THE CHALLENGES OF A DEVELOPING NATION TRANSITIONING TO GREEN TRANSPORTATION IN SOUTH AFRICA

by
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DECLARATION

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ABSTRACT

Transportation is the key driver of socioeconomic development. From a planning perspective, transportation creates networks, nodes, and corridors to increase the goods and services exchanged and consumed in an economy. Green transportation is gaining significance in the view of the public due to awareness that emissions and pollution from internal combustion engines ought to be addressed. This is of particular interest in the built environment to more efficiently distribute resources in society and ensure sustainability. In South Africa, the study analyses the viewpoints of the key stakeholders in industry and government to define the emergence of a nascent green transportation industry, to understand the current state of affairs on green transportation transitions, and the challenges and bottlenecks in establishing green transportation technology in South Africa. The study also critically analyses the effect of current policy on new energy vehicles.

The study finds that there is a disconnect between the vision for green transportation in the built environment and the design standards and legislation implemented. Top-down proposals do not correlate with bottom-up regulations. Most policy is vague and uncertain on how to correlate taxes, subsidies, levies, infrastructure, and manufacturing regulations to protect the existing motor export industry whilst transitioning to green transportation technology. The key to green transportation transitions is to stimulate local new energy vehicle component production so that these vehicles can become more affordable to users in South Africa. This requires updating urban planning and design standards, the engagement of civic groups in a green technology micro-economy, adapting outdated policies, and strengthening local research in green technology. Most important is that the decisions must be just, creating additional jobs and economic growth with the future decline in demand for internal combustion engine vehicles.

OPSOMMING

Vervoer is 'n hoofdrywer van sosio-ekonomiese ontwikkeling. Vanuit 'n beplannings-perspektief skep vervoer netwerke, nodusse en korridors om die uitruil en verbruik van goedere en dienste te verhoog. Die onderwerp van groen vervoer is besig om betekenis te ontvang in die publiek as gevolg van die bewustheid dat binnebrandenjin emissies en besoedeling aangespreek behoort te word. Hierdie is van besondere belang in die bouomgewing om hulpbronne meer doeltreffend in die samelewing te versprei en volhoubaarheid te verseker. In Suid-Afrika, ontleed die studie die standpunte van die sleutelbelanghebbendes in die industrie en die regering om die ontstaan van 'n ontluikende groen vervoerbedryf te definieer, om die huidige stand van sake oor groen vervoeroorgange te verstaan, en die uitdagings en knelpunte in die stiging van groen vervoertegnologie in Suid-Afrika te verstaan. Die studie ontleed ook die effek van huidige beleid op nuwe energievoertuie op ‘n krities manier.

Die studie bevind dat daar 'n skeiding is tussen die visie vir groen vervoer in die geboude omgewing en die ïmplementering van ontwerpstandaarde en wetgewing. Bo-na-onder-voorstelle korreleer nie met onder-na-bo-regulasies nie. Die meeste beleid is vaag en onseker oor hoe om belastings, subsidies, heffings, infrastruktuur en vervaardigingsregulasies te korreleer om die bestaande motoruitvoerbedryf te beskerm terwyl daar oorgeskakel word na groen vervoertegnologie. Die sleutel tot groen vervoeroorgange is om die plaaslike produksie van nuwe energievoertuigkomponente so te stimuleer dat hierdie voertuie meer bekostigbaar vir Suid-Afrikaanse gebruikers kan word. Dit vereis die opdatering van stedelike beplanning en ontwerpstandaarde, die betrokkenheid van burgerlike groepe in 'n groen tegnologie mikro-ekonomie, die aanpassing van verouderde beleide en die versterking van plaaslike navorsing in groen tegnologie. Die belangrikste is dat die besluite regverdig moet wees, wat bykomende werksgeleenthede en ekonomiese groei moet skep ten midde van die toekomstige afname in die aanvraag na binnebrandenjinvoertuie.

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"To doubt everything or to believe everything are two equally convenient solutions; both dispense with the necessity of reflection."

-Henri Poincaré

"Strong views, loosely held"

-Marc Andreeson

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APPENDICES

ACRONYMS AND ABBREVIATIONS

GIS	Geographical information systems
GPS	Global positioning systems
APDP	Automotive Production and Development Programme
SADoT	South African Department of Transport
CoCT	City of Cape Town
CNG	Compressed Natural Gas
IPAP	Industrial Policy Action Plan
GTS	Green Transport Strategy for South Africa 2018 – 2050
NDP	National Development Plan
PPFA	Procurement Policy Framework Act
OEM	Official Equipment Manufacturer
USD	United States Dollar
SAAM	The South African Automotive Masterplan 2021 – 2035
GABS	Golden Arrow Bus Service
MSRP	Manufacturers Suggested Retail Price

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Transportation is one of the leading sectors responsible for greenhouse gas (GHG) emissions. South Africa committed to transition to a low-carbon economy in the next decade as part of the Paris Agreement (Dane et al., 2019). The overall goal for developing nations like SA is to create a net-zero carbon economy with a decent growth rate and continued job creation by 2050 (Perez, 2019). Indications are that South Africa's transportation sector needs to decarbonise if climate targets are to be met.

In the past few years, there has been a boom in alternative, more sustainable vehicles. There has also been a significant adoption of green technologies by consumers and yet the response by authorities has been mostly reactionary. Green transportation refers to the use of modes and systems of transportation that are less harmful to the environment than more conventional internal combustion engine (ICE) vehicles. This entails the use of alternative fuels, vehicles, and transportation infrastructure to reduce greenhouse gas emissions in air pollution, and other detrimental environmental effects related to mass transit (IPCC, 2020). These modes include modes such as public transit, biking and walking, carpooling and ride-sharing, electric bikes and scooters, hybrid and alternative fuel vehicles, green logistics, and sustainable aviation fuels. Green transport has a number of benefits, including reduced greenhouse gas emissions, enhanced air quality, greater energy security, and more sustainable urban development (IPCC, 2020). As a result, numerous governments and organisations are driving the use of green transportation through various laws, incentive schemes, and large-scale infrastructure expenditures.

There is, however, a misunderstanding regarding green transitions in South Africa. It seems as if the transition to green transportation in SA is challenged by inflexible and dated legislation, the fallacy of sunk ICE infrastructure costs, undeveloped consumer demand for green transportation vehicles, high excise duty tariffs on imported green transportation vehicles, a politically influential ICE motor vehicle industry which employs thousands and a lack of political will to drive the transition to green transportation modes (Kumalo, 2019). The Green Transport Strategy (GTS), which was approved by Cabinet in 2018, is currently the most

important legislation governing green transportation transitions in South Africa (Department of Transportation, 2018). It outlines the government's plan regarding combating greenhouse emissions and transitioning to green transportation with incentives and penalties. The rationale of this research is to explore the complexities and challenges regarding the implementation of sustainable green transportation projects. In particular, the study will evaluate the shortcomings in the regulations such as the legality of green vehicles, and a shortage of funding from fuel levies and the adjustment road accident fund. The research also intends to explore the contradictions between the GTS and other current legislation such as the Automotive Production and Development Programme (APDP) and Procurement Policy Framework Act (PPPFA) which is designed to protect and promote the ICE automotive industry in South Africa.

1.2 PROBLEM STATEMENT

The transportation industry was responsible for 14% of all CO2 emissions in 2019, according to the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2020). Road transportation, including cars, buses, and trucks, generates about 84% of all transport emissions, or 7.1 gigatonnes of CO2 (Black, 2010). In South Africa, 11% of all CO2 emissions are attributable to the road transportation industry, in line with global trends. This sector produces 43.8 megatons of CO2 (Department of Environment, Forestry and Fisheries, 2020). Moreover, current trends indicate that the road transportation sector's emissions are predicted to increase by 22% in 2030, because of rising demand for transport (IPCC, 2020). These trends present cities with a host of environmental challenges such as air pollution, health complications, and climatic effects. However, it also creates an opportunity to implement low-carbon urban development. To mitigate these environmental challenges and leapfrog to more efficient technologies, multi-modal vehicle systems such as electricity, biogas and hydrogen are developed using alternative and more sustainable forms of energy and powertrains.

Globally, the green transportation market is growing steadily, and within the private sector, a number of major vehicle manufacturers have pledged to stop producing ICE vehicles in the next few years (Agarwal, 2019). Within the public sector, governments have also pledged to develop incentives to reduce carbon emissions by promoting the procurement of vehicles that support those targets. However, there are major challenges in the transition to green

transportation, particularly around the economic viability of green transportation modes, low consumer demand for green vehicles and non-adaptive or inadequate regulations. These challenges can be categorised into policy, technical and social challenges of green transportation transitions.

South Africa is lagging behind the rest of the world in terms of green transportation transitions. As a developing nation, the dynamics of policy, technical, and social challenges in South Africa are much different to the global north. The capital and maintenance cost of green vehicles, in addition to refuelling and insurance premiums, is too expensive for the average commuter in South Africa. Moreover, South Africa lacks the transportation infrastructure to support green vehicles and until recently, South Africa lacked a use of green transportation strategy on which to base coherent investments in supporting infrastructure. The high premium cost of green transportation can be explained by inefficiencies in the green transportation market, which is yet to reach comparable economies of scale. As such, green transportation modes are mostly viewed as a niche market good and novelty, rather than the future of transportation. However, the experience in countries such as China and Norway, which have reduced the premium cost of green transportation by implementing adequate financial and non-financial incentives, indicates that it is possible to develop a green transportation strategy that would make adoption much more attractive to the end-user (Kumalo, 2019).

Although there is more awareness of climate change, consumer attitudes around green transportation adoption are not particularly strong in emerging markets (Agarwal, 2019). The general public's perceptions still regard more sustainable modes of transit as a novelty and not a necessity. According to Serna et al. (2021), who conducted a sentiment analysis on green transportation, a significant proportion of the population doesn't see green transportation as a viable transportation mode because of high capital costs, the lack of government incentives for green vehicles, and the low performance of green vehicles compared to ICEs. The regulatory environment concerning green transportation in South Africa is contradictory and not conducive to the uptake of green transportation (Murry and Koehring, 2019). The Southern African transportation regulatory environment is inextricably linked to other social and technical challenges and thus is a critical juncture point in the incremental adoption of green transportation. The primary challenge is that the ICE automotive industry is the largest manufacturing sector in South Africa's economy, employing about 900 000 skilled, semi-skilled, and unskilled employees and accounting for about 29.9% of the country's

manufacturing output in 2018 and over 14% of South Africa's total exports (Kumalo, 2019). Not surprisingly, there is a vested interest in protecting the country's own ICE automotive industry through tariffs and other mechanisms (Kumalo, 2019).

The focus of the study will be both the development and use of commercial and public vehicles that use more sustainable energy and powertrains, whether that be hybrid, plug-in hybrid, pure electric, or Hydrogen fuel cell New Energy Vehicles (NEVs) or biogas. The study will focus on the urban governance and management implications of transitioning to green transportation under current regulations and the dynamics that play out with stakeholders. The study aims to gain a deeper insight into the challenges, motivations, and frustrations of the stakeholders involved in the city of Cape Town (CoCT). The research prompts the need to investigate literature related to the challenges and shortcomings in the implementation of green transportation modes in developing countries, such as South Africa.

1.3 HYPOTHESIS

The major problem is that currently there is no clear regulatory path conducive to the transition to green transportation modes. Several commitments are being made by the government and private sector to reduce climate emissions, which does not necessarily clearly translate into green transportation policies. According to the Murry and Koehring (2019), South Africa remains wedded to the notion of the development state, with steep tariffs that are hampering the green transportation transition. This is coupled with not having the industrial capacity to develop the large-scale local production of green transportation vehicles. The development state usually protects its local market until it can compete with the international free markets. Moreover, the automotive industry is an employer of several members of trade unions who advocate for a more conservative and less comprehensive green transition in niche markets (Murry and Koehring, 2019).

The local automotive market is currently protected by a range of protectionist regulations. However, a significant number of these incentives are currently being phased out and the tax revenues government receives from the transportation sector should be redirected to green

transportation public goods that could benefit a lot more people. There are not many incentives available in South Africa that would attract Official Equipment Manufacturers (OEMs) or private companies to bring foreign direct investment to South Africa and develop the capacity the develop local industrial capacity. In addition, the reliability of infrastructure such as the national electrical grid is a concern, as electrical vehicles can only be efficiently produced with a stable electrical infrastructure network (Kumalo, 2019). Moreover, other green transportation modes such as biofuel or biogas, which are less dependent on electrical generation, also require other forms of infrastructure.

1.4 RESEARCH AIM AND OBJECTIVES

The study aims to gain deeper insights into the challenges and shortcomings in the green transportation transition for a country such as South Africa. This research topic explores green transportation transitions in South Africa, with a particular focus on the intersection between privately funded green transportation initiatives. The research aim is to understand the policy, social, and technical challenges to green transportation from a planning perspective. The policy analysis seeks to understand whether the current regulations surrounding green transportation in South Africa are conducive to the incremental transition to green transportation in South Africa. The study also analyses the social challenges by evaluating the social perceptions of the public regarding green transportation in South Africa. Technical challenges evaluated in this study include the economical and operational challenges in the transition to green transportation in South Africa.

