drivers of Smart and sustainable urban electromobility (Yigitcanlar, 2022)

Assessment of various approaches of e-mobility, implementation by Matlab/Yalmip environment and solved using Gurobi as solver is a mathematical method employed by Piazza et al. (2023). They set out to present an optimization-based approach to assess how electric mobility affects the best design for communal self-consumers of energy produced from renewable sources. In order to assess several scenarios with various levels of electric transportation entry, a stochastic optimization algorithm created in Yalmip/Matlab is used to study and discuss the combination of green power and battery storage alongside charging facilities for electric vehicles. The study demonstrates how the existence of electric vehicles dramatically raises the ideal installed capacity for energy-producing plants, coming from 15% to greater than 25%.

The optimization model used in this work is a MILP mathematical model that considers linear constraints and a linear objective function while using continuous (real) and discrete (integer and binary) decision variables. This model aims to determine the best size for the power technologies (PV, storage batteries, and electric vehicle charging stations) that can be installed in a building to provide electricity and transportation services to a group of end users who are combined as collective self-consumers of renewable energy, as shown in Fig. 2-3.

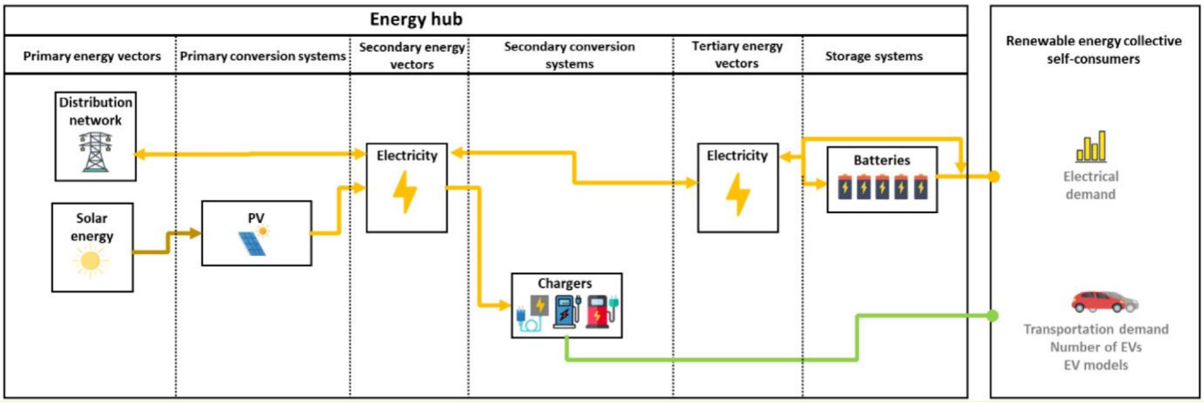

Figure 2-4: The architecture of the energy system ((Piazza et al., 2023)

The model not only identifies the best combination of technologies to install, but it also offers suggestions for the most suitable scheduling of the technologies. To meet the users' energy needs, it is necessary to determine the technologies to install, in terms of size and number, and how to manage their daily operation on normal days. Each average day d (d = 1... D) of the optimization model's time horizon, which is one year, is divided into T time intervals of duration. The single d-type day serves as a proxy for the Nd annual days.

The study however focused on evaluating the impact of electric mobility on renewable energy collective self-consumers. The conceptual framework might lack a comprehensive integration of how e-mobility interacts with the renewable energy consumption patterns of the collective, warranting the present study.

A model-based approach for managing intricacy and compatibility of the architectural of e-mobility systems was developed by Kirpes et al. in 2019. The study also performed a comparative examination of the most recent e-mobility architectural concepts and platforms. The study suggested the E-Mobility Systems Architecture (EMSA) framework, an all-encompassing system design framework for the e-mobility industry, based on the gaps in prior studies that were observed. The investigation included a harmonised role model, operational reference construction, component and system distribution, translation of data protocols and protocol connections, and assignment of all pertinent organizations from the e-mobility industry to the EMSA components. The method of case studies is then used to qualitatively and statistically assess the model versus the specifications. The study however presents conceptual gaps in terms of how the framework accommodates scalability and aligns with sustainability principles. Contextually, the study also fails to consider the context-specific infrastructural factors that might influence the framework's effectiveness and applicability in diverse settings.

By using the Open-Source energy MOdelling SYStem (OSeMOSYS), Quevedoa and Moya (2022) modelled the Dominican Republic's energy systems in order to evaluate potential scenarios for the growth of energy from renewable supplies. Four potential scenarios for the growth of the power supply were generated using OSeMOSYS predicated on information acquired from worldwide reports and data found in national databases. The unique features of the various scenarios were taken into account, including reserve margin, increase in the population, cost associated with technology installation, greenhouse gas emissions, scientific performance, energy demand, and the incorporation of new generating projects. The findings show that energy-efficient techniques are going to have a significant role, with adoption levels of more than 40% expected in the near future. The study however presents gaps in terms of limited attention to the socio-economic and contextual implications of the proposed expansion strategies and potential uncertainties in input data for the model.

In an attempt to give decision-makers Roumboutsos et al. (2021) designed an instrument to evaluate innovations and analyze transformation over time in response to the need for smart transportation to manage modifications in addition to ensure durability and defend against adverse impacts. Mobility as a Service (MaaS), a flagship innovation in the investigation, was subjected to the suggested EcoSystem Innovation Framework (ESIF). In contrast to other places where MaaS was used, the program is for the City of Budapest, which has heavily utilized infrastructure and a low rate of car ownership. Through qualitative investigation (interviews, stakeholder workshops, document analysis, and collection) for three separate time points—summer 2018, summertime 2019, and towards the end of 2020—the ESIF was created. Leaders were helped by the ESIF study, which also highlighted possibilities future developments and showed the ESIF framework's possibilities. The study however exhibits gaps in terms of potential limitations in capturing qualitative aspects of innovation beyond quantitative metrics, insufficient consideration of the diverse stakeholder perspectives that influence smart mobility strategies, and the need for further validation of the tool's effectiveness in real-world decision-making scenarios.

Nemoto et al. (2021) set out to suggest a way to analyze sustainably in order to measure the effects of shared automated electric vehicles (SAEV) on mobility. A set of measures is created after conducting a comprehensive review of the literature in the framework of AVENUE, a European project implementing autonomous shuttles in public transportation of European cities. The many mobility indication characteristics help to fill in missing information about SAEV effectiveness. The suggested approach increases suggestions for transportation regulations that are based on science by allowing an examination and assessment of SAEV to other modes of mobility. The study however exhibits gaps in terms of potential limited consideration of indirect and cascading effects of SAEV adoption on urban infrastructure, insufficient exploration of behavioral changes and user preferences that could influence the sustainability assessment outcomes, and the need for more robust integration of economic indicators alongside environmental and social aspects to comprehensively capture the full spectrum of sustainability impacts.