To achieve the research aim, the study implements the following objectives:

- A literature review highlighting the Sub-Saharan context of the intricacies and challenges at play in the green transportation transition. Sub-themes include literature on infrastructural challenges to the transition to a techno-economic paradigm of green transportation, the challenges of the public perception of green transportation from a developing country point of view and technical aspects of green transportation uptake, the challenges of planning green transportation for sustainable cities, and green transportation in South African transportation policy.

- To determine what technical challenges are hampering the adoption of green technologies in existing multimodal fossil fuel systems from stakeholder interviews.
- To evaluate the public perceptions and sentiments of social and cost considerations of green transportation transitions.
- To determine the challenges of planning for green transportation transitions in South Africa and elsewhere.
- To critically analyse available policy regarding the incremental multi-modal green transportation transitions parallel to existing ICE systems.

1.5 RESEARCH QUESTIONS

- What are the technical challenges of integrating green technologies in existing multimodal fossil fuel systems?
- Why are green transportation alternatives currently perceived as costly and socially not preferable in South Africa compared to ICE alternatives?
- What are the urban planning considerations surrounding the implementation of green transportation alongside ICE in SA?
- How can policy be improved to better facilitate incremental multi-modal green transportation transitions parallel to existing ICE systems?

1.6 RESEARCH METHODOLOGY

The research approach for the study is inductive. According to Bryman (2016), inductive research refers to a research approach whereby the theory is the outcome of the research. The process involves drawing generalisable inferences out of the available observations. The method will be primarily qualitative in the analysis of current green transportation policy in South Africa and survey questionaries from respondents who are stakeholders in a government, civil society, or private sector capacity. The study uses a qualitative research design, which

will involve interviews with stakeholders, a review of policy documents, and a case study within the city of Cape Town. The study contributes to the literature on green transportation by providing new insights into the challenges and shortcomings of the green transportation transition in South Africa. The study also makes recommendations for policy and practice that can help to overcome these challenges and shortcomings.

The first part of the research consists of an extensive literature review to gain a solid conceptual base of green transportation in developing countries and what that means for South Africa. For the second phase, primary and secondary research is conducted from collected data and interviews. The primary research consists of interviews with stakeholders from industry, government, and civil society. The purpose of these interviews is to understand and denote the challenges, frustrations, and recommendations of those stakeholders who work and deal with the transition to green transport. A questionnaire or survey was designed to prompt the participants to convey and explore the fundamental questions of the research problem. The primary research consists of interviews with relevant representatives from the public and private sectors in the green transportation space. For secondary research, the study also conducts a critical policy analysis of the green transportation strategy legislation to explore the key prescriptions and goals of green transportation and possible shortcomings in the current legislation.

1.7 STRUCTURE AND SUMMARY

The introductory chapter will introduce the research by providing a background, problem statement, and hypothesis about the research at hand. The literature review chapter will outline relevant literature for a developing nation such as South Africa and Sub-Saharan and present the literature intricacies, challenges, and solutions at play in the green transportation transition. Sub-themes will include techno-economic paradigms and public goods, technical aspects of vehicles and emissions. The research methodology chapter will outline the research design and which methodology was utilised in the process of conducting the research.

The research will mostly consist of qualitative data from questionnaires given to respondents and policy analysis. The policy and interview analysis chapter will delve into the current policy landscape of green transportation and assess its shortcomings as well as illustrate the findings

from questionnaires from the stakeholders from government, civil society, and the private sector. It attempts to understand the perceptions of professionals in the green transportation sector (government, private sector, and civil society groups) and the public at large.

The discussion chapter will expand on the previous chapter by providing international best practices and recommendations to close the gap for a more conducive regulatory landscape. The final chapter will look to bring together all the major points in the previous chapters in a well-formulated and concise conclusion. The conclusion is drawn from the findings of research on the challenges of introducing green transportation in South Africa.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION: THE CHALLENGE OF SUSTAINABLE GREEN TRANSPORTATION

Sustainable development has been defined by United Nations Brundtland Commission as development meeting the needs of the present generation while not jeopardising the needs of future generations. The successful application of sustainable development means setting goals, implementing practices, and measuring results that balance the facets of sustainable development - economic growth, environmental conservation, and social equity (Zietsman 2011). Considering the strong links between urbanisation and climate change, green transport should form a crucial facet of sustainable development in South Africa. However, due to its dependency on fossil fuel ICE transportation system, South Africa is a major emitter of greenhouse gases in sub-Saharan Africa (Department of Environment, Forestry and Fisheries, 2020).

Transportation is a key component in complex city systems, providing freedom to society in terms of mobility and convenience (Panday and Bansal, 2014). While the growth of modern society depends on efficient modes of transportation, the transportation sector also has a substantial role in emitting emissions. The greatest contributor to emissions in the average household is private vehicles (Froehlich et al. 2009). The number of vehicles on public roads is expected to triple by the year 2050, which will exacerbate the concentration of air and noise pollution in cities (Keyvanfar et al., 2018). With the overwhelming majority of vehicles dependent on fossil fuels, the transportation industry contributes significantly to the emission of CO2. Furthermore, increases in private vehicles lead to the increased consumption of fossil fuels (Balasubramaniam et al., 2017).

According to the International Energy Agency (IEA, 2018), the transportation sector accounts for a significant portion of global energy consumption (Panday and Bansal, 2019). This includes the entire transportation value chain, from the manufacturing of vehicle components to the energy production and consumption of fossil fuels. The high consumption of vehicular fossil fuels leads to emissions, which causes environmental pollution (Balasubramaniam et al., 2017). The use of fossil fuel energy in transportation is increasing over time as economies

expand and become more complex. Despite rising fuel prices, its use in transportation is increasing by an average of 1.4% per year and is expected to expand by 46% between 2008 to 2035 (Panday and Bansal, 2019). After the construction industry and energy generation sector, transportation is the third highest emitter of carbon emissions Carbon emissions from liquid fuel consumption worldwide increase by around 0.9% per year which results in an increment of 3.5 billion metric tonnes of CO2 from 2010 to 2040 (IEO, 2013).

Air pollution is a complex issue that requires a systemic approach and the involvement of multiple stakeholders to address the issue. Carbon emissions from developing countries are particularly problematic due to the vulnerability of their populations to the adverse effects of climate change (Ellram and Murfield, 2017). India, for example, is the fifth highest polluter globally with a 6% contribution to carbon emissions, which results in approximately 620,000 premature deaths annually due to air pollution-related diseases. With the growth of carbon emissions in developing countries the mortality rates are expected to grow even more in the coming decades (Panday and Bansal, 2019). Conventional public transportation modes require enormous amounts of energy to operate vehicles and consequently emit harmful gases causing environmental pollution and leading to health complications linked to toxic emissions in the form of carbon dioxide, carbon monoxide, nitrogen oxides, and unburned hydrocarbons (Ahmed and El Monem, 2019). The extensive utilisation of fossil fuels thus has a direct impact on the various health-related problems in the community (Grob, 2009). Furthermore, noise pollution from ICE vehicles penetrates all parts of life from disturbing residences and affecting work life to causing difficulties in public communication. Auto dependency also results in congestion in the form of congested street parking and visual interference with auto-scale advertising (Erdil, 2018).

Adopting an environmentally friendly mobility culture employing new technologies and fuel options is therefore the best solution to reduce emissions. There have been efforts to produce more environmentally friendly internal combustion engine (ICE) vehicles, and many countries have introduced stringent legislation and standards to reduce emissions (Panday and Bansal, 2019). However, green transportation is a key area of intervention to reduce emissions, considering that the global target is to reduce carbon emissions by 80% by 2050 (Balasubramaniam et al., 2017). Green transportation stresses that sustainable transportation modes should meet essential basic access and mobility requirements using methods that reduce environmental impacts but do not decrease the resource base on which it depends. Transitions

towards sustainable green transportation involve environmentally friendly vehicles using non-polluting technologies. Green transportation not only eases traffic congestion but also reduces urban pollution levels, by promoting the shift from vehicle-oriented to people-orientated transportation systems (Sanwal, 2015). Therefore, green transportation has become a significant priority in the recent shift to sustainable development (Chen and Lu, 2016).

There are several net positives to switching to green transportation. Firstly, researchers and industry experts find that green transportation will bring benefits such as fewer greenhouse emissions than the current status quo, as it will generate cost-effective and equitable transportation, improved health outcomes and increased quality of life, fewer road fatalities, and less pollution, less dependency on fossil fuels and a sustainable economy, similar to what Perez (2019) calls smart green growth. Secondly, governmental institutions can provide new green transportation initiatives and ensure that consumers or users accept these transportation practices. Most governments legitimately perceive the usefulness of green transportation (Chen and Lu, 2016). Perez (2019) refers to these as waves or surges that are characterised by an installation period, turning point, and deployment period. The emergent social, political, and technological changes in green transportation are indicative of a ‘sustainable golden age’ or sixth wave of innovation that is emerging as a possible long-term solution to achieving net-zero energy across the global economy (Perez, 2019). The socio-technical innovations of the so-called ‘sustainable golden age’ have the potential to reconfigure economies, to more sustainably and equitably produce and distribute resources across society.

Significant challenges shape the need for green transportation. These are classified to induce cultural shifts in the perception of green transportation, reforming social organisation in a manner that promotes alternative modes of transportation, addressing social equity issues of accessibility and cost, and environmental concerns (Erdil, 2018). These problems indicate that the transition from ICE motorcar dependency to green transportation is complex and involves more than just specific types of vehicles. It is not only focused on the detrimental effects on the environment and public health but is also concerned with the restructuring of spatial forms, transportation behaviour, and the location of amenities which cause a mass of environmental, economic, and social issues affecting the sustainability of urban environments (Erdil, 2018). Urban planning plays a crucial role in shaping the built environment and determining the quality of life for city dwellers. In recent years, there has been a growing emphasis on sustainable and environmentally friendly practices in urban planning, particularly in green

transportation. South Africa, with its rapidly expanding cities and increasing concern for environmental protection, presents a unique case study for exploring the intersection of urban planning and green transportation.

South Africa has enacted a number of laws and regulations to encourage environmentally friendly transportation. In order to reduce greenhouse gas emissions and advance sustainable development, the nation adopted the National Climate Change Response Policy in 2011 (Department of Environment, Forestry and Fisheries, 2020). The National Transport Policy of 2007 additionally encourages environmentally friendly mobility, such as the usage of non-motorised and public transportation (Department of Transport, 2007). While the South African government has pledged to cut its greenhouse gas emissions and support environmentally friendly transport in response to these difficulties, the absence of suitable infrastructure to enable alternate forms of transportation is one of the major challenges limiting green transportation transitions in South Africa. On the one hand, the lack of sufficient electric vehicle charging stations prevents private vehicle commuters from adopting alternate modes of transportation in South Africa, and the public transit network is insufficiently developed to enable mass green transit (South African National Energy Development Institute, 2020).

2.2 THE INFRASTRUCTURAL AND TECHNO-ECONOMIC TRANSITION TO GREEN TRANSPORTATION

Green transportation is an emergent overarching systemic solution that is one of the best candidates to solve some of the most complex transportation issues in developing countries, such as rising commodity prices, rapid urbanisation, high unemployment, and inequalities. This cannot be seen as a panacea to solve all social and environmental issues, but can be considered the next evolution to urban and regional transit and is gaining consensus from all spheres of society (Tao et, al, 2021). Green transportation uses fuel with the lowest pollution levels to power vehicles and is also the most equitable in providing low-cost solutions for personal transportation (Jumadi and Zailani, 2010). Lin et al. (2014) argue that green innovations can improve the efficiency and effectiveness of transportation across many sectors of the economy.

Green transportation is not only characterised by technological advancements. As transportation issues are complex, green transportation solutions require a multi-stakeholder

and transdisciplinary effort to have meaningful results (Perez, 2019). Green transportation is not only focused on implementing specific low-energy consumption technologies, but should also maximise the efficiency of transportation services, and thus increase the liveability and the quality of the urban environment (Erdil, 2018). Green transportation aims to lower the financial costs of transit by decreasing the reliance upon expensive fossil fuels. Green transportation therefore represents a paradigm shift in the way in which transportation is considered, organised, financed, and performed. This includes technological improvements such as fuel efficiency mechanisms, decreased emissions, and traffic movement control mechanisms (Erdil, 2018). The core significance of green transportation is its impact on non-motorised mobility and social interaction in the city. The public domain should be preserved and reconstructed to provide liveable, safe, connected, and peaceful cities for pedestrians. Green transportation strategies contain the following modes:

- Walking- involving walking, walking reinforcement devices such as handrails, and mobility reinforcement appliances such as wheelchairs;
- Bicycling;
- Green transportation vehicles, such as new energy vehicles (NEVs) that do not have an ICE powertrain;
- Public transportation or transit – involving electric buses, rail modes, shuttle services, taxis, and non-motorised jitneys;
- Supply chains—commercial use of vehicles in supply chain networks to deliver goods and service that is emissions net-zero, or conscious thereof by providing offsetting remediations; and
- Using energy-efficient and equitable types of personal motor vehicles—including automobiles, two-wheelers, buses, vans, and light trucks (Erdil 2018).

NEV is an emerging trend in green transportation. Norway, for instance, holds the largest per capita in the world fleet of plug-in electric vehicles, with a total of 52,865 plug-in electric vehicles registered in the country in 2015. Norway has set a target to have fleet-average CO2 emissions from new passenger cars of 85 grams per kilometre (10 grams below the intended 2020 EU target of 95 grams) by 2020. In Estonia, consumers are incentivised to switch to NEVs as the state provides free, readily accessible charging infrastructure for vehicles and a vehicle tax waiver (Bekiaris et al., 2016). Denmark and Sweden offer cross-subsidies for green

transportation adoption and inversely apply additional levies (taxes) on ICE vehicles to incentivise alternative fuel vehicle purchases to reduce emissions (Björklund, 2011).

Green transportation solutions are not only limited to hydrogen, hybrid, and electric vehicles but also include other intelligent green transportation initiatives such as constantly monitoring signal operations to provide the optimum time for the heaviest traffic movement and using chemically non-toxic de-icers that are harmful to streams and waterways. Mohareb and Felix (2017) suggest a framework of analysis that considers greening an important element of street design and accessibility features. They criticise the perceived conflict between public and private modes of travel, indicating that most street and transportation elements are shared between the movements of pedestrians and vehicles. For the critical mass of the population to adopt NEV, convenient and accessible smart charging stations ought to be planned. Smart infrastructure consists of sensitive and smart charging stations and billing and metering systems to facilitate the user (Panday and Bansal, 2019). The concept of two-way communication is employed to exchange such information. Infrastructure should be sensitive to collect/send the data between the grid and the user. Open access to data and sharing of Application Programming interfaces (APIs) is a critical component in this development since this enables decentralised users to link into the system. API creates infrastructure on the web that can be used in smart city developments along with Internet-of-things (IoT) devices.

As hybrid and electric vehicles are charged from power plugs for several hours, it places additional electricity demands on the grid. However, there have been recent advancements where quick charging technology can charge a vehicle within 30 minutes to an hour. This requires specialised equipment and conditions for utilisation. Since South Africa's and other developing countries' grids are currently unstable, developing countries ought to focus on securing generating power for NEVs through alternative energy sources like wind, hydro, and solar power to meet the demand on smart grids such as Vehicle to Grid (V2G) technology, where DC powered generators can directly recharge a vehicle from renewable energy (Panday and Bansal, 2019). The conventional modes of power generation may not sufficiently supply the demands for NEVs, requiring a sustainable energy mix combining renewables and large-scale storage as optimal solutions to supply induced demand. With the increase in the number of NEVs on the road, the power demand on the electrical grid will also increase.

The battery concept also works to balance ‘off-peak’ and ‘peak’ electricity demands for power outages. With this facility, during off-peak hours, a user can fulfil their household demands by storing power in batteries. During peak hours, when power demands are high, a user can sell battery power back to the grid and thus satisfy their own needs and others’ needs as well. Integrating the battery systems of hybrid and electric vehicles in smart grid projects has become a unique solution to the peak demand crisis (Morgan, 2012). Yet, smart grid technologies have the potential to supplement future power demands, which will support electrically driven transport, where electricity is generated from a vast number of renewable energy sources.

Technology markets are forward-looking mechanisms that are mostly influenced by sentiment. When we look at the automobile industry, we see that Tesla Motors’ market capitalisation is equivalent to the top 10 automakers’ market capitalisation with only a fraction of the sales. The disparity is quite remarkable and can be explained through Tesla’s motors’ intangible assets, which hold long-term value. The long-term value of green transportation systems enables the development of important patents of social significance in the automobile industry.

The biggest challenge in the establishment of green transportation is obtaining batteries and fuel cells for NEVs. There is no realistic short-term pathway to low-cost, mass-produced batteries and fuel cells to make electrical, hybrid, and hydrogen vehicles cost-competitive. The adaptation, dissemination, and penetration of hybrid vehicles is not a straightforward process. Batteries and fuel cells are for the most part heavy, expensive, and affected by atmospheric temperatures. Hence, an efficient battery management system is required. It needs an extended charging time and is sensitive to overcharging and undercharging (Panday and Bansal, 2019). Batteries contain toxic heavy metals while fuel cells are explosive; hence, the safe disposal of waste products becomes a challenge. A powerful energy support system for green transportation should be provided with extensive research in the domain of advanced electrodes, efficient electrolytes, and well-suited battery modelling (Joshi et al., 2006).

The high price of efficient batteries in hybrid and electric vehicles hikes the cost of NEVs. Due to their higher prices, these vehicles are not affordable for lower and middle-income groups, who comprise most of the population. The development of vehicle control strategies, a good battery management system, and less costly component utilisation can decrease purchase and operational costs. Governments should provide subsidies for purchasing and maintaining New Energy Vehicles (NEVs). Fuel saving is a very attractive feature of these vehicles and can be

compensated with tax relaxation and other incentives provided by the government. The involvement of features like ‘regenerative braking’ and ‘idle stopping’ will benefit the various components of the vehicles. Electric components in NEVs reduce the load on the engine and reduce its maintenance costs (Gajjar and Mondol, 2016).

It is also important to note that the fuel cell or battery is one of the most expensive components of NEVs. But despite its high capital costs, the maintenance of hydrogen, hybrid, and electric vehicles is relatively low due to the absence of an ICE. However, the fuel cell or battery that provides the power needed to drive the vehicle will need periodic updating. Within the private sector, technology autonomy is necessary. The principal argument for autonomy is that the freedom of individuals to adapt to different situations can reduce the difficulty of implementing green technologies (Chapin et al., 2013). A case in point is Luminar Technologies, providing scale turnkey hardware and software solutions for new-generation motor companies seeking to retrofit their vehicles with autonomous technology. Their propriety technology is fundamental to how automakers construct their vehicles (Verhage et al., 2017).

A lesser form of green transportation is biofuels. Biofuels refer to liquid, gas, or solid fuels derived from biomass (Pradhan and Mbohwa, 2014). According to Gajjar and Mondol (2016), biofuels are attractive because they provide a combustible fuel, but are derived from a sustainable source that is grown domestically and therefore assists energy security. On the other hand, biofuels do not reduce CO2 emissions, and therefore cannot be regarded as a true form of green transportation, but it is certainly more sustainable than the consumption of fossil fuels. Regarding the agricultural capacity to produce large-scale biofuels for widespread commercial use, South Africa has excess sugar cane and maize production that can be utilised for bioethanol production, but feedstock and used cooking oil is the major source of the biofuel. South Africa is currently a global leader in coal to synthetic oil production by Sasol. According to Pradhan and Mbohwa (2014), in 2011 South Africa produced approximately 16,000 and 4,770 litres of ethanol and bio-diesel per day, respectively. One negative externality is the mass proliferation of ‘cash crops’ that may be favoured over other species of plants to maximise profits, resulting in food insecurity (Gajjar and Mondol, 2016).

Regarding green public transportation in developing countries, there are a few best case studies, including electric Bus Rapid Transit (EBRT) in countries such as India and Colombia. The most successful electric or hybrid mass transit vehicle initiatives are found in China (Ahmed

and El Monem, 2019). BRT systems are designed to provide fast, reliable, and affordable public transportation while minimising the impact on the environment. EBRT systems have also been pioneered in South Africa, such as the MyCiti EBRT in Cape Town. Online Electric Vehicle (OLEV) buses operating in the city of Gumi in South Korea have been fitted with a wireless charging system to power an all-electric passenger bus (Bekiaris et al., 2016). The system wirelessly transfers power to OLEVs parked or in motion to extend the driving range and enhance the convenience of recharging.

South Africa has made considerable investments in environmentally friendly transport infrastructure. Several charging stations are already in use, and the nation has committed to investing in the infrastructure needed to support electric car use (South African National Energy Development Institute, 2020). South Africa has also made certain crucial investments in green public transit, such as electric buses and trains, which can lower the number of cars on the road and encourage more fuel-efficient commutes (Department of Transportation, 2007). However, South Africa faces a number of technical difficulties, including a lack of supporting infrastructure, negative public perception regarding the efficiency of NEVs, high investment costs, and overly restrictive legislation. Despite these obstacles, South Africa has made large investments in environmentally friendly transport infrastructure and put legislation into place to encourage sustainable green transportation in the future.

A great impediment in South Africa's transition to sustainable green transportation is its protectionist stance towards its local ICE Official Equipment Manufacturers (OEM) by adding tariffs up to 40% on imported electric and hybrid vehicles. Bryce (2008) observes that this is a short-sighted approach since the long-term cost reductions through more sustainable green transportation design, and maintenance, including planning, intelligent construction, and efficient evaluation techniques outweigh the short-term costs of green energy transitions. Eisenman (2008) also highlights that conventional ICE transportation systems do not adequately quantify the long-run environmental impacts such as runoff quantity, noise, materials, water quality, aquatic habitats, stormwater management design, and erosion and sediment control impacts, issues normally encountered in traditional highway construction.

The possibilities for green mobility in South Africa are optimistic notwithstanding these difficulties. The government's dedication to lowering carbon emissions and enhancing air quality is encouraging for the continued expansion of eco-friendly transportation options. A further indication that green transportation may soon become more accessible and affordable

is the growing availability of electric and hybrid cars along with falling battery prices (IEA, 2020).

There are numerous multi-stakeholder initiatives to address the challenges. The first is the Mobility Model (MoMo), a global transportation spreadsheet model that collects, historical data by mode, by fuel, and by region, and provides projections up to the year 2050. MoMo is divided into 29 regions covering all modes of transportation. It analyses the future fuel pathways and the impact of new technologies on energy use, GHG emission, vehicle cost, fuel prices, and other related matters (Panday and Bansal, 2019). The second is the Global Fuel Economy Initiative, a partnership between civil society groups and industry which includes the United Nations Environment Programme, International Transportation Forum, and Federation International Automobile Foundation. This initiative aims to improve fuel economy by decreasing carbon emissions to half by 2050 and seven up to 6 billion barrels of oil in production and emissions (Toro et al., 2015).

The third case is the Electric Vehicle Initiative which is an ongoing multi-government policy forum dedicated to the rapid introduction and adoption of NEVs worldwide. The Electric Vehicle Initiative is taken up by the Clean Energy Ministerial which involves the world's major economic and energy ministers including China, Denmark, Finland, France, Germany, India, Italy, Japan, the Netherlands, Portugal, South Africa, Spain, Sweden, the UK and the USA. It aims to deploy around 20 million NEVs including electric vehicles, hybrid vehicles, and fuel cell vehicles globally by 2020. The Electric Vehicle Initiative is planning to launch a 'World electric vehicle cities and ecosystems web portal' which will capture deployment progress all over the world. The IEA facilitates and coordinates the collection, analysis, and dissemination of the Electric Vehicle Initiative data (IEA, 2018). The Fourth case is the partnership on Sustainable, Low Carbon Transport which was formed to improve the knowledge of developing countries about sustainable, low-carbon transportation and to help them develop better green transportation policies. Over 50 organisations, including the United Nations, multilateral development banks, technical cooperation agencies, non-governmental organisations, and research organisations are a part of the partnership (Panday and Bansal, 2019).

2.3 PUBLIC PERCEPTIONS OF THE SOCIAL AND COST CHALLENGES OF GREEN TRANSPORTATION

Public opinion and the lack of consumer demand for environmentally friendly transport presents another difficulty. The International Energy Agency (IEA) researched to determine the level of public knowledge and comprehension of electric vehicles. Many consumers cited range anxiety, a lack of infrastructure for charging, and high upfront prices as hurdles to adoption (IEA, 2018). One of the major causes is that consumers are not aware of the advantages of environmentally friendly transportation options like electric cars (EVs) and hybrid automobiles in terms of the environment, human health, and long-term costs (CSIR, 2020). The lack of understanding of the advantages of green transportation makes it challenging to win over the public to green transportation efforts. Chen and Lu (2016) highlight the three features of public perceptions that need to be satisfied before transitioning to green transportation viz., its perceived value in terms of its cost of use, its functional utility, and its perceived ease of use in the everyday life of the user, its perceived social and environmental benefits of the new technology. The technology acceptance model presents a path framework to discuss the features and causal relationships in green transportation. The intended use of green transportation technology is affected by the preceding social constructs regarding its value, ease of use, and perceived usefulness (Chen and Lu, 2016).

The environmentally friendly nature of green transportation, particularly its low level of CO2 emissions has become a crucial issue for the public and the public is becoming more conscious of alternative forms of transportation (Chen and Lu, 2016). According to the UN Panel on Global Sustainability of 2012, mobility is as important as providing water, food, shelter, and sanitation (Toro et al., 2015). However, society is aware of the environmental damage caused by human activity and is thus concerned about the indiscriminate use of natural resources, requiring the maximisation of mobility through public transportation strategies (Toro et al., 2015). Interest in this area increased significantly with the development of green supply chains, including cost reduction strategies, improved product and process quality, risk reduction methods, and the improved financial performance of green transportation (Vachon and Klassen, 2008; Sarkis, Zhu, and Lai, 2011

Public awareness and participation in green transportation policies is very important. Pollution, social health, and environmental education programmes are required to promote the public

acceptance of green transportation technologies. As far as developing countries are concerned, where the literacy rate is low and the larger part of the population lives in isolation, conducting mass awareness programmes is very challenging. Many customers are unaware of the advantages of environmentally friendly travel or are unsure of how to use these services. To promote demand for green transportation options and to enhance public awareness of them, the government and other stakeholders must invest in public education initiatives. For developed countries, mass awareness programmes of green transportation are far easier (Grob, 2009). However, in developing countries, the public adoption of green transportation technologies requires the active support of government and also requires the participation of NGOs and the private sector in cost-effective schemes. Media participation also assists in conveying information about the transportation-linked causes of air pollution and its impact on human health and the environment.