In order to better understand how electric transportation options are implemented in Dar es Salaam, Kigali, Nairobi, and Kisumu, (Galuszka et al., 2021), looked into the stakeholder celestial bodies and policy-level solutions that have been established in these cities. The investigation uses two main methodologies, including interviewing of stakeholders associated with transportation transformations alongside the evaluations of regulatory and programmatic texts. The results of the investigation show that despite an increase in policies (particularly in Kenya and Rwanda) and local advancements, a variety of economic and technical challenges continue to exist. However, the study presents gaps in terms of limited examination of the effectiveness of the identified policy-level solutions, insufficient depth in analyzing the specific challenges faced by each city, potential oversights in exploring the role of local cultural and socioeconomic factors on e-mobility adoption, and the need for a more comprehensive comparative analysis to identify best practices and transferable lessons across these distinct urban environments.

2.4 Research Gaps

The review of literature reveals that there was limited research on sustainability of electromobility infrastructure in Kenya. Most research studies focussed on socio-economic factors of e-mobility acceptance thus limited to essential requirements for enhanced uptake of EVs. It is further revealed that there is limited attention to socio-economic and contextual implications of proposed expansion strategies, potential uncertainties in input data for the model, focus on evaluating the impact of electric mobility on renewable energy collective self-consumers lacking comprehensive integration with renewable energy consumption patterns of the collective, and potential limitations in capturing qualitative aspects of innovation beyond quantitative metrics, insufficient consideration of diverse stakeholder perspectives influencing smart mobility strategies, and the necessity for further validation of the tool's effectiveness in real-world decision-making scenarios.

The development of a model equation to ascertain a sustainable electromobility infrastructure aims to address existing research gaps and advance knowledge in the field. The researcher acknowledges the need to fill gaps in understanding the infrastructural requirements for a sustainable e-mobility ecosystem, highlighting the importance of establishing a comprehensive model to guide decision-making. The primary objectives of the model development include, establishing the infrastructural requirements for a sustainable e-mobility infrastructure, development of a model to determine the infrastructural needs for a sustainable e-mobility infrastructure and validating its performance.

The validation of the developed model is crucial for ensuring its accuracy, reliability, and effectiveness in guiding decision-making processes related to electromobility infrastructure informing policy and planning efforts in transition to sustainable transportation. By focusing on these objectives, the study seeks to bridge existing research gaps and contribute to a better understanding of the complexities involved in achieving a sustainable electromobility infrastructure.

2.5 Conceptual Framework

Figure 2.4 presents the conceptual framework, which graphically illustrates the conceptual relationship among the study variables.

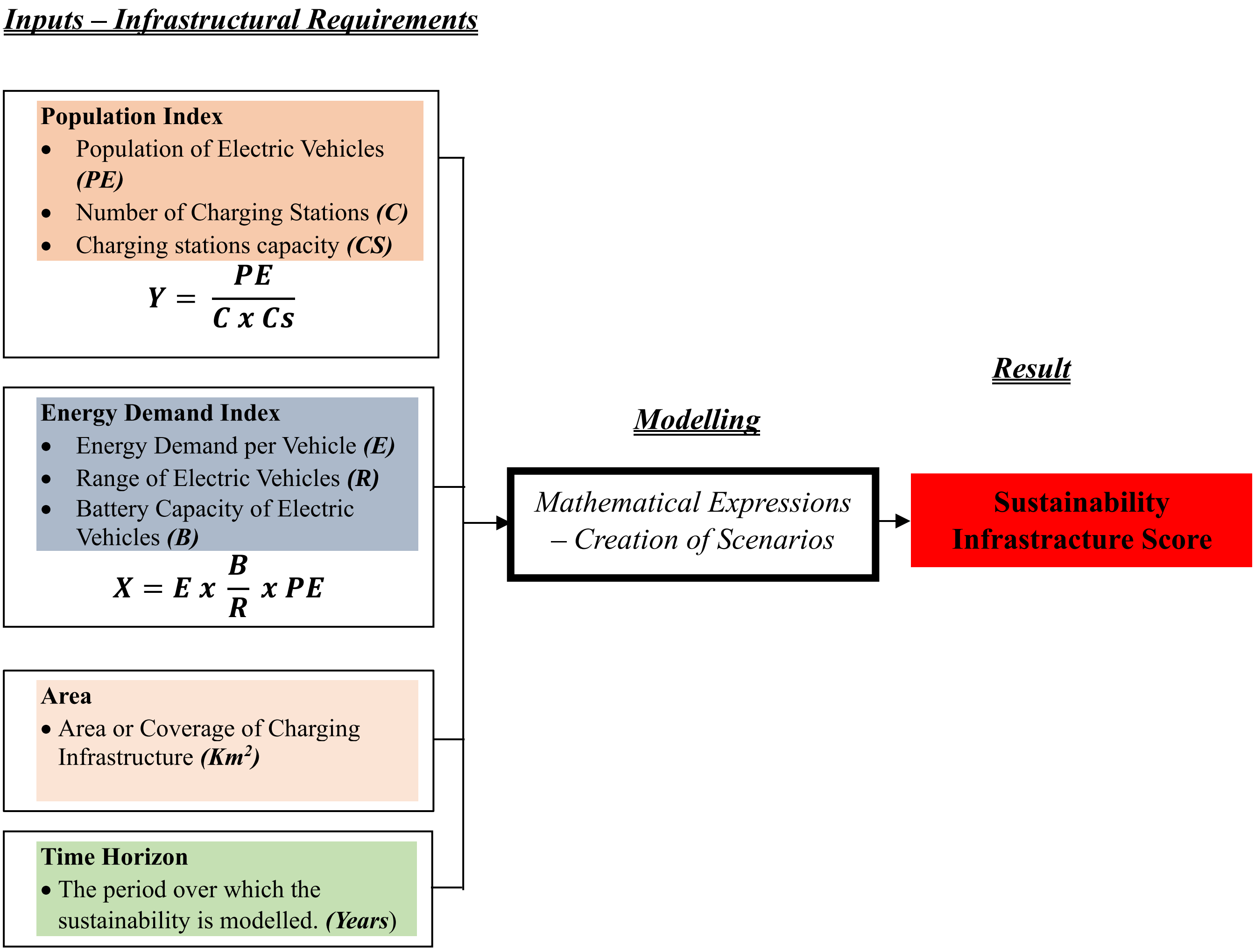

Figure 2-5: Conceptual Framework

Source: Author (2023)

Chapter 3: Research Design and Methodology

3.1 Introduction

The research methodology chapter serves as the blueprint for the systematic exploration of the research objectives and questions, providing the essential framework for the study's execution and analysis. This chapter delves into the intricacies of the research design, population, sample size, sampling techniques, data collection procedures, and data analysis methods that underpin the entire research endeavour. Through a comprehensive examination of these elements, the study describes how the research was planned and executed, ensuring the generation of meaningful insights and contributing to the advancement of knowledge in the field.

3.2 Research Design

A successful research endeavour must proceed through three key phases. The research is first planned, with goals established, treatments to be included, measurements to be taken, subject type, and most importantly the research design decided upon.. (Jr, 2010). The current study adopted a combination of desktop and descriptive research designs.

3.2.1 Type of Research

The desktop research design was employed in sourcing for data, primarily relying on the analysis of existing secondary data sources, including government reports, industry publications, and relevant documentation spanning the past decade. This approach allows for a comprehensive and longitudinal examination of the subject matter, leveraging the wealth of information that has been accumulated over the last ten years to inform and underpin the research objectives, thus ensuring a robust and evidence-based exploration of the chosen research objective, "to develop a model for a sustainable e-mobility charging infrastructure."