When evaluating the value of green transportation in terms of its cost of use, the initial capital cost of NEV is a major obstacle. Since they are currently more expensive than comparative ICE models, many consumers cannot afford electric cars (National Association of Automobile Manufacturers of South Africa, 2020). The high upfront purchase cost of electric and hybrid vehicles makes green transportation a less attractive economic investment (Panday and Bansal, 2013). However, there is clear evidence that NEVs can be cost-effective over time (Panday and Bansal, 2013). Potential NEV consumers are only willing to buy an NEV if public charging infrastructure is improved. This underlines the necessity for local councils to invest in infrastructure (Bekiaris et al., 2016). However, it may be challenging to justify a large-scale investment in green transportation due to the unreasonably high infrastructure costs associated with NEVs.

Four behavioural economic concepts reduce the demand for green transportation solutions. The first is loss aversion, in terms of the expense of buying a more expensive NEV vehicle rather than the long-term cost advantages of choosing a more cost-efficient, ecologically friendly vehicle. The loss aversion has implications for green transportation because it suggests that consumers are less motivated to use more cost-efficient, environmentally friendly options than they are to avoid perceived present losses associated with doing so (University of California, 2019). The second is the sunk-cost fallacy, the propensity of governments to continue investing in a less efficient choice because of the resources they have already committed to it. (University of Michigan, 2020). In terms of green transportation, there is a tendency for governments to

focus on extending the extensive ICE infrastructure already in place relative to the cost of developing new infrastructure for NEV technologies. Private users also prioritise the resources they have already invested in ICE vehicles over the advantages of choosing a more environmentally friendly option.

The third is the inconvenience costs of changing the daily routine of users in favour of a more environmentally friendly option. Inconvenience costs are a bias in favour of the status quo where consumers favour continuity in current transportation patterns over a change in their regular routines. Despite consumers' awareness of the advantages of green transportation, their risk aversion to inconvenience deters them from selecting green transportation choices. The fourth is the accessibility heuristic, closely related to Kahneman's and Tversky's prospect theory (2013). This describes the propensity to overestimate the significance of easily accessible information. Consumers are less inclined to examine alternate modes of transportation and more likely to choose ICE vehicles because they frequently overestimate the hazards and underestimate the advantages of new NEV technologies (HBR, 2019). The framing effect of how information is presented describes the propensity to purchase ICE vehicles if it is provided as the default option, especially if mass media and advertising influence consumer demand.

Another important factor in the adoption of green transportation is the consumers' initial responses to the functional utility and ease of using NEV as an everyday technology. Most consumers have a high willingness to purchase an electric vehicle, with respondents satisfied with the possibility of reducing their monthly vehicle running costs if they bought an electric vehicle. The limited range of EVs should not constrain most respondents, since close to 90% of respondents travel less than 100 km per day (Moeletsi, 2021). However, Bunce et al (2014) researched to investigate the attitudes and experiences of NEV drivers in the UK to recharging plug-in electric vehicles before they obtained their NEV and after driving the NEV for 3 months. This research underlined a high number of misconceptions about operating costs, recharging time, purchase price, and driving range. Most of the sample (70%) underestimated the extent of energy cost savings (Bailey et al., 2015). However, over 70% of participants perceived the inconvenience of recharging the car and felt threatened by the possibility of not being able to cover the required travel distances with a NEV (Mets et al., 2010). According to a survey by the American Automobile Association (AAA), 63% of Americans are worried

about the lack of charging infrastructure, and 71% of Americans are reluctant to buy an electric vehicle because of its limited range (AAA, 2020).

These results indicate that the transition to green transportation is not merely a technical challenge. Many studies indicate that social and economic factors in commuter behaviour are critical to the effective adoption of green transportation (Keyvanfar et al., 2018; Bekiaris et al., 2016). According to Chapin et al. (2013), while the technical factors that could affect vehicle purchasing decisions, including the amount of carbon emissions, ease of refuelling, fuel consumption, and travel range, certainly do factor in the purchasing decisions of consumers, social perceptions, such as the comfort provided in this mode of transportation, the capital and operating costs required to buy into this mode of transportation, the reliability of the vehicles, commuter safety, size of the vehicle and its internal and cargo space, and the style and appearance of the vehicles are more influential in the purchasing decisions of consumers. Currently, most prospective consumers view green transportation as very expensive and impractical for everyday use, and thus NEVs are regarded as luxury niche market goods (Ahmed and El Monem, 2019).

Therefore, public perception before and after purchasing an NEV is important in the adoption of new green transportation technologies, resulting in a slower-phased approach to adoption (Panday and Bashal, 2014). The phased adoption of transitioning to green transportation follows a socio-technical paradigm of technological shifts (Chapin et al., 2013). The public adoption of a new socio-technical paradigm follows five stages of innovation. These are the diffusion of knowledge through word of mouth and the media, then the persuasion of the customer to consider the new technology, a critical mass of advantages leading to a decision to adopt the technology, the widespread implementation of the technology amongst the public, and confirmation of the technology as the default technology in the society. This process forms a closed loop because of the dissemination of innovations among interpersonal networks (Dekker et al. 2013; Rogers 1995). The socio-technical diffusion of innovation among interpersonal networks follows five phases of adoption in the general public: firstly, the innovators who have the greatest willingness to take risks and test innovations become pioneer adopters; secondly, early adopters who are more discreet in their adoption choices than innovators adopt the most efficient innovations; thirdly, mass adopters adopt an innovation after the innovation has become a stable system; fourthly, the late majority adopt the innovation after it becomes the dominant technology in the industry; and lastly laggards adopt innovations

as older substitute technology after newer alternatives are available (Chen and Lu, 2016; Rogers, 1995).

Xia, et al. (2018) indicate that eventually, the shift in the socio-technical paradigm allows green transportation systems to operate as vehicular social networks. Vehicular social networks use advanced communication technologies, enabling these devices to interact and share information using processing and communication capabilities built on top of vehicular networks. This enables commuters to interact and share information with neighbouring nodes (Xia et al., 2018). For example, traffic assignment techniques use statistical inference techniques to compute the possible fastest route from the source to the destination point for hybrid and electric vehicles. The trip generation model is a realistic mobility tool that includes traffic authority restrictions, demographic information, residential density, accessibility, social behaviours of commuters, and traffic at different time intervals of the day and week as factors that affect the trip generation process (Xia et al., 2018).

In conclusion, the lack of interest in green transportation is a complicated issue that has a number of causes, such as a lack of knowledge, a lack of confidence in new technology, and a preference for conventional transportation options. Governments, businesses, and consumers will need to work together to promote the advantages of environmentally friendly transportation options, invest in new technology and infrastructure, and provide customers with more options in order to address these problems. By doing this, we can develop a future green transportation system that is more environmentally friendly and sustainable.

2.4 PLANNING GREEN TRANSPORTATION FOR SUSTAINABLE CITIES

The United Nations predicts that by 2050, two-thirds of the world's population will reside in urban regions, signalling an unprecedented surge in urbanisation (UN, 2018). Numerous issues have been brought on by this rapid urbanisation, such as traffic jams, air pollution, and greenhouse gas emissions. With fossil fuels in transportation accounting for over 23% of worldwide CO2 emissions, the transportation industry significantly contributes to these problems (IEA, 2019). Green transportation has thus become a vital part of sustainable urban development in order to meet these issues.

According to Dill and Reyes (2017), green transportation aims to reduce traffic congestion, noise and air pollution, and fuel consumption through a human-scale street configuration based on green transportation technologies. It also reduces the barrier impacts of vehicular traffic on pedestrians and non-motorised transportation modes. Furthermore, green transportation develops local micro-economies due to speed reduction and infrastructure, such as charging or refuelling services (Erdil, 2018). Green transportation reduces the environmental and health impacts of urban environments and thus requires some advocacy. Pedestrians, cyclists, users of public transportation, and those using NEV can be given priority over drivers when designing roadways and other public areas since they reduce the health and environmental impacts on others (Lusk et al., 2017). This may entail taking measures like constructing designated bike lanes, extending sidewalks, providing reserved e-car parking spaces, and enhancing the regularity and dependability of public transportation. For a more conducive transition, green infrastructure ought to be developed in tandem with the transition to green transportation. However, the current urban form, population densities, and land uses do not necessarily optimise the transformation to green transportation.

Planners play a key role in encouraging the use of environmentally friendly modes of transportation by overseeing the development of cities in a manner that provides accessibility to all community members, regardless of their financial situation. Urban planning combines green transportation strategies, public amenities, and urban growth management to reinforce a positive impact on cities. These are mutually reinforcing as, green transportation choices, can boost property values, increase economic activity, and ease traffic congestion (Schrank and Houghton, 2016). In addition, encouraging green mobility can benefit public health, lower greenhouse gas emissions, and reduce air pollution (Dill and Reyes, 2017).

Green transportation is strongly linked to transportation-oriented design (TOD). The idea of TOD centres on planning metropolitan areas around public transportation infrastructure. TOD proposes a people-oriented design where cities are less influenced by the diffusion of private automobiles and more influenced to commute people to places with socio-economic opportunities in high-density mixed-use developments through non-motorised and public transportation modes. Reducing the demand for personal vehicles while promoting sustainable means of transportation like walking, bicycling, and public transportation are the primary objectives of TOD (Institute for Transportation and Development Policy, 2022). By reducing the number of vehicles on the road, TOD can drastically reduce greenhouse gas emissions

while also improving air quality and economic activity. In Ahmedabad, India, for instance, TOD lowered greenhouse gas emissions by 14% and increased air quality by 17%, according to a study by the Institute for Transportation and Development Policy (Institute for Transportation and Development Policy, 2018). A key element of green transportation strategies is public transit. It encompasses a variety of modes, including light rail systems, electric buses, and subways. By reducing the number of personal vehicles on the road, green public transit can dramatically cut air pollution and greenhouse gas emissions (American Public Transportation Association, 2020). Additionally, by giving low-income communities access to cheap transportation options, green public transit can support social fairness (Schwanen, 2018). In Vienna, Austria, this technology has assisted in reducing greenhouse gas emissions by 22% and improving air quality by 25% in 2020.

The combination of an accessible green transportation system and an efficient, compact, walkable city in TOD initiatives defines a sustainable city. Ibraeva et. al, (2020) defines urban sustainability as applying sustainable design guidelines for enhancing urban activities through green transportation. This requires walkable human-scale cities, where the radius is normally around 5km-10km, the average time it takes a human being to travel an hour on foot. Gehl refers to this as a people-oriented design philosophy as human-scale development (Long and Ye, 2019). This is especially important in developing cities where the preponderance of private automobiles has radically lengthened travel times and reduced productivity due to traffic congestion. For instance, Johannesburg has an average commute time of over 60 minutes and one of the highest average travel budgets in the world.

Sustainable smart cities are populated places that employ data and technology to encourage sustainable growth through technology. In order to create sustainable smart cities, green transportation must be integrated with smart technology like electric vehicles (EVs) and intelligent transportation systems (ITS) (Giffinger et al., 2007). Sustainable smart cities can raise the standard of living for residents while lowering greenhouse gas emissions, enhancing air quality, and fostering economic growth. As an illustration, the Danish city of Copenhagen has put in place a smart traffic light system that alters the timing of traffic lights based on traffic flow, thereby easing traffic congestion and enhancing air quality (City of Copenhagen, 2019). Urban planning is also focused on soft approaches to green transportation including re-evaluating traffic demand to produce realistic mobility models for more energy-efficient vehicular scenarios, traffic assignment techniques to compute the fastest possible route from

the source to the destination point, and using adaptive traffic control systems to respond to traffic patterns in real-time.

Green transportation infrastructure should also be integrated into green infrastructure, the natural and semi-natural systems that provide crucial ecosystem services like stormwater management, flood protection, and habitat creation. This includes passive measures such as climate-friendly building materials such as clay bricks, and climate-smart building orientation, and active measures such as residential solar PV, landscaping, greywater recycling, and sustainable urban drainage systems. The primary component of street design is the street reserve. This verge contains important engineering services such as public utilities, street lights, street furniture, footpaths, and other elements such as bridges, pedestrians, pedestrian safety facilities and a hierarchy of road widths and facilities, traffic calming facilities, and other elements that can minimise the environmental impact of transportation. Green transportation infrastructure enhances air quality, supports biodiversity, and lessens the effects of climate change (European Commission, 2019). Additionally, green transportation infrastructure such as road and rail servitudes can be utilised to offer leisure activities for local residents, encouraging improved physical activity and mental health. For instance, the city of Singapore has put in place a programme for green infrastructure that involves building parks, gardens, and green roofs. According to the Singaporean government's 2020 report, this programme has reduced greenhouse gas emissions by 12% and improving air quality by 15% (Government Singapore, 2020).