The experimental design was used to test the model by creating many scenarios for the investigation. The variables were adjusted based on presumptions whereas the descriptive design was employed in collecting primary data in instances where published secondary data was not available.

3.2.1 Type of Research Data

Quantitative research data is necessary to support decision-making, evaluate alternatives, and guarantee the efficacy and efficiency of the selected techniques in the endeavour to create a sustainable e-mobility infrastructure. The key types of research data crucial for implementing a sustainable e-mobility infrastructure included the population of electric vehicles, energy demand per vehicle, number of charging stations, battery capacity of electric vehicles and most importantly the geographical coverage of the charging infrastructure.

3.2.2 Modelling procedure

The modelling cycle for developing a sustainable electromobility infrastructure involved several key steps aimed at analyzing, designing, and implementing infrastructure solutions. Table 3.1 outlines the steps employed towards the modelling.

Table 3.1: Steps towards modelling

Key Steps	Key Area	Description
1.	**Data Collection and Analysis**	This entailed gathering of relevant data pertaining to various aspects crucial for the development of electromobility infrastructure. This data included included the population of electric vehicles, energy demand per vehicle, number of charging stations, battery capacity of electric vehicles and most importantly the geographical coverage of the charging infrastructure. This was followed by a comprehensive analysis to uncover prevailing trends, patterns, and key variables that significantly influence the trajectory of electromobility infrastructure development.
2.	**Model selection and Development**	Developed the mathematical equations required for the selected model. The

		relationships between variables were defined, parameters, and constraints, drawing upon the analysis of gathered data. Additionally, the integration of a sustainability criterion into the model.
3.	**Scenario Development**	Scenario analysis involved envisioning and exploring various potential future states of the electromobility infrastructure. Different scenarios were considering factors such as EV population increase, energy demand variations within a given timeline.
4.	**Simulation**	Conducted simulations using the developed model to assess the performance of each scenario under various conditions.
5.	**Validation**	Ensured the accuracy and reliability of the model's output by validating it against data from a different geographical location. This was crucial in verifying the model's effectiveness and its applicability beyond specific contexts
6.	**Results, Discussion and Recommendations**	Provide decision-makers with insights and recommendations based on the model's results.

3.3 Data Collection Methods

3.3.1 Method of data collection

The study collected quantitative data from secondary data sources including the 2019 national census survey by KNBS (2019); traffic survey reports by the National Transport and Safety Authority (NTSA); annual reports by the Energy and Petroleum Regulatory Authority (EPRA) and Ministry of Energy as well as other pertinent reports as guided by the study objectives, variables and indicators.

3.3.2 Population Description

The study performed a case study of Westlands region of Nairobi County. This is because Westlands offers a middle-income demographic setting with potential for EV uptake due to the presence of modern residential units, office buildings, shopping malls and recreational facilities. The location's proximity to Nairobi's CBD informs the traffic volumes in and out of the Central city at different times of the day and week.

3.3.3 Sampling Distribution

The target population for the study comprised of policymakers and relevant administrators in the Ministries of Energy, Environment and Forestry, Transport, and Infrastructure. Top administrators from pertinent Ministries, Departments, and Agencies were identified through a purposive sampling technique to offer primary data in cases where published secondary data may not be sufficient.

3.3.4 Dataset Description

The dataset required to train the model encompassed various features crucial for assessing the sustainability of e-mobility infrastructure. These features included the population index (Y), energy demand index (X), time range (T), and area of coverage (in square kilometres). Additionally, the dataset contained corresponding sustainability index (SI) scores to serve as the target variable for model training. Sample observations in the dataset included population density, electricity consumption patterns, timeframes representing short, medium, and long-term projections, and the geographical extent of e-mobility infrastructure coverage.

The dataset was managed to ensure data integrity and quality. Initially, data cleaning techniques were employed to remove any inconsistencies, errors, or missing values from the dataset. Subsequently, the dataset was organized into a structured format using spreadsheets.

3.3.5 Key Variables

The model required key variables such as the population index, energy demand index, time range, and area of coverage to make accurate predictions regarding the sustainability of e-mobility infrastructure. These variables served as crucial determinants of infrastructure sustainability, with population density indicating demand, energy consumption patterns reflecting usage, the timeframe providing context for projections, and the area of coverage defining the geographical extent of infrastructure deployment. Additionally, auxiliary variables such as charging station capacity, renewable energy integration, and grid stability further enhanced the model's predictive capabilities, providing a comprehensive understanding of the factors influencing e-mobility sustainability. To enable reliable model training and precise predictions, the majority of these variables were included in the dataset that was selected.

3.3.6 Hypothesis formulation

The study did not formulate any specific hypotheses to test. Instead, the objective was to establish infrastructural requirements and develop a predictive model for sustainable e-mobility ecosystems in Kenya. This approach was justified methodologically by conducting a comprehensive analysis of charging station capacities, geographical coverage, and demographic and energy demand indices. The study aimed to uncover patterns as well as flexibly adapt to the complexities of e-mobility infrastructure planning and modeling without the constraints of preconceived hypotheses. This methodology allowed for provision of a robust foundation for generating actionable insights and recommendations.

3.6 Validity and Reliability of Research Instruments

The amount to which the statements measure what they are intended to assess is referred to as validity. According to Kothari (2014), validity refers to the degree to which an indicator accurately gauges a measure, a direct assessment of how well the indication serves its objective. Both content and face validity were examined in the current investigation. A measure's content validity determines whether it is reflective of all the construct's features, as opposed to face validity, which examines whether the constructs seem to measure what they are intended to (Saunders et al., 2016). An expert opinion was sought to assess the legitimacy of both the face and the content. To demonstrate content validity, the interview guide was provided to the Supervisor and other experts in the research field who evaluated it and provided guidance and representativeness to guarantee that it assesses the variables. The vetting procedure resulted in the removal of all invalid questions from the interview guide.

The reliability of an approach corresponds to how consistently it evaluates a given phenomenon. If the measurement regularly yields the same result using the same methods and under identical circumstances, it is said to be reliable. To check on reliability of data, the study employed theoretical triangulation to assess consistency of results by cross verification with existing theories of different perspectives.

3.7 Utilization and Dissemination of the Findings

The adoption of the outcome of the study revolutionized the energy and transportation sector by developing a model that will inform a sustainable e-mobility ecosystem. The study was resourceful to the government's efforts to enhance uptake of e-mobility by ensuring accessibility of reliable charging infrastructure to power the sector. The model was a tool useful to policy makers as they derived informed and practical interventions. Additionally, the study informed potential investors and implementers of policies and strategies on considerations to support or oppose the investment into advancement of e-mobility in Kenya. The results also served as a resource for academicians and researchers who are considering conducting research pertinent to the subject area. As a result, the nation's corpus of knowledge increased, particularly on the implementation of interventions aimed at enhancing renewable energy uptake through promotion of e-mobility in Kenya.

As is well put by Gunn et al., 2022, the final, significant and critical phase in research is the presentation and communication of scientific findings to stakeholders. The study therefore focused on ensuring proper dissemination is done targeting the key stakeholders and beneficiaries. Graphs, charts and tables were employed to effectively communicate the results. The findings were presented in dissertation class lectures, published journal articles and/or conferences.

3.8 Risk and Benefit Analysis

Determining and characterizing risks aided in the study's achievement of objectives. Any potential challenges were found and addressed by the analysis. The likelihood for low-quality data is one of the main risks. It is accepted that errors, missing numbers, and discrepancies in the data could compromise the quality and dependability of the study conclusions. To mitigate this risk, a variety of data cleaning and preprocessing techniques were employed. The techniques contributed to improving the overall quality of the dataset, eliminating outliers, and guaranteeing data consistency.

3.9 Ethical Considerations

The study upheld the ethical standard of honesty and prevent plagiarism. Through reporting techniques, methods, results, and data as directly as possible, the study guaranteed objectivity. No information shall be invented, faked, or distorted. Through appropriately crediting sources using both in-text citations and referencing, the study further avoid plagiarism.

In an article by Gajjar (2013) on Ethical Considerations in research, it is evident that there are many ethical demands imposed on researchers(Gajjar, 2013). They need to adhere to governmental, institutional, and professional requirements for undertaking research. In this regard, the study was subjected for review by the Strathmore University's Scientific and Ethics Review Committee and thereafter seek for a Research License from NACOSTI. In addition, all respondents were appraised of their rights to participate in the study, to the extent allowed by law.

Chapter 4: Results and Analysis

4.1 Introduction

The study built on the Complex Proportional Assessment (COPRAS) model, that assesses the optimal location of electric vehicle charge stations based on economic, environmental, social, technical, political and traffic factors (Abdel-Basset et al., 2023). As per the model, the established Sustainable Infrastructure score is 0.293198. This averages different scores, including the sum of the beneficial factors (0.377020); sum of non-beneficial factors (0.125555); and the proportional significance of each of the selected locations (0.3770203).

4.2 Data Collection and Data Analysis

In this study, MATLAB was employed to develop and implement the mathematical model for sustainable e-mobility charging infrastructure. MATLAB's versatility and computational power make it an ideal choice for handling the intricacies of the model, enabling us to perform complex mathematical computations, simulations, and data analysis. The study leveraged MATLAB to derive meaningful insights, optimize the model parameters, and conduct simulations that aid in the evaluation of sustainable e-mobility infrastructure.

To effectively communicate and visualize the results and findings of our analysis, Tableau was utilized. Tableau's interactive and user-friendly data visualization capabilities allow for creation of compelling and insightful dashboards and visual representations of the model outcomes, facilitating a clear understanding of the sustainability of e-mobility charging infrastructure among stakeholders, policymakers, and the general public. These integrated tools, MATLAB and Tableau, worked in tandem to ensure a comprehensive and data-driven exploration of our research objective, enriching both the analysis and communication of our findings.

$$SI = ln\left[\left[\frac{Population\ Index\ (Y) x\ Energy\ Demand\ Index\ (X)}{Area\ of\ Coverage\ (Km^2)}\right] T\ (Time)\right] \quad \text{Equation 4.1}$$

The Sustainable Infrastructure Score (SI) as depicted in the mathematical expression above is a measure of how well the e-mobility charging infrastructure meets sustainability objectives. It considers factors related to the number of electric vehicles, charging station capacity, energy efficiency, coverage, population density, battery capacity, grid capacity, time horizon, and funding availability.

Where:

SI = Sustainable Infrastructure Score

and;

Table 4.1: Factors Considered in the SI Score equation

PE = Population of Electric Vehicles	*The number of electric vehicles in the region being considered*
C = Number of Charging Stations	*The total number of charging stations in the area*
CS = Charging Station Capacity	*It is the maximum number of vehicles a single charging station can serve*
E = Energy Demand per Vehicle	*The average energy consumption of each electric vehicle.*
R = Range of Electric Vehicles	*It is the maximum distance an electric vehicle can travel on a full charge.*
A = Geographical Coverage of Charging Infrastructure	*Geographical extent covered by the charging infrastructure*
P = Population Density	*Population density in the area*
B = Battery Capacity of Electric Vehicles	*Is the capacity of the electric vehicle's battery*
T = Time Horizon	*Represents the time period over which the sustainability is assessed or modelled.*

Descriptive statistics was used to give an overview of the different variables in the model and perform trend analysis. The weights and the intercept term were determined by using historical data and statistical techniques. The computations gave an idea of how much each variable contributes to the sustainable e-mobility infrastructure.

4.2.1 Infrastructural Requirements

The study sought to establish the infrastructural requirements for a sustainable e-mobility ecosystem. To this end, the sustainability score threshold was used to determine whether the infrastructure at present, including charging stations, charging station capacity and area coverage, is sustainable. A case of Westlands Sub-County, Nairobi, Kenya. This was then used as a basis to determine how much of each infrastructural attribute to increase or decrease at different time scales (between 5 to 15 years) in order to attain optimal sustainability. To obtain the sustainability score threshold, three variables were used, including population index, energy demand index, time range and area of coverage. Table 4.2 presents an overview of the variables alongside the respective data obtained.

Table 2.2: Data Overview for Westlands Sub-County

	Parameter	Details	Data
Population Index	PE = Population of Electric Vehicles	The number of electric vehicles in the region being considered	476
	C = Number of Charging Stations	The total number of charging stations in the area	6
	CS = Charging Station Capacity	It is the maximum number of vehicles a single charging station can serve	5
Energy Demand Index	E = Energy Demand per Vehicle	The average energy consumption of each electric vehicle.	0.2KWh/ Km
	R = Range of Electric Vehicles	It is the maximum distance an electric vehicle can travel on a full charge.	300km
	B = Battery Capacity of Electric Vehicles	Is the capacity of the electric vehicle's battery	50.3kWh
Area	A = Geographical Coverage of Charging Infrastructure	Geographical extent covered by the charging infrastructure	$25km^2$
Time	T = Time Horizon	Represents the time period over which the sustainability is assessed or modelled.	1, 5, 10, 15, year iterations

Population Index……………………......………………………………………………………….I

The study first computed the population index, by dividing the population of electric vehicles (PE) by the product of the number of charging stations (C) and charging station capacity (Cs) as given by the formula:

$$Y = \frac{PE}{C \times Cs} \qquad \text{Equation 4.2}$$

Y = 3.173

Energy Demand Index……………………….……………………………….……………….....………....II

The energy demand index was then computed by multiplying the Energy Demand per Vehicle (E) by the division of the Battery Capacity of Electric Vehicles (B) by the Range of Electric Vehicles Range of Electric Vehicles (R); by the population of electric vehicles (PE) as given by the formula:

$$\boldsymbol{X = E\,x\,\frac{B}{R}\,x\,PE} \qquad \text{Equation 4.1}$$

X = 15.96187

Time Range…………………………………………………………………….………….………….III

Sustinability and infrastructural automization was tested across 5 incremental time periods spanning 5 to 25 years. Across this time period, the population of electric vehicles was adjusted assuming a 58.3% annual growth rate in Kenya (KIPPRA, 2023; Autoparts East Africa, 2023). The number of charging stations was also incrementally adjusted following a 32.4% annual growth rate as per AfEMA (2023). An annual growth rate of 20.2% was further considered in adjusting for the charging station capacity across the time range (Autoparts East Africa, 2023).