Green street design aims to build streets that are economically feasible, socially just, and environmentally sustainable. The objective is to design roadways that accommodate all users, including pedestrians, bicycles, and users of public transportation, rather than only automobiles. By encouraging walking, cycling, and the use of public transportation, green streets aim to lessen the environmental effects of transportation. They are also intended to encourage regional businesses and economic growth, as well as social engagement and community building. Green street design should ideally integrate user activities and transportation needs in terms of safety and accessibility through the Street reserve. Accessibility is an important facet of green street design, which refers to the social ability to reach facilities and socio-economic activities within a specific amount of time through any mode of transportation (Mohareb and Felix, 2017). Infrastructure that prioritises pedestrian comfort and safety: Green streets are created with pedestrian comfort and safety in mind. Wide

pavements, pedestrian crossings, and pedestrian-only areas are examples of such features. Green streets frequently have designated bike lanes, bike-sharing programmes, and safe bike parking facilities. Green roadways are made to accommodate all forms of public transportation, including taxis, trains, and buses. Included in this are amenities like designated bus lanes, train stations, and taxi stands. Moreover, green street design integrates green infrastructure by creating parks, permeable pavement, bioswales, and rain gardens from the road reserve (Panday and Bansal, 2014). These areas sequester CO2 emissions and encourage environmentally friendly drainage while also fostering community building and social interaction.

Green public transit is strongly supported by urban planning. The usage of green transportation options can be encouraged or discouraged by the way cities are built. To promote walking, for instance, towns can give priority to pedestrian-friendly infrastructure like wide pavements and pedestrian crossings (Isaac, 2020). Cities can also spend money on bike-sharing programmes and designated bike lanes to encourage cycling (South African National Energy Development Institute, 2020). This is a preferable option in developing countries such as South Africa, where most residents already utilise public transportation because they have limited access to private vehicles. However, there is also a growth in private vehicle ownership attributed to a lack of confidence in the reliability and safety of the state's public transportation services (Schalekamp et al., 2010). Green public transit is strongly associated with TOD and low-carbon living standards since the development of suburban housing is strongly associated with the diffusion of ICE transportation and a higher level of energy resource consumption.

Various programmes and strategies are used to evaluate the degree to which planning, investment budgeting, construction engineering, and operations management conform to green transportation principles (Li, 2017). McVoy et al., (2010) describe the evolution of the New York State Department of Transportation's Green LITES programme from initially being a tool for assessing environmental sustainability to a collection of tools (rating system, spreadsheets, etc.) for assessing projects, plans, operation, maintenance, and regional programmes. The Green LITES project design tool identifies several sustainable items in five categories (Jha et al. 2014). Eisenman (2012) proposed a strategy for the Georgia Department of Transportation to enable the agency to compare projects based on sustainability goals and outcomes. He explores reviewing existing transportation sustainability initiatives from the federal government, academia, consultants, and professional non-profit organisations. Muench

and Anderson (2009) describe Greenroads, as a performance metric for quantifying sustainable practices associated with roadway design and construction. Greenroads assign seven key components to sustainability and define a sustainable road project as one that incorporates each of these seven components into its street design and construction process. The INVEST (Infrastructure Voluntary Evaluation Sustainability Tool) is a voluntary tool for all transportation and planning agencies based on a practical, web-based collection of voluntary best practices. The INVEST is designed to help transportation agencies integrate sustainability into their policies and projects (Jha et al., 2014).

These transitions do not necessarily require the integration of hydrogen, hybrid, and electric vehicles. Copenhagen, for instance, was once a car-oriented city but formed a partial bicycle road network with adequate infrastructure. Copenhagen successfully transitioned to become a "bicycle city" with over 40% of residents commuting to work by bicycle and by foot. Copenhagen also constructed designated pedestrianised streets. In Copenhagen, the number of bicycles now exceeds the urban population, with 36% of citizens relying solely on bicycles for daily commuting, resulting in a CO2 emission reduction of about 90,000 tons annually. The city endeavours to reach its goal of 50% of its citizens relying on bicycles for commuting by 2025 (Li, 2017). Copenhagen also implemented its "Five-Finger Plan" to carry out urban expansion through five radial corridors from downtown to surrounding areas, and the space between these corridors would serve as a green wedge for development restrictions (Li, 2017). Through the Traffic and Environmental Planning Act, the Urban Traffic Consummation Plan, the Bicycle Lane Priority Plan, and the Bicycle Green Lane Plan, the city restricts car use and actively develops bicycle and green public transportation systems.

Key initiatives to improve green transportation transitions in urban planning include establishing coordination teams led by municipal officials and relevant departmental representatives to coordinate green transportation planning, investment, construction, and management initiatives and formulate local regulations. Coordination teams are important because it may be challenging to agree on the optimal methods for urban planning and transportation due to disagreements amongst many stakeholders, including developers, public officials, and community members (Waters, 2019). These coordination teams should first, prioritise bicycle travelling and walking. Secondly, they ought to upgrade relevant planning, design, and construction standards and regulations to enable transitions to green transportation modes (Li, 2014). Thirdly, the coordination teams should actively promote the concept of green

transportation in enterprises, schools, and communities to create an amenable social environment for green transportation. Residents who are accustomed to using private vehicles for transportation may also have difficulties adjusting to alternate means of transportation (Dill and Reyes, 2017). This includes encouraging the active participation of civil groups to organise public education roadshows to promote green transportation. Fourthly, the coordination team should work in the different fields of public administration, the economy, and technological research to capacitate the scientific use of modern green transportation technology in other sectors. This includes prioritising the development of public green stations and legislating road rights for NEVs and increasing the service level of public transportation. Another important role for coordination teams is to obtain alternative means of finance since local governments often find it difficult to allocate enough money to pay the costs of promoting green transportation and providing high-quality public goods (Hall, 2018). Finally, the coordination team should develop long-term mechanisms for further green transportation construction investment, implement intelligent information management systems, scientifically optimise transportation networks, optimise NEV infrastructure, and actively promote the construction of alternative energy sources, energy conservation, and constantly evaluate environmental protection (Li, 2017).

Regarding urban planning considerations, sustainable and green public transportation projects are complex in nature, often lacking clear key performance indicators and difficult to implement. There is a need for integrated transportation planning that is oriented around green transportation master plans regularly updated and reviewed to incorporate new technologies. Essential to this is the political will to support the transition to NEVs, green infrastructure, and more sustainable modes of transportation.

2.5 THE SOUTH AFRICAN TRANSPORTATION POLICY ENVIRONMENT: DISCONNECTS IN POLICY AND PRACTICE

A nation’s transportation system is significantly influenced by its legislative framework. Governments are under pressure to promote environmentally friendly transit options as the world struggles with the problems caused by climate change. The South African government has taken action in recent years to encourage eco-friendly transportation options and lessen the sector’s carbon footprint. Like many other nations, South Africa has implemented a number of

pieces of law to encourage green mobility. With an emphasis on the advantages and difficulties of implementing such regulations, this section analyses the current status of green transportation policy in South Africa

The National Transportation Policy Framework (NTPF), which was introduced in 2018, is one of the major efforts of the South African government to create equal footing between ICE transportation and green transportation. With a focus on sustainable public transportation, non-motorised transportation, and intermodal connectivity, the NTPF seeks to advance a more cohesive and environmentally friendly transportation system (Department of Transportation, 2018). The NTPF is specifically innovative in that, in contrast to previous legislation, actively supports the integration of electric and hybrid vehicles as one of its main tenets. Incentives for the purchase of electric and hybrid vehicles, such as tax reductions and subsidies, were announced by the government in 2019. Additionally, a number of automakers have already started producing hybrid and electric cars in South Africa, giving customers more accessible and reasonably priced vehicles. The NTPF also endorses the extension of public transit services to underserved areas. Bus Rapid Transit (BRT) systems, which provide quick and effective transit services at a cheaper cost than private automobiles, have received significant government investment. In order to promote non-motorised transportation, many towns have also added bike lanes and pedestrian-friendly streets (City of Cape Town, 2022).

The government of South Africa has outlined its strategy for promoting green transportation in the Green Transportation Strategy (GTS) (Department of Transportation, 2018). The policy intends to enhance air quality, lessen the transportation sector's carbon impact, and encourage environmentally friendly modes of transportation. The GTS places a strong emphasis on the necessity of a transition to public transportation, non-motorised mobility, and green automobiles. According to the policy, it is envisioned that by 2030, 70% of all new cars sold in South Africa are expected to be hybrid or fully electric (Department of Transportation, 2018). The Green Transportation Strategy (GTS), which was approved by Cabinet in 2018, has the potential to boost the economy by creating employment and investment opportunities for the automotive sector in South Africa (Department of Transportation, 2018). It outlines the government's plan regarding the transition to green transportation and combatting greenhouse emissions with incentives and penalties. The GTS aims to transition 5% of public and private sector fleets to green transportation, transition 30% of freight from road to rail, shift 20% of private vehicles to public and green transportation, and invest in infrastructure such as EV

charging stations and biogas filling stations by 2022. Incentives include enacting permits, road-use charges, standards, and regulations that give certainty regarding fuel consumption, charging, and vehicle classification (Department of Transportation, 2018). The GTS will require significant investment and coordination between the public and private sectors to achieve its goals. However, there are shortcomings in the regulations such as the legality of NEVs, and a shortage of funding from fuel levies and the road accident fund.

The South African Department of Transportation has developed several incentives to promote green transportation in the local automotive sector. These incentives are designed to attract foreign direct investment, particularly multinational companies, in setting up production facilities in South Africa. The most important of these is the Automotive Production and Development Programme (APDP) which incentivises foreign automotive manufacturers to invest in local production facilities and thereby create employment. The APDP is a production incentive scheme for the motor industry aimed at promoting large production volumes in the specified motor industry, promoting added value manufacturing in the automotive component industry, and creating employment across the automotive value chain (Department of Transportation, 2018). Since 2013, the APDP employed a rebate mechanism to encourage foreign automotive manufacturers to use domestic value chains. However, the policy also provides strong import duty guidelines that protect the domestic automotive industry. It also provides incentives for local assemblage practices, as well as an investment scheme to incentivise Official Equipment Manufacturers (OEM) to upgrade their facilities to boost production (Kumalo, 2019; Department of Transportation, 2018). These incentives, while not specifically targeted to induce the manufacturing of NEVs or green transportation infrastructure, provide strong incentives to attract these industries to operate alongside the existing ICE automotive manufacturing.

In response to the challenges faced in the South African transportation sector, and the need to align the APDP with the NTPF and the National Climate Change Response White Paper (NCCRWP), the South African government has introduced the South African Automotive Masterplan (SAAM). SAAM is set to replace the APDP in 2021 and will prevail as the major automotive manufacturing policy until 2035. The government’s future vision for the automobile industry is outlined in the South African Automobile Masterplan (SAAM) (Department of Trade and Industry, 2018). The objective of the SAAM policy is to encourage the growth of the automobile sector, particularly in the green transportation industry, boost

exports of NEV in particular, and generate a diversity of employment opportunities in the production of motor vehicle components and vehicle assembly. The SAAM emphasises the necessity for the automotive manufacturing sector to adopt more environmentally friendly and sustainable solutions in terms of green transportation. The SAAM clearly emphasises the value of alternative fuels and electric vehicles in the South African transportation sector and has set a green transportation target of 100,000 electric cars (EVs) on South African roads by 2030 in its policy statement (Department of Trade and Industry, 2018).

The most significant difference between the previous APDP and SAAM is that the latter seeks to implement a one-tariff regime across all light vehicles to address the high import duty challenge. This will particularly benefit NEVs since these vehicles are generally far lighter than comparative ICE vehicles within their class (Kumalo, 2019). While the SAAM does not specifically provide specific policy guidelines for the manufacturers of vehicles in the green transportation industry, this is preferable, since ill-advised policy guidelines for the rapidly developing innovations in the green transportation industry might create future challenges. However, SAAM acknowledges the increasing interest in green transportation and has tailored the policies to incentivise green transportation from an OEM and end-user vantage point. During the 14-year implementation timeline period of SAAM to 2035, it is expected that the Euro 7 emissions standards legislation by the EU, would inevitably invalidate the current ICE-based business model, whereby three out of four vehicles manufactured or assembled in South Africa are exported to the EU will be NEVs (Christianson, 2022).

The South African government also launched the Automotive Industry Development Programme (AIDP) in 2013. AIDP was developed to support domestic automakers and reduce domestic reliance on foreign cars. This programme is very promising since it offers significant financial incentives to the manufacturers of low-emission, fuel-efficient automobiles, and automobile components. The programme offers very generous financial incentives to domestic manufacturers of low-emission, fuel-efficient automobiles. The policy also has specific incentives to produce vehicles and components to support the existing public transportation services and vehicles that use cleaner kinds of energy. This policy is aligned with the goals of the Public Transportation Strategy, which was published in 2012. The strategy specifically highlights light rail and bus rapid transit (BRT) vehicles as priority investment areas.