Area of Coverage……………………………………………………….…………….…………….IV

Area coverage refers to the distance covered by the charging stations. At present the area covered by the existing charging stations in Westlands is 25km^2. This implies an average of 5KM^2 per charging station. Considering the current 6 charging stations and 32.4%. annual increment, the subsequent number of charging stations across the time range was multiplied by 5 to establish the projected area coverage.

Sustainable Infrastructure Score………………………………………………………………….V

The sustainable infrastructure score was computed by multiplying the division of the product of the population index (Y) and energy demand index (X) by the area of coverage; by the time range as given by the formula:

$$SI = ln\left[\left[\frac{Population\ Index\ (Y) x\ Energy\ Demand\ Index\ (X)}{Area\ of\ Coverage\ (Km^2)}\right] T\ (Time)\right]$$

As presented in Table 4.2, the results were log transformed to stabilize variance for statistical modeling and compared against the established minimum Sustainable Infrastructure score of 0.293198 as per Abdel-Basset et al. (2023). A decision was then made as to whether or not the current infrastructure is sustainable, based on whether or not the calculated SI Score was equal to or greater than the minimum score (0.29). As a general guideline, the calculated score should ideally be either equal to or nearing the minimum score, with a value falling between the range of zero (0) and one (1) (Abdel-Basset et al., 2023).

Table 4.3: Sustainable Infrastructure Score for Westlands Sub-County

Y	X	Area	Time Range	SI Score	Sustainability
15.867	15.962	25	Current	2.316 (>0.29 and >1)	Not Sustainable
11.796	62.491	65.5	5	4.030 (>0.29 and >1)	Not Sustainable
8.769	244.651	171.61	10	4.828 (>0.29 and >1)	Not Sustainable
6.519	957.809	450	15	5.339 (>0.29 and >1)	Not Sustainable

Results depicted in Table 4.3 indicate that the current EV infrastructural capacity (charging stations, charging station capacity and area coverage) is not sustainable. This is also the case in the short term (5 years), medium term (10%) as well as long term (15 years). The findings present a pessimistic outlook, indicating that the current state of electric vehicle (EV) infrastructure, including charging stations, their capacity, and the overall area coverage, does not meet the criteria for sustainability.

Moreover, the study assessed sustainability across different time frames—short term (5 years), medium term (10 years), and long term (15 years). Interestingly, the results consistently show that the existing EV infrastructure not only fails to meet but also falls short of the sustainability score threshold across all these timeframes. This weak sustainability performance suggests that the current infrastructure is poorly aligned with the anticipated growth in population, energy demand, and geographical expansion over the specified time periods. The negative outcomes underscore the inadequacy and insufficiency of the current EV infrastructure in Kenya, undermining the foundation for the country's e-mobility ecosystem. As such, these findings may serve as a valuable guide for policymakers and stakeholders in the continued development and enhancement of sustainable electric mobility solutions in Kenya.

4.3 Equation Model

The study set out to develop a model to determine the infrastructural requirements for a sustainable e-mobility infrastructure. To develop an equation model based on the findings and considering the given equation:

$$SI = ln\left[\left[\frac{Population\ Index\ (Y) x\ Energy\ Demand\ Index\ (X)}{Area\ of\ Coverage\ (Km^2)}\right] T\ (Time)\right]$$

Where:

- *SI* is the sustainability index,
- *Y* is the Population Index,
- *X* is the Energy Demand Index,
- *Area of Coverage* is the geographical coverage in square kilometres,
- *T* is time,

From the original equation, the sustainability index is a product of the Population Index, Energy Demand Index, and Time, divided by the Area of Coverage and log transformed to stabilize variance for statistical modeling. Given that the study has not found the current EV infrastructure to be sustainable, the equation cannot be adapted to reflect this:

$$SI = ln\left[\left[\frac{Population\ Index\ (Y) x\ Energy\ Demand\ Index\ (X)}{Area\ of\ Coverage\ (Km^2)}\right] T\ (Time)\right]$$

The model can be refined further by incorporating the specific findings from the study. Based on the data and resulting indices displayed in Table 4.2, and considering the rule of thumb that the sustainability score should be either equal to or approaching the minimum threshold of 0.29, with a value falling between the range of zero (0) and one (1), an equation model can be developed to determine the infrastructural requirements for a sustainable e-mobility infrastructure. The equation is first represented as follows:

$$SI = \left[\frac{Y\ x\ X\ x\ T}{Area\ of\ Coverage\ (Km^2)}\right]$$

To ensure the calculated score meets or exceeds the threshold (0.29), we can introduce a multiplier *k* to account for this threshold:

$$SI = k\ \left[\frac{Y\ x\ X\ x\ T}{Area\ of\ Coverage\ (Km^2)}\right]$$

In this model, *k* is a constant multiplier, and the sustainability index (SI) should be greater than or equal to the threshold for the infrastructure to be considered sustainable. The multiplier *k* helps adjust the scale of the equation to meet the specified threshold.

Using the provided data to determine the value of *k*. We can take the smallest set of values (representing the current infrastructure) and solve for *k*:

$$2.316 \times k = 0.29$$

$$k = \frac{0.29}{2.316}$$

$$k \approx 0.1255$$

So, the developed equation model for determining the infrastructural requirements for a sustainable e-mobility infrastructure is:

$$SI = 0.1255\ x\ \left[\frac{Y\ x\ X\ x\ T}{Area\ of\ Coverage\ (Km^2)}\right]$$

This equation incorporates the threshold condition and allows for calculation of the sustainability index for different scenarios based on the Population Index (*Y*), Energy Demand Index (*X*), Area of Coverage (Area), and Time Range (*T*). The calculated score should be compared against the threshold of 0.29 to assess sustainability.

4.4 Model Validation

In order to ensure the model aligns with the requirements and desires of stakeholders and fulfills its intended purpose, the study explored an alternative location within the broader Nairobi County. Subsequently, extensive data collection and analysis were conducted, specifically targeting the verification of the model's functionality.

4.4.1 Validation Case and Results

To validate the model, a different geographical location was selected within the larger Nairobi metropolis and pertinent data collected to be fitted into the model to test its practical applicability. To this end, Lang'ata Sub- County was selected as it is the second most populated with EV chargers totaling three (3) covering $15KM^2$. Table 4.4 summarizes the data obtained from Lang'ata Sub- County.

Table 4.4: Data Overview for Lang'ata Sub-county

	Parameter	Data
Population Index	PE = Population of Electric Vehicles	282
	C = Number of Charging Stations	3
	CS = Charging Station Capacity	5
Energy Demand Index	E = Energy Demand per Vehicle	0.2KWh/Km
	R = Range of Electric Vehicles	300km
	B = Battery Capacity of Electric Vehicles	50.3kWh
Area	A = Geographical Coverage of Charging Infrastructure	$13km^2$
Time	T = Time Horizon	1, 5, 10, 15, year iterations

The data fitted in the validation model is as summarized in Table 4.4.

Table 4.5: Sustainable Infrastructure Score for Lang'ata Sub-county

Y	X	Area	Time Range	SI Score	Sustainability
18.8	9.456	13	Current	0.540(>0.29 and<1)	Sustainable
13.976	37.022	34.06	5	2.255 (>0.29 and >1)	Not Sustainable
10.390	144.940	89.237	10	3.053 (>0.29 and >1)	Not Sustainable
7.724	567.442	233.802	15	3.564 (>0.29 and >1)	Not Sustainable

As illustrated Table 4.5, the calculated sustainability index score of 0.540 slightly exceeds the specified threshold of 0.29 and is less than the upper limit of one (1), indicating that the current infrastructure is considered slightly sustainable for the given population, energy demand, and coverage area. In the short term, the calculated sustainability index score of 2.255 is well above the threshold, suggesting that the infrastructure will not be sustainable in the near future with increased population, energy demand, and expanded coverage within the next 5 years. In the medium term, the calculated sustainability index score of 3.053 indicates that the infrastructure is expected to remain unsustainable over the next 10 years, considering the projected changes in population, energy demand, and coverage area. In the long-term, the calculated sustainability index score of 3.564 suggests that the infrastructure is not projected to remain sustainable even in the long term, accounting for significant changes in population, energy demand, and expanded coverage. This is therefore a clear indication of the need to have strategies and policies to meet the infrastructure threshold for sustainable electromobility.

The findings from Lang'ata Sub-county support the practical applicability of the developed equation model for assessing the sustainability of e-mobility infrastructure. The calculated sustainability index scores do not consistently meet the specified threshold, suggesting that the infrastructure in Lang'ata Sub-county may not be projected to be sustainable across different timeframes, considering the anticipated changes in population, energy demand, and coverage area. This validation enhances the credibility and reliability of the developed model for assessing e-mobility infrastructure sustainability.

4.4.2 Model Simulation and scenario development

To verify the model's credibility, a further validation step entailed simulating a range of random variable values. This approach, detailed in Table 4.6 below, vividly portrayed diverse scenarios. Through these simulations, the study illuminated the intricate relationships among infrastructure requirements pivotal for ensuring the sustainability of electromobility infrastructure.

Table 4.6: Data on Scenario Development

Population of Electric Vehicles (PE)	Number of Charging Stations, C	Charging stations capacity (CS)	Population Index, Y= PE/(C x Cs)	Energy Demand per Vehicle, E	Range of Electric Vehicle (R)	Battery Capacity of EV(B)	Energy Demand Index, X=E x B/R x PE	Area (Km2)	Population Index (Y) * Energy Demand Index (X)/Area (Km2)	Sustainability Infrastructure (SI) Score				
										Year 1	Year 5	Year 10	Year 15	Year 20
100	1	2	50	0.2	300	50.3	3.353333333	10	16.76666667	2.819392788	4.428830701	5.121977881	5.52744299	5.815125062
300	2	4	37.5	0.2	300	50.3	10.06	25	15.09	2.714032273	4.323470185	5.016617366	5.422082474	5.709764546
350	4	8	10.9375	0.2	300	50.3	11.73666667	120	1.069748264	0.067423353	1.676861266	2.370008446	2.775473555	3.063155627
380	8	16	2.96875	0.2	300	50.3	12.74266667	25	1.513191667	0.414221107	2.023659019	2.7168062	3.122271308	3.40995338
476	6	5	15.86666667	0.2	300	50.3	15.96186667	25	10.13046471	2.315547192	3.924985104	4.618132285	5.023597393	5.311279466
1000	12	10	8.333333333	0.2	300	50.3	33.53333333	300	0.931481481	-0.07097897	1.538458943	2.231606124	2.637071232	2.924753304
1500	24	20	3.125	0.2	300	50.3	50.3	25	6.2875	1.838563535	3.448001448	4.141148628	4.546613737	4.834295809
1700	1	6	283.3333333	0.2	300	50.3	57.00666667	222	72.75625626	4.287114899	5.896552811	6.589699992	6.9951651	7.282847173
1800	2	8	112.5	0.2	300	50.3	60.36	25	271.62	5.604404031	7.213841943	7.906989124	8.312454232	8.600136304
2000	3	10	66.66666667	0.2	300	50.3	67.06666667	121	36.9513315	3.609601682	5.219039594	5.912186775	6.317651883	6.605333955

Drawing from the findings above, it is evident that EV population growth and rising energy demands directly impact sustainability. Expanding the number of charging stations and their capacity without a proportional increase in the electric vehicle (EV) population diminishes the sustainability score. This underscores the critical necessity for meticulous planning to avert overinvestment in electromobility infrastructure without anticipating demand. Such foresight is imperative to prevent the emergence of white elephant projects.

Chapter 5: Discussion

5.1 Introduction

The chapter delves into the comprehensive analysis and interpretation of the study's findings, focusing on the establishment and validation of infrastructural requirements for a sustainable e-mobility ecosystem. Through rigorous examination of charging station capacities, geographical coverage, and the development of a predictive model, this section elucidates the implications of the study's findings. The Discussion sheds light on the current state of e-mobility infrastructure, its alignment with sustainability goals, and avenues for future research and action.

5.2 Discussion

The discussion is thematically structured into three sub-sections, based on the study objectives. These include infrastructural requirements for a sustainable e-mobility ecosystem; a model to determine the infrastructural requirements for a sustainable e-mobility infrastructure; and model validation.

5.2.1 Infrastructural Requirements for a Sustainable E-Mobility Ecosystem

The study set out to establish the infrastructural requirements for a sustainable e-mobility ecosystem. Through a comprehensive analysis of charging stations, their capacities, and geographical coverage, the study yielded significant insights into the current state of e-mobility infrastructure and its alignment with sustainability goals. Results depicted indicate that the current EV infrastructural capacity (charging stations, charging station capacity and area coverage) is sustainable (SI=2.316 (>0.29)). This is also the case in the short term (5 years) (SI=4.030 (>0.29)), medium term (10%) (4.828 (>0.29)) as well as long term (15 years) (5.339 (>0.29)).

The findings indicate a negative outlook, with the existing electric vehicle (EV) infrastructural capacity deemed sustainable across various metrics. Notably, the sustainability index (SI) scores consistently discredit the established threshold of 0.29, affirming the current infrastructure lacks robustness and adequacy in addressing the demands of a growing population and evolving energy landscape. This suggests that the infrastructural foundation for sustainable e-mobility already in place is laying the groundwork for further development and expansion of electric mobility solutions in the region in order to meet the existing and growing demand.

The study's findings underscore the importance of proactive planning and investment in e-mobility infrastructure to accommodate the projected growth in electric vehicle adoption and usage. Through demonstrating the sustainability of the current infrastructure, policymakers and stakeholders are encouraged to prioritize strategic investments in charging stations, grid infrastructure, and supportive policies to ensure continued sustainability and resilience. Moreover, the study's validation of the developed equation model further enhances its utility as a decision-making tool for guiding future infrastructure development initiatives. The model provides a reliable framework for assessing the infrastructural requirements for sustainable e-mobility, facilitating informed decision-making and resource allocation to meet evolving transportation needs.