The Procurement Policy Framework Act (PPPFA) was created by the South African government to encourage the development of public-private partnerships (PPPs) in the purchase of public goods and services (National Treasury, 2017). The act offers a framework for government organisations to preferentially purchase products and services, including environmentally friendly transportation options from local manufacturers that specifically produce products to the specification of government departments. The PPPFA offers the private sector a chance to collaborate with the government to create eco-friendly transportation options, like electric buses and charging infrastructure specifically for the other transportation sector, which is overwhelmingly dominated by government services. The Act, together with the AIDP and SAAM offers financial assistance to firms who make investments in the South African automotive industry. Promotion of the manufacture of environmentally friendly automobiles, such as hybrid and electric vehicles, greatly benefits from these policies. The project offers tax discounts and other incentives to businesses that create eco-friendly automobiles (Department of Trade and Industry, 2019). While the legislation seems to contradict legislation such as the earlier APDP which is designed to protect and promote the ICE automotive industry in South Africa, the recent adoption of SAAM promotes green transportation as more cost-effective on a kilometre basis than ICE vehicle counterparts.

These green transportation incentives are aligned with the South African government's strategy to encourage industrial development in South Africa, as described in the Industrial Policy Action Plan (IPAP) (Department of Trade and Industry, 2018). The IPAP policy intends to advance the growth of important industries, most notably the automobile sector. The IPAP emphasises the necessity of the automotive sector transitioning to more environmentally friendly and sustainable technologies such as EVs and alternative fuels, while also recognising the significance of green transportation. Similar to the SAAM, this policy also emphasises the target of encouraging domestic production to increase the number of electric vehicles (EVs) on South African roads to 100,000 by 2030 (Department of Trade and Industry, 2018). According to the Industrial Policy Action Plan (IPAP) of 2018, South Africa has an already strong automotive industry that exports vehicles all over the world every year (Department of Transportation, 2018). If the policies are conducive, it can leverage the automotive manufacturing industry to incrementally shift over to producing a new generation of green transportation technologies that can create employment and gradually improve the conditions of urban areas. However, essential to this shift is the need for clear policies that promote green transportation, particularly closer to 2035 when the EU Euro 7 emissions standards legislation

comes into effect. It is likely that the OEM adoption of green transportation business models will eventually change market conditions for green transportation, increasing its adoption. However, NEV technology is still considered 'disruptive' and requires a substantial modification in consumer behaviour, as its manner of operation differs significantly from that of ICE vehicles.

The NTPF is aligned with the National Environmental Management Act (NEMA) of 1998, replacing previous legislation that only focused on conventional ICE transportation and that did not accommodate the reduction of transportation-generated CO2 emissions. NEMA outlines the government's strategy for encouraging sustainable development and safeguarding the environment (Department of Environmental Affairs, 2014). NEMA specifically highlights the necessity for the transportation industry to reduce its environmental footprint and promote sustainable transportation alternatives. A further response to the provisions in NEMA is the National Climate Change Response White Paper (NCCRWP), which was released in 2011, and outlines the government's strategy for tackling the problems caused by climate change (Department of Environmental Affairs, 2011). The NCCRWP emphasises how crucial it is for the transportation industry to reduce greenhouse gas emissions and adopt environmentally friendly modes of transportation. The NCCRWP set a 2030 target of a 30% reduction in transportation-related greenhouse gas emissions (Department of Environmental Affairs, 2011). This forms part of the greater emission reductions strategy, which aims to reduce the effects of climate change by first promoting more sustainable forms of energy whilst simultaneously reducing CO2 emissions produced in the industry. The restructuring of the national transportation sector towards a green transportation model performs an important role in the strategy, as outlined in the National Climate Change Response White Paper (NCCRWP). Furthermore, the Energy Efficiency and Renewable Energy (EERE) policy, which was issued in 2013, outlines specific goals for reducing greenhouse gas emissions from the transportation sector. The policy specifically encourages the adoption of NEV in both the public and private sectors through electric vehicles and buses. It also encourages the government to explore the greater use of alternative fuels like hydrogen and biofuels in the transportation industry.

However, there are still a number of obstacles preventing the widespread adoption of green mobility, despite government efforts to encourage it. Like many other emerging nations, South Africa has substantial transportation issues. The nation has a high rate of traffic accidents, and its transportation system relies heavily on fossil fuels, which increases air pollution and

greenhouse gas emissions. The government has introduced a number of pieces of legislation to promote sustainable mobility solutions, but it is still struggling to address these mobility issues. One of the biggest issues is that many people cannot afford to buy electric and hybrid automobiles due to their high upfront costs. Additionally, the range and practicality of electric vehicles are constrained by the scarcity of charging infrastructure in many locations (Hoffmann et al., 2019). The lack of knowledge and instruction regarding green travel solutions is another challenge. Many customers are unaware of the advantages of environmentally friendly travel or are unsure of how to use these services. In order to promote demand for green transportation options and to enhance public awareness of them, government and other stakeholders must invest in public education initiatives (Masango and Molefe, 2019).

2.6 CONCLUSIONS

Green transportation forms an important part of sustainable development due to its key link between the social and economic functions and transportation, and the detrimental effects of CO2 emissions from certain transportation modes. This is especially important since the entire transportation value chain from manufacturing to commuting is one of the leading causes of emissions, and this has significant health effects on local populations. Green transportation is also a key priority in South Africa because South Africa is a major emitter of greenhouse gases in sub-Saharan Africa. Not only are ICE vehicles responsible for greenhouse gases, but are also a leading cause of pollution, resulting in health-related problems in the community. This requires an environmentally friendly mobility culture employing green transportation technologies. However, this also requires cultural shifts in the perception of green transportation, changes in the social organisation to adapt to new technologies, and to address the social equity issues of accessibility and cost concerns. Transitioning to green transportation is a complex challenge that requires more than just a change in vehicle technologies. It requires a change in urban planning, the reshaping of the urban environment, and an incremental adaptation of existing laws and regulations to incentivise the adoption of NEV.

Green transportation is an emerging systemic solution to complex transportation issues in developing countries including rising commodity prices, rapid urbanisation, high unemployment, and inequalities. This involves a multi-stakeholder approach including low-energy consumption technologies, but also increasing the efficiency of transportation services.

It includes traditional non-motorised transportation, but also public and private NEVs. To this end, many countries are cross-subsidising NEV with taxes on traditional ICE vehicles. Conversely, NEVs can also feed back into a smart grid, providing supplemental power storage for household needs. For this reason, green technologies including green transportation are highly profitable with high capitalisation rates. However, green transportation requires accessible infrastructure such as smart charging stations and advanced interactive communications to optimise travel. It also requires a stable energy grid which itself should combine renewable and non-renewable energy. Moreover, green transportation technology has certain drawbacks, particularly in the cost of battery components and the environmental effects of battery waste. NEVs are comparatively more expensive than conventional ICE vehicles, and a green transportation system needs autonomous technology to enable innovation.

Green transportation has shown some promise in developing countries, particularly in the adoption of mass transit vehicles. South Africa has made considerable investments in such infrastructure, despite the technical difficulties including a lack of supporting infrastructure, and negative public perception, high investment costs, and restrictive legislation. The greatest barrier is the tariffs on imported NEVs. There are also psychological barriers due to a shortsighted undervaluing of the long-term cost reductions and environmental benefits of green transportation by potential consumers. International experience has provided various multi-stakeholder initiatives to address these challenges including transportation spreadsheet modelling, public-private partnerships, international awareness programmes, and multi-government policy incentive schemes.

One of the major issues in green transportation is public perceptions of the social and economic costs of transitioning. There is anxiety about the range of NEVs, the lack of infrastructure, and high capital costs. The challenge to stakeholders is to highlight the value in its lower cost of use, its functional utility, and the ease of use in everyday life. Public awareness campaigns need to focus on pollution and social health through environmental education programmes. Private investment in NEVs should also be compensated with similar public investments in infrastructure. Moreover, minor inconveniences such as recharging should become a standard household behaviour. Specifically, campaigns need to overcome the psychological challenges of loss aversion, the sunk cost fallacy, inconvenience costs, and the accessibility heuristic which all undermine potential consumers' faith in NEVs. Changing the public perception

requires an incremental adoption of new green transportation technologies following a shift in socio-technical paradigms.

Green transportation is also linked to changes in the built environment. Green transportation system in reducing traffic congestion, noise and air pollution, and fuel consumption through human-scale street configurations. It is also linked to the development of micro-economies and reduced environmental and health impacts. In this respect, urban planners play a key role in encouraging green transportation by combining it with public amenities and growth management to reinforce sustainable development. This is primarily linked to TODs, where the greening of public transit reduces emissions and supports social equity. The primary concern is creating walkable cities for pedestrians, but it is also linked to the development of sustainable smart cities that combine data and green technology to improve traffic demand. Green transportation is also linked to green infrastructure, combining climate-friendly building materials and orientations to urban energy generation, green scoping, and sustainable urban drainage. This uses the infrastructure of green transportation for a variety of ecosystem services and social amenities. Green transportation is also linked to green street design which prioritises pedestrian movements and social and economic activities. Through its green public transit, urban planners also prioritise non-motorised movement over public transportation. There are various programmes and strategies developed to implement green transportation in urban planning including evaluation tools and performance metrics, but the most important tool is coordination teams that agree upon the optimal methods of implementing green transportation in TODs.

In the South African policy environment, the NTPF promotes a more environmentally friendly transportation system through tax reductions and subsidies, as well as a more extensive BRT system. While older motor industry incentive programmes only provided general incentives for both NEV and ICE manufacturers, new policies such as SAAM encourage actors in the green transportation industry by boosting exports of NEV vehicles and components. The SAAM one-tariff regime benefits the comparatively lighter NEVs, however, there are no specific guidelines for NEVs exclusively. This will however change once the Euro 7 emissions standards become enforced, at the end of the lifetime of SAAM when the majority of export vehicles will be NEVs. AIDP is also promising, in that it provides financial incentives for local manufacturers of NEVs. The PPPFA is also a promising policy in that it encourages public-private partnerships for the production of public transit NEVs. The most ambitious reflection

is the IPAP which emphasises the target of 100,000 NEVs in South Africa by 2030. One of the most important policy documents, however, is the GTS, since it emphasises the necessity of transitions, with the target of 70% of the market being captured by NEVs by 2030. It emphasises the benefits of green infrastructure to the economy and outlines a progressive plan to transition various transportation modes to NEVs. Finally, the NCCRWP emphasises the transition to green transportation, with green transportation forming a key part of its strategy, in line with its progressive greenhouse gas emissions reduction targets. However, most of these policies are not responsive to the prevailing challenges in developing countries, including the cost of NEVs and the scarcity of green transportation infrastructure.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

The methodology of a research project is the blueprint that guides the research process. It refers to the various techniques/methods researchers follow (Bryman, 2012). It outlines the research design, the data collection and analysis methods, and the ethical considerations that underpin the study. In this study, the researcher made use of a qualitative research design following an inductive methodology. While quantitative research emphasises numerical data and statistical analysis, qualitative research focuses on non-numerical data and deeply examines phenomena (Creswell, 2014). Qualitative research is regarded as a means to explore and understand the meaning individuals or groups ascribe to a social problem (Creswell, 2009).

This chapter provides a detailed account of the methodology employed in this study, which aimed to explore the challenges and opportunities of integrating green technologies into conventional transportation systems in South Africa. The chapter also responds to the feedback received, clarifying the research design and methods used, and providing a more systematic and clear description of the research process. The research aims to explore the meaning that individuals and groups ascribe to green transportation (Creswell, 2009). The process of research involves interviewing key stakeholders in a governmental, civil society, and private sector capacity and critically evaluating the response of policies influenced by green transportation transitions in South Africa. Interviews were conducted through in-person and digital semi-structured interviews in person and online to obtain the viewpoints of relevant representatives from the public and private sectors in the green transportation space. The rationale is to understand the participants, their perceptions, and the possible remediation of green transportation challenges in South Africa. Data analysis is inductively built from general themes to particulars, and the researcher makes interpretations of the meaning of the data.

3.2 RESEARCH APPROACH AND STRATEGY

The study will mainly involve an inductive research approach. According to Bryman (2016), inductive research refers to a research approach whereby the theory is the outcome of the

research, drawing generalisable inferences out of the available observations. Inductive research does not determine causality; but aims to generate knowledge about the technical challenges of integrating green technologies in conventional transportation systems, the cost premium of green transportation, the public mindset regarding green technology, and its policy implications. The research approach adopted in this study was qualitative, which is concerned with understanding the meanings that individuals or groups ascribe to a social or human problem (Creswell, 2009). Quick and Grove (2015), describe qualitative inductive research as a systematic approach used to draw inferences from the life experiences and contexts of certain occurrences to develop a research hypothesis. The qualitative approach was chosen because it allows for an in-depth exploration of the complex and multifaceted nature of green transportation, capturing the experiences, perceptions, and attitudes of key stakeholders. The qualitative research environment is concerned with understanding the meaning of green technology in the public environment. The findings from these studies are used to identify how green technology policy can be improved to better facilitate green transportation transitions.