Furthermore, the study's validation of the model in a different geographical location, such as Lang'ata Sub-county, highlights the versatility and applicability of the developed framework across diverse urban contexts. The consistent sustainability index scores obtained from Lang'ata Sub-county validate the effectiveness of the model in predicting and evaluating the sustainability of e-mobility infrastructure, further reinforcing its practical utility for policymakers and urban planners. This validation not only strengthens the credibility of the model but also provides valuable insights into the specific infrastructural requirements and challenges faced by different regions, guiding tailored interventions and investments to address local needs effectively.

5.2.2 A Model to Determine the Infrastructural Requirements for a Sustainable E-Mobility Infrastructure

The study also sought to develop a model to determine the infrastructural requirements for a sustainable e-mobility infrastructure. To this end, the model was refined further by incorporating the specific findings from the study. To ensure the calculated score meets or exceeds the threshold (0.29), a multiplier *k* was introduced to account for this threshold:

$$SI = k \left[\frac{Y \, x \, X \, x \, T}{Area \ of \ Coverage \ (Km^2)} \right]$$

Using the provided data to determine the value of k. The smallest set of values (representing the current infrastructure) was taken to solve for k, yielding 0.1255. The developed equation model for determining the infrastructural requirements for a sustainable e-mobility infrastructure is thus:

$$SI = 0.1255\ x\ \left[\frac{Y\ x\ X\ x\ T}{Area\ of\ Coverage\ (Km^2)}\right]$$

The development of the equation model represents a significant advancement in the field of e-mobility planning and infrastructure development, offering policymakers and stakeholders a valuable tool for informed decision-making and strategic planning. Through quantifying the infrastructural requirements for sustainable e-mobility, the model facilitates targeted investments, resource allocation, and policy interventions aimed at promoting the growth and resilience of electric mobility solutions. Moreover, the validation of the model in a different geographical location, such as Lang'ata Sub- County, further underscores its practical applicability and versatility across diverse urban contexts, enhancing its credibility and utility for guiding infrastructure development initiatives.

Furthermore, the equation model provides a scalable and adaptable framework that can accommodate evolving socio-economic and environmental factors influencing e-mobility infrastructure sustainability. Through incorporating variables such as population growth, energy demand, and temporal considerations, the model offers a dynamic approach to infrastructure planning that can respond to changing needs and priorities over time. This flexibility enables policymakers to anticipate future challenges and opportunities, proactively shaping the trajectory of e-mobility development to meet long-term sustainability goals.

5.2.3 Model Validation

The study further sought to validate the performance of the model. To this end, a different geographical location was selected within the larger Nairobi metropolis and pertinent data collected to be fitted into the model to test its practical applicability. To this end, Lang'ata Sub-County was selected. The calculated sustainability index score of 0.540 (>0.29) indicates that the current infrastructure is approaching the sustainability score for the given population, energy demand, and coverage area. In the short term, the calculated sustainability index score of 2.255 (>0.29) suggests that the infrastructure is not sustainable with increased population, energy demand, and expanded coverage within the next 5 years which is in the same case with the medium term, over the next 10 years and in the long-term.

The validation of the model in Lang'ata Sub-county within the larger Nairobi metropolis serves as a crucial step in assessing its practical applicability and effectiveness in diverse urban contexts. The calculated sustainability index scores for Lang'ata Sub-county provide valuable insights into the performance and resilience of e-mobility infrastructure in this specific geographical area. With a sustainability index score of 0.540 (>0.29), indicating sustainability of the current infrastructure, Lang'ata Sub-county exemplifies the model's ability to accurately assess the sustainability of e-mobility infrastructure based on local demographic, economic, and spatial factors. This suggests that the infrastructure in Lang'ata Sub-county is currently well-equipped to meet the transportation needs of its population while remaining environmentally sustainable, highlighting the importance of localized infrastructure planning and development.

Moreover, the model's projections for the short, medium, and long terms in Lang'ata Sub-county provide valuable insights into the future sustainability of e-mobility infrastructure under varying scenarios. These findings underscore the robustness and adaptability of the model in predicting the long-term sustainability of e-mobility infrastructure, accounting for changes in population dynamics, energy demand patterns, and geographical coverage areas.

Furthermore, the validation of the model's performance in Lang'ata Sub-county reinforces its practical utility as a decision-making tool for policymakers, urban planners, and stakeholders involved in the development and management of e-mobility infrastructure. Through providing accurate assessments of infrastructure sustainability, the model enables informed decision-making and resource allocation, guiding strategic investments and policy interventions to support the growth and resilience of electric mobility solutions in urban areas. Additionally, the model's validation in a real-world setting enhances its credibility and reliability, instilling confidence in its ability to guide sustainable infrastructure development initiatives across different geographical locations.

Simulating a range of random variable values vividly portrayed diverse scenarios. Through these simulations, the study illuminated the intricate relationships among infrastructure requirements pivotal for ensuring the sustainability of electromobility infrastructure.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

In this chapter, the study provides a concise summary of key findings and insights derived from the extensive analysis of charging stations, their capacities, and geographical coverage, the developed equation model and validation. Following the summary, the conclusion draws definitive insights, discussing the sustainability of the existing e-mobility infrastructure in Kenya and addressing the alignment with anticipated future demands. Lastly, the recommendations section outlines strategic suggestions for policymakers, stakeholders, and industry participants to further enhance and promote sustainable e-mobility, providing a roadmap for continued development and resilience in the evolving landscape of electric vehicle infrastructure.

6.2 Conclusion

The study underscores a negative outlook for the sustainability of the existing EV infrastructure in Kenya, establishing a robust foundation for a sustainable e-mobility ecosystem. The comprehensive analysis, incorporating charging stations, their capacities, and geographical coverage, reveals that the current EV infrastructural capacity is far beyond the established sustainability threshold (SI=2.316 (>0.29)). Notably, this discouraging trend persists across varying timeframes, including the short term (5 years), medium term (10%), and long term (15 years), with sustainability indices consistently exceeding the stipulated threshold (SI=4.030, 4.828, and 5.339, respectively). These findings highlight the inadequacy and inflexibility of the current infrastructure to meet the evolving demands of a growing population, increasing energy demand, and expanding geographical coverage, casting doubt on the viability of Kenya's e-mobility ecosystem in fostering sustainable transportation solutions. Consequently, the study concludes that the existing EV infrastructure is ill-prepared to support and sustain the envisioned growth of electric mobility in Kenya over the foreseeable future.

The study's successful development of an equation model, utilizing a constant multiplier (k) determined to be 0.1255, represents a significant achievement in predicting and assessing the infrastructural requirements for a sustainable e-mobility ecosystem. The developed model not only aligns with the empirical data but also provides a practical tool for evaluating sustainability across different scenarios. The conclusively calculated value of k indicates the necessary adjustment to ensure the sustainability index (SI) adheres to the predetermined threshold, underscoring the model's robustness in accommodating varying factors such as population index (Y), energy demand index (X), time range (T), and area of coverage. This equation provides stakeholders and policymakers with a reliable framework to gauge and plan for the sustained growth of e-mobility infrastructure in Kenya, thus fostering informed decision-making in the pursuit of a resilient and environmentally friendly transportation landscape.