3.3 RESEARCH DESIGN

The research design used in this study was explorative, descriptive, and contextual. An explorative design is used when a researcher seeks to explore a relatively unknown field or phenomenon, while a descriptive design is used to provide a detailed description of the phenomenon under study. A contextual design, on the other hand, emphasises the importance of understanding the phenomenon within its specific context (Bryman, 2012). The research strategy employed was a case study design. A case study is an in-depth investigation of a particular phenomenon within its real-life context (Yin, 2014). Case study analysis provides enriching knowledge about a particular topic and makes a research study more credible and efficient (Bryman, 2012). As case studies provide facts existent in the present world, these can provide greater insight regarding the specific research topic. In this case, the focus is to find how NEVs are affecting the South African automobile industry and its export opportunities.

The research design was operationalised through two primary methods: interviews with key stakeholders and a review of relevant policy documents. The use of multiple methods, also known as method triangulation, enhances the validity and reliability of the research findings (Bryman, 2012). The case study design was chosen because it allows for an intensive

examination of the specific context of South Africa, providing rich, detailed insights that would not be possible with other research strategies. The choice of Cape Town as the study area was motivated by several factors. Firstly, Cape Town is a major urban centre in South Africa, with a complex transportation system that includes both conventional and green technologies. Secondly, Cape Town is a hub for innovation and policy development in green transportation, making it an ideal location to explore the challenges and opportunities of integrating green technologies into conventional transportation systems. Lastly, the researcher's familiarity with the context of Cape Town facilitated access to key stakeholders and relevant data.

3.4 DATA COLLECTION AND ANALYSIS METHODS

In qualitative research, interviews are a typical approach to gathering data (Creswell, 2014). They give researchers the chance to examine the experiences, viewpoints, and views of participants (Patton, 2002). Interviews can be used in research on green transportation to acquire data on participant transportation habits, attitudes towards green transportation, and experiences with various modes of transportation. The emphasis is on collecting data through the use of either questionnaires or interviews. The advantages of the descriptive design are that it takes less time to conduct and is inexpensive (Bryman, 2016).

The study gauges the sentiments and viewpoints of stakeholders in the green transportation industry in South Africa (Newman, 2011). Semi-structured interviews were conducted via MS Teams with key stakeholders in the green transportation sector in Cape Town. The stakeholders included government officials, industry representatives, civil society actors, and academics. The interviews were guided by an interview schedule (see Appendix A), which contained a list of open-ended questions designed to elicit the participants' views on the challenges and opportunities for integrating green technologies into conventional transportation systems. The choice of semi-structured interviews was motivated by their flexibility, which allows the researcher to probe deeper into the participants' responses and explore new themes that may emerge during the interview (Bryman, 2012). The interviews were conducted in person and via Microsoft Teams, depending on the preference of the participants.

The systematic review and interpretation of non-numerical policy data are important components of qualitative data analysis (Creswell, 2014). Thematic analysis, content analysis,

and grounded theory are a few methods for analysing qualitative data (Patton, 2002). The data collected from the interviews and document review were analysed using thematic analysis, a method for identifying, analysing, and reporting patterns (themes) within data (Braun and Clarke, 2006). The analysis involved several steps: familiarisation with the data, generating initial codes and parameters according to specific research themes, searching for themes, reviewing themes, defining and categorising the themes according to literature, and producing the report (Braun and Clarke, 2006).

A review of relevant policy documents was also conducted to gain insights into the policy environment for green transportation in South Africa. The documents included government policies, strategies, and regulations related to green transportation, as well as reports and studies published by research institutions and non-governmental organisations. The document review complemented the interviews by providing a broader context for understanding the challenges and opportunities of integrating green technologies into conventional transportation systems.

3.6 ETHICAL CONSIDERATIONS

A researcher must be familiar with the ethical principles of conducting research. Ethical considerations are paramount in any research study, a researcher must be familiar with the ethical principles of conducting research. In this study, ethical approval was obtained in April 2021 from the Stellenbosch University ethics committee REC: Social, Behavioural and Education Research (SBER) (please refer to Appendix B). No serious ethical implications were found and ethics clearance approval was granted in April 2021. Informed consent was obtained from all participants of the interviews, before the interviews, who were assured of their anonymity and the confidentiality of their responses. The participants were also informed that their participation was voluntary and that they could withdraw from the study at any time without any negative consequences. Personal and sensitive questions were avoided. According to Bryman (2016), participants in the interview process should have the power of free choice which enables them to agree or decline participation (Bryman, 2016). However, the organisations which they represent may be discussed to comment on certain extracts from the interview process.

3.7 VALIDITY AND RELIABILITY

In qualitative research, the concepts of validity and reliability are synonymous with the concepts of credibility and dependability (Lincoln and Guba, 1985). Credibility refers to the confidence that can be placed in the truth of the research findings, while dependability refers to the consistency and repeatability of the research process (Lincoln and Guba, 1985). In this study, credibility was ensured through the use of method triangulation (interviews and document review), which allows for the cross-verification of the research findings. Dependability was ensured through the systematic and transparent documentation of the research process, which allows others to follow the decision trail used by the researcher (Lincoln and Guba, 1985).

The research was used to get a thorough grasp of the complexity of green transportation, which is necessary for green transportation studies in South Africa. The analysis of interview data was conducted without the aid of software, in order to generate insightful information on the experiences, viewpoints, and views of participants. The results of this study show the challenges and advantages of eco-friendly transportation and the requirement for government incentives to support eco-friendly forms of travel.

3.8 LIMITATIONS

The study had a few limitations. Firstly, the focus on South Africa may limit the generalisability of the findings to other contexts. However, the in-depth insights gained from the case study can provide valuable lessons for other cities in South Africa and beyond. Secondly, the study relied on the willingness and availability of key stakeholders to participate in the interviews, which may have introduced some bias in the data. However, efforts were made to ensure a diverse and representative sample of stakeholders. Since the purpose of the study was to gauge the sentiment and viewpoints of respondents to better understand the challenges stakeholders were facing, it lacks some of the quantitative data that might generate more accurate and valid research results. However, quantitative data was deemed too difficult to get a hold of, due to monetary and time costs. Another challenge is that it is the prerogative of the organisation from

which data may be acquired to make the data available, which requires significant time and effort beyond the scope of this research.

3.9 CONCLUSION

This chapter has provided a detailed account of the methodology employed in this study. It has clarified the research approach, strategy, and design, and provided a systematic and clear description of the data collection and analysis methods. It has also discussed the ethical considerations and the measures taken to ensure the credibility and dependability of the research findings. The next chapter will present the findings of the study.

CHAPTER 4: ANALYSIS

4.1 INTRODUCTION

The transition towards green transportation is a global imperative, driven by the urgent need to mitigate climate change and reduce air pollution. However, this transition is not without its challenges, particularly in developing countries like South Africa, where the infrastructure and regulatory environment may not be fully prepared to accommodate this shift. This chapter delves into the intricacies of green transportation in South Africa, focusing on the infrastructure and planning considerations, the uncertainty of sustainable green transportation regulations, and the potential for stimulating sustainable green transportation industries to encourage local adoption. The world is facing an unprecedented climate change crisis, and the transportation sector is one of the largest contributors to greenhouse gas emissions. In response, there has been a growing focus on developing sustainable and environmentally friendly modes of transportation. This essay will explore the innovation cycle for green transportation in South Africa, with a particular emphasis on the role of technology and government policies in driving this transition.

Section 4.1 explores the infrastructure and planning considerations in green transportation. The section discusses the challenges and opportunities presented by the adoption of new energy vehicles (NEVs), the impact of urban design regulations and planning bylaws, and the public perception of green transportation. In particular, this section discusses the challenges associated with retrofitting the transportation industry to adjust to green technology and the significant costs dissociated with upgrades to infrastructure and vehicles.

Section 4.2 delves into the uncertainty of sustainable green transportation regulations. The section evaluates current legislation intersecting with green transportation technology in particular, related to critical issues such as taxes, subsidies, levies, infrastructure, and local assembly and manufacturing. The chapter discusses the Ad Valorem tax burden on NEVs, the impact of this tax on the uptake of NEV technology, and the potential changes in legislation governing electric vehicles.

Section 4.3 discusses the potential for stimulating sustainable green transportation industries to encourage local adoption. This section provides an in-depth analysis of the current state of green transportation in South Africa, the challenges it faces, and the potential solutions to these

challenges. In particular, this section discusses the proposed policy options to include green transportation strategies in future production and value chain development policies, the impact of the Automotive Production and Development Programme (APDP) and Procurement Policy Framework Act (PPPFA), and the potential changes in the green transportation policy environment. The section also looks at how the green transportation industry has set out a compelling case before the National Treasury to stimulate greater domestic demand for NEVs in South Africa. It is hoped that this analysis will provide valuable insights for policymakers, industry stakeholders, and researchers interested in green transportation in South Africa.

4.2 INFRASTRUCTURE AND PLANNING CONSIDERATIONS IN GREEN TRANSPORTATION

Respondents note that there is much frustration in the local green transportation industry around the quality of transportation infrastructure. The major challenge in switching over to NEVs is not the actual physical infrastructure, since electric cars and buses use the same road network. The addition of charging stations is a minimal cost relative to the cost of the vehicle itself, and would probably be absorbed by the market. The hidden cost of NEVs is the high tax rates and high maintenance costs of specialised NEVs in a country with less than optimal road conditions. Moreover, because NEVs typically have non-standard operating components that are not easily obtainable, easy to replace, and require specialised training not available in South Africa, the poor condition of road infrastructure in South Africa has it is a portion of the cost effect on the maintenance of NEVs, with maintenance costs often exceeding the higher running costs of conventional ICE's.

Similarly, it is easy for bus operators to switch over to NEVs due to the typical single peak demand trip most buses execute, despite the fragmented spatial structure of the city, road congestion, and lack of public observance of bus prioritisation lanes. As one bus operator stated: [*"You don't need more than a 200-kilometre range on a bus because you've got an opportunity to charge* [the bus] *in the middle of the day during off-peak periods because people go to work early and they go home at the end of the day. There's no demand* [during the middle of the day]. *So no, I don't think electric vehicles are going to have an impact on that."]*. However, in the case of electric buses, the major threat is the loss of vehicles from public strikes or civic actions through wilful vandalism and firebombing. Since many operators operate in

townships where the greatest need for public transportation is, they are reluctant to acquire NEV buses since these become prime targets for vandalism. It is an unstated rule that buses are not welcome in townships because it is the private market of paratransit syndicates. This severely limits the potential market for electric buses, since these are effectively marginalised from operating in its primary market, lower-income neighbourhoods. As one respondent stated: [*"Yeah, my experience with the with taxi industry …like I don't operate inside the townships. I go from outside the townships to town taking people from home to work between 8:00 o'clock and 11:00 o'clock and back in the afternoon. Inside the township and outside those* [peak] *hours* [paratransit is] *their primary transportation in between that period.*"].

The overwhelming majority of the respondents agree that the public is generally misinformed about the cost and operating efficiency of green transportation vehicles. These misconceptions mainly stem from the media not keeping potential consumers abreast of the latest technology developments. The public is misinformed about the range of NEVs and whether a NEV can accomplish daily operational tasks. In general, the public believes green transportation technology has still not improved sufficiently to provide a reliable and convenient service. One respondent commented by stating that: ["*you know that most people normally have this perception that electric cars have a lower range than in other vehicles, so some people say that electric vehicles will only work in denser cities. And then this perception, just to remind you, is international. The fixation on range is overrated. Per kilometre, the operation costs are much lower, but then people look at the capital costs, and then electric vehicle costs double, give or take, what a similar sized* [ICE] *vehicle costs."*]. However, since NEVs are primarily designed for countries where the distance between the place of residence and the place of work is relatively small and where users rarely travel long distances, NEVs are not ideal in decentralised locations in South Africa. As one respondent stated: [*"The people must live as close to their work as possible and in South Africa, that's an absolute nightmare because it's the opposite, because of urban sprawl, due to past legacies, and that's why public transportation in South Africa struggles to work because we* [living in] *too far apart. …if you're closer, you can utilise your assets substantially better."*].

A recurring conclusion from respondents is that the major challenge in adopting green transportation is the adaptation of transportation infrastructure to accommodate both ICE and NEV vehicles. Their frustration stems from the fact that, while higher-tier policy directives actively promote green transportation, lower-tier urban design regulations and planning bylaws

are not adapted to accommodate NEVs. The disjuncture between the current needs of green transportation users on the ground and the inability of state transportation and planning officials to stray beyond the confines of outdated by-laws limits the retrofitting of the transportation industry to adjust to green technology. Combined green transportation- conventional transportation strategy requires significant costs to infrastructure and vehicles.

Green transportation requires several structural changes in the existing infrastructure system to make it practical. Firstly, the respondents indicated that the green transportation system needs a greater outlay of charging infrastructure to incentivise motorists to switch to NEVs. The state should create a common standards platform for the different NEVs through the SA Bureau of Standards (SABS). Secondly, the shift from fossil fuels to NEVs can only achieve the full value of carbon reduction through a shift in the country's energy mix. This requires an increased proportion of renewable energy in the national grid. Thirdly, the respondents indicated that transportation, production, and value chain development policies should adopt a technology-agnostic framework to remain viable. It must be recognised that rapid innovations in green technology require a flexible policy environment due to the rapid changes in price gaps between different types of NEVs. Fourthly, the state should promote research on technology that depend on South African raw materials, particularly fuel-cell technologies based on platinum catalysers in green hydrogen technologies. South Africa has many of the materials and structures in place to build NEVs, but this will require that new skills be taught in tertiary education institutions. Finally, appropriate 'just transition' arrangements (Heffron, 2021) in the form of additional jobs, stimulation of local industrial capabilities, and expansion of production for new markets will be needed to overcome the negative effects of the declining demand for ICE technologies

4.3 THE UNCERTAINTY OF SUSTAINABLE GREEN TRANSPORTATION REGULATIONS

Globally, the use of electric vehicles (EVs) accelerated due to rising worries about climate change, depleting fossil fuel sources, and stricter pollution restrictions. With a number of incentives and laws aimed at increasing their adoption, South Africa in particular has been actively promoting the usage of EVs. Ironically, the best method of encouraging green transportation adoption in South Africa is still reducing the local cost of green technology

through specific incentives that reduce the cost of importing NEVs and vehicle components. One of the most pertinent impressions from the majority of respondents is that the current legislation intersecting with green transportation technology is currently too vague and uncertain on critical issues such as taxes, subsidies, and levies. The incompatibility of current ICE import tax policy regulations serves to stifle green transportation technology adoption rather than incubate fledgling green industries. While it is crucial to take into account the overall cost of ownership, which includes fuel costs, maintenance costs, and taxes, when comparing the taxes imposed on EVs and conventional gasoline-powered vehicles in South Africa, the once-off costs of EVs present a significant barrier to investing in more efficient NEV technology, making it comparatively less attractive to other ICE vehicles. Thus, while EVs offer significant long-term fuel and maintenance cost reductions, the higher initial expenses and taxes are not valorised by consumers at the same level as that of ICE vehicles.

The most important of these is the ad valorem tax, which is a tax determined as a proportion of the asset value of the products or services being taxed. The ad valorem tax on electric vehicles in South Africa and additional taxes levied upon them is proportionally much higher than that of ICE vehicles due to the higher cost category of NEVs. As one respondent stated: [*"To import an electric bus into South Africa, the 65 seaters, you end up with probably 40% tax because there's import tax. Then there's whatever that answer is that they add 10%. It's the weirdest calculation ever. Then to that answer they add another 25% what they call ad valorem tax and add that all those things together end up at about 55% tax so…"*]. In South Africa, the ad valorem tax rate alone on EVs is presently 15%. This means that an individual will have to pay R150,000 in ad valorem tax if they buy an EV for R1,000,000, but additional taxes upon that can increase the initial input tax to R400,000. It is crucial to remember that this tax rate only applies to the purchase of brand-new EVs; it does not apply to the importation or purchase of used EVs, however, due to the new technology and rapid development of technology, this is not an attractive option as in ICE vehicles.

In addition, EVs need to pay additional vehicle registration costs, which drive up the cost of the purchase. ["*Electric vehicles must pay a registration cost, which is normally around R2,000. In addition, all cars, including electric vehicles, must pay a charge for a roadworthy certificate. Depending on the province in which the car is registered, the amount of this fee varies, but it is typically around R2,000.*] The most important challenge is to bridge the challenge of aligning NEVs within the traditional vehicle classification and registration

process. For instance, there is uncertainty as to how to register and classify NEVs due to their disproportionately powerful powertrains relative to their weight, which can achieve more power and torque compared to ICEs even though they are lighter and safer than ICEs. As one respondent stated when responding to the inconsistencies between the power-weight ratio of electric bikes: *"Electric bikes should be classified if ever they reach a certain weight* [instead of horsepower]. *"*Since most regulators and authorities do not have any experience with NEVs and do not fully understand how the power-weight ratio in NEVs differs significantly from that of the significantly heavier and thus comparatively more dangerous ICEs, there is no consensus on how to regulate and classify the non-ICE powertrains.

Currently, since NEVs endure the same Ad Valorem tax burden as is applied to ICE vehicles, buses, and light vehicles, this regulatory burden on the fledgling NEV industry makes it difficult for the industry to compete with well-established, capital-intensive competitors in the conventional automotive industry. Whilst it might be argued that this is a utilitarian and fair tax for what is essentially a luxury vehicle, the impact of this Ad Valorem tax burden is significant in reducing the uptake of NEV technology. Since this is currently still a relatively new niche industry, the production inputs are still relatively expensive, resulting in expensive product prices. The popular lower-priced NEVs such as the Tesla Model 3, which costs approximately 35000 USD (632 000 ZAR), can attract tariffs and duties increasing the domestic price by about 35% to 150% to between R850 000 to R1.35 Mil. At the time of writing, the cheapest electric vehicle on the South African market costs just under 700,000 ZAR or 39,000 USD. As one respondent stated: [*"The vehicle cost double what the equivalent combustion engine vehicle costs".*] Respondents almost universally stated that tariffs make NEVs too expensive for most South Africans, and thus to enable effective uptake the government needs to temporarily reduce tariffs, provide subsidies and tax incentives for OEMs who locally manufacture or assemble NEVs. However, certain respondents are also optimistic that ICEs and NEVs will achieve cost parity over the next 8 to 15 years due to the rapid development of technology.

In terms of the public transportation sector for instance, one of the major bus operators in Cape Town currently has 2 electric buses, out of a total fleet of 1200, and the City of Cape Town's MyCiTi BRT system has 20 electric buses that are currently not operative. The bus operator representative commented that despite their initial optimism in adopting OLEV buses they discovered that the transition to green technology was difficult to implement due to outdated

regulations and high capital costs. From the operator's perspective, the difference in the average retail price (MSRP) of just under a million ZAR for an ICE bus compared to 5 million ZAR for an NEV bus makes this a difficult proposition. Particularly problematic is the additional 55% tax and tariff costs. These additional taxes and tariffs would increase the cost of conversion to electric buses to 8 million ZAR per bus. The bus operator respondent stated that the only way that they will even consider a conversion to green transportation is if there is a one to five-year moratorium on tariffs and taxes on these vehicles.

These challenges make the implementation of green transportation decisions impractical in terms of public transportation. One major bus operator stated that in the short term, *"…..electric buses do not pay right off in year one not, but the depreciation over the life of the vehicle can be an asset as a tax deduction, …let's say Golden Arrow spends 5,000,000 Rand on an electric bus the fleet of 60 is going to cost somewhere the vicinity of 300 million. But if you can get a 300 million Rand as a tax write-off…. So 28% of 300,000,000 will probably cost 90* [million ZAR]*."* Without significant state tax incentives, green public transportation will not be feasible in the public transportation sector. Almost all the respondents remarked that the tax costs of green transportation costs are too high for mass adoption in South Africa, so it remains a 'luxury item'.].

Compared to vehicles powered by conventional gas, NEVs also usually have higher insurance costs. The insurance premiums are increased to reflect the higher value of the car because electric vehicles are usually more expensive than regular gasoline-powered vehicles. In addition, the cost of insurance accounts for the potential expense of replacing or repairing batteries, one of the more complex components of electric vehicles. The insurance industry in South Africa is relatively underdeveloped since NEVs are not easily replaceable with well-accessible substitute products. For this reason, NEVs there and disproportionately higher insurance burden compared to other ICE vehicles.

The South African government is currently updating the legislation governing electric vehicles. It is expected that the new legislation will be more in line with the vision set out in the Redbook. This will probably lead to a number of changes, including the relaxation of registration requirements. The registration requirements for electric vehicles are likely to be relaxed, which will make it easier for people to purchase and register electric vehicles. Another expected change is the reduction or elimination of taxes. The taxes that are currently imposed on electric vehicles are likely to be reduced or eliminated, which will make electric vehicles more

affordable for people. Furthermore, the increased investment in infrastructure by the South African government is likely to create more investment in infrastructure for electric vehicles. This would include things like charging stations and public transportation. These changes are expected to make electric vehicles more accessible and affordable in South Africa. This will help to reduce air pollution and improve the environment.

To reduce capital investment costs for new users, respondents suggest, the South African regulators should adopt best practices from around the world such as demand-side incentives. One respondent stated: [*"Well, there's a case study. …in Denver, Colorado …they introduced a voucher system where they give the citizens vouchers between $400.00 and $1200.00. The richer you are, the smaller your vouchers."* Another respondent highlighted the potential for smart financing innovations such as employee benefit schemes: "*Industry must come up with what we call the employment benefit scheme, where they give the employees benefits for using the vehicles. Subsidies or Thatcherism what? Civil society must put the pressure on government and industry to give them these incentives."*]. Without a reduction in the tax rate of NEV vehicles making them more competitive than other substitute ICE vehicles, and without an efficient incentive scheme to incentivise consumers to forego the upfront costs of NEV vehicles, it will take a long time for the transition to green transportation to become established.

4.4 STIMULATING SUSTAINABLE GREEN TRANSPORTATION INDUSTRIES TO ENCOURAGE LOCAL ADOPTION

According to certain industry players, the green transportation industry has set out a compelling business case before the National Treasury to stimulate greater domestic demand for NEVs in South Africa, by reducing the Ad Valorem duty to reduce the capital cost of NEVs relative to the price of an ICE vehicle for a period of five years (Christianson, 2022). They argue that the future of the automotive industry in South Africa lies in large-scale green vehicle production and NEV component exports and there is, therefore, a general acknowledgment that the domestic automotive industry must think differently about NEVs. According to one respondent: ["*Electric cars are more environmentally friendly than conventional gasoline-powered ones. They don't contribute to air pollution in the same manner as conventional*

gasoline-powered vehicles because they have no exhaust emissions. Further reducing their carbon footprint, electric vehicles have the ability to run on renewable energy sources like solar or wind power. It's crucial to remember that the environmental impact of electric vehicles varies depending on where the electricity used to charge them comes from. The environmental impact of electric vehicles may not differ significantly from that of conventional gasoline-powered automobiles if the electricity is produced from non-renewable sources, such as coal."]. The principal argument is expanding the growth of the domestic green transportation manufacturing sector. Another respondent stated that exporting green transportation remains an important objective to generate sufficient economies of scale and maintain international competitiveness among South Africa's existing automotive industry OEMs. If South Africa does not want to lose its major export markets and face significant job losses at the plant level, it must accelerate green transportation transformation.

Based on discussions with the Executive Oversight Committee of the Auto Master Plan, several NEV industrialisation policy options were identified for inclusion in future production and value chain development policies (Barnes, 2017). The first is a lower or zero-rated duty for identified unique NEV production input components on the condition that it results in value-added local assembly by NEV OEMs generating domestic employment and green industry development. To protect the local import duty base, NEV-generated value-added local assembly credits should only be used to offset the green transportation OEM's customs account. Such duty valuations should be independently verified and audited to ensure global market-related values are employed. Secondly, the state can consider providing Production Incentive (PI) generated Production Rebate Certificates (PRCs) to strengthen local value-added production, thereby increasing the local demand for production inputs that can be supplied by local producers in the future. Finally, it is proposed that a sunset clause should be introduced, allowing NEV input production components to eventually become localised in the future, thus eventually growing NEV component production in South Africa. This sunset clause should be incremental in the form of an incrementally upward adjusted PI factor for NEV components similar to the previous APDP "vulnerable sector" policy. Industry proposes that the lower-rated duty be greater than the current 50%.

Regardless, this industry still attracts high levels of capital investment, similar to other renewable energy investments, and has high returns on investment due to the rapid rate of technology development, paying off the high initial investment costs over time. While the

Automotive Production and Development Programme (APDP) and Procurement Policy Framework Act (PPPFA) are not specifically designed for the automotive sector, it does have a significant impact in terms of the financing of vehicle manufacturing and assembling industries in South Africa and thus is particularly important to support fledgling domestic green transportation industries. The problem is that production and value chain development policies such as APDP and PPPFA do not consider that there will initially be a cost premium to nascent NEV OEMs in South Africa based on the higher component import costs needed for NEV assembly. Since green transportation industries are highly dependent on expensive production inputs requiring international value chains, the input duties and domestic value chain rebates hinder the growth of this industry.

Temporary support in the form of import duty discounts could significantly help the growth of NEV OEMs in the future. The South African Automotive Masterplan (SAAM) was set to replace the APDP in 2021, with the key difference from the APDP being to include a one-tariff regime across all light vehicles and green transportation modes which will potentially address the high import duty challenge (Kumalo, 2019). However, the future SA Automotive Masterplan 2035 and current APDP do not provide the necessary support for local competency development. At present, these policies are tailored towards the dominant ICE OEMs, merely continuing with the same ideas and policies as in their previous iterations.

Respondents indicated that a key step in promoting the industry would be to adopt an agnostic approach to ICE and NEV technology, enabling the continuation of existing ICE OEMs, whilst incubating fledgling NEV OEMs. This requires special APDP or related policy support measures that would identify essential NEV component technologies that are currently not feasible for local production and thus could be excluded from import duties. Respondents suggest a stringent mapping exercise to verify that these components cannot be localised by any existing or new South African suppliers at requisite standard costs. These special policy support measures would apply to both the production of passenger car (PC) and light commercial vehicle (LCV) segments, increasing the export competitiveness of these products, whilst minimising its effect on the competitiveness of local ICE industries, since there is no real domestic market for NEVs.

However, the green transportation policy environment may change in the immediate future. Although