The study's validation of the developed model through data from Lang’ata Sub- County signifies its practical applicability and effectiveness in assessing the sustainability of e-mobility infrastructure in diverse geographical contexts. The calculated sustainability index scores for Lang’ata Sub- County consistently surpass the established threshold of 0.29, affirming the model's ability to accurately predict and evaluate the sustainability of electric vehicle infrastructure. The findings underscore the versatility and reliability of the model, reinforcing its utility as a valuable decision-making tool for policymakers, urban planners, and stakeholders involved in the development and enhancement of e-mobility infrastructure.

6.3 Recommendations

To ensure the continued sustainability of the e-mobility ecosystem, policymakers should prioritize integrated planning and investment strategies. This involves collaboration between government agencies, private sector stakeholders, and urban planners to develop a cohesive framework that addresses not only the current needs but also anticipates future demands. Strategic investments in charging infrastructure, taking into account the findings from the developed model, should align with urban development plans to ensure accessibility, coverage, and scalability. Integrating electric mobility considerations into broader transportation and urban planning initiatives facilitated a seamless transition towards sustainable transportation solutions.

Policymakers should explore mechanisms to incentivize and support technological innovation within the e-mobility sector. This includes offering financial incentives, tax breaks, or subsidies for businesses engaged in the development of advanced charging technologies, energy storage solutions, and smart grid integration. Encouraging innovation not only fosters a competitive market but also accelerates the evolution of sustainable and efficient electric vehicle infrastructure. Collaborations between the public, County Governments and private sectors, academia, and research institutions can further drive technological advancements, positioning the region at the forefront of cutting-edge e-mobility solutions.

Establishing clear and supportive regulatory frameworks is critical for the effective deployment and operation of e-mobility infrastructure. Policymakers should work towards creating standardized regulations that cover aspects such as permitting, safety standards, interoperability of charging stations, and fair market competition. A clear and predictable regulatory environment instills confidence in investors and facilitates the smooth operation of charging networks. Additionally, governments should consider adopting international standards to promote compatibility and interoperability, ensuring a seamless experience for electric vehicle users and fostering a more interconnected and efficient e-mobility ecosystem.

To accelerate the adoption of electric vehicles and enhance public acceptance of e-mobility infrastructure, policymakers should invest in public awareness campaigns and educational initiatives. These campaigns can highlight the environmental benefits of electric vehicles, dispel myths about range anxiety, and promote the convenience and cost-effectiveness of sustainable transportation. Furthermore, educational programs should target both consumers and businesses, providing information on the benefits of electric mobility, available incentives, and the evolving landscape of e-mobility technologies. By fostering a positive public perception and awareness, policymakers can contribute to the broader societal shift towards sustainable and environmentally friendly transportation practices.

6.4 Suggestions for Further Research

The present study sought to develop a model to determine the infrastructural requirements for a sustainable e-mobility infrastructure in Kenya. This was with a focus on Westlands Sub-county, which is an urban area. Future studies could focus on rural areas for comparison purposes. Further, in-depth studies on the integration of renewable energy sources into EV charging infrastructure, as well as the development of smart grid technologies, could contribute to a more comprehensive understanding of the environmental sustainability of e-mobility.

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Appendix A: Timeline of Activities

Activity	2022			2023												2024			
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	April	May	June	July	Aug	Sep	Oct	Nov.	Dec.	Jan.	Feb.	Mar.	April
Choice and approval of the Research Topic																			
Background, statement of problem and objectives																			
Theoretical, Empirical review and Conceptual framework																			
Research methodology and instruments																			
Proposal Defense																			
Submission for Ethical Review																			
Amendments as per ethics review																			
Research Permit Approval																			
Data Collection																			
Data analysis and interpretation																			
Report writing																			
Submission of report for final defense																			

Appendix B: Consent Form and Data Collection Tools

If you require any further information, please contact Mr. David Amiani on 0728 914 181, a postgraduate student at Strathmore University, School of Computing and Engineering Sciences.

Please respond by selecting within the relevant box (Yes or No).

Consent on	**Yes**	**No**
I have been made aware of the study objectives and have been given the opportunity to raise questions concerning my involvement, and they were well addressed.		
I agree to participate in responding to the interview guided by the research team member.		
I willingly agree to participate in this investigation, and I am aware that I can decline to answer any questions with which I do not feel confident.		
I understand that I can leave the investigation by getting in touch with the researcher before data are analyzed, without having to give a reason.		
I am aware that the data I supply will be employed in academic research and publishing. I am aware that the data will only be disseminated in completely anonymous form.		
I am aware that the team conducting the research will not disclose any personally identifying information regarding me that may be employed to recognize me, including my job title or age.		
I recognize that my information (transcribed anonymously) will be kept securely in a Library and be used for academic purpose only.		
I agree to being quoted anonymously.		
I am aware that I may refuse to participate at any point in the course of the study		
I have been assured by the Researcher that my identity will be kept private and that there will be no sharing of my personal information including identifiers		

Appendix C: Budget

ITEM	AMOUNT
Typing, editing and printing	10,000
Data collection	20,000
Internet Services	15,000
Stationery, photocopies and binding	10,000
Miscellaneous	20,000
TOTAL	**65,000**

Appendix D: Letter of Transmittal

David Amiani,
P.O Box 50678-00100,
Nairobi, Kenya

29th August 2023

Dear Respondent,

RE: MODELLING A SUSTAINABLE E-MOBILITY INFRASTRUCTURE

I am a Postgraduate student at Strathmore University, School of Computing and Engineering Sciences pursuing a Master of Science Degree in Sustainable Energy Transitions. I am carrying out research entitled "*Modelling A Sustainable E-Mobility Infrastructure*."

Your participation in the study has been chosen, and your reaction will be much valued. Please see attached, an informed consent for your action.

Yours Sincerely

David Amiani

Appendix E: Ethical Approval

Strathmore UNIVERSITY

22nd November 2023

Mr Amiani David Mukisira,
david.amiani@strathmore.edu

Dear Mr Amiani,

RE: Modelling a Sustainable Electromobility Infrastructure

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** research proposal. Your application reference number is **SU-ISERC1857/23.** The approval period is from **22nd November 2023 to 21st November 2024.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) https://research-portal.nacosti.go.ke/ and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC

STRATHMORE UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICAL REVIEW COMMITTEE
(SU-ISERC)
22-Nov-2023
Email:ethicsreview@strathmore.edu
P.O BOX 59857-00200
NAIROBI-KENYA

Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000
Email admissions@strathmore.edu www.strathmore.edu

Appendix F: Research License

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **127758**

Date of Issue: **13/December/2023**

RESEARCH LICENSE

This is to Certify that Mr.. David Mukisira Amiani of Strathmore University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: Modelling a Sustainable Electromobility Infrastructure for the period ending : 13/December/2024.

License No: **NACOSTI/P/23/32049**

127758

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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See overleaf for conditions

Appendix G: Similarity Index Report

22.03.2024 Emobility Thesis.pdf

독창성 보고서

20%	17%	14%	8%
유사성 지표	인터넷 출처	출판물	학생 보고서

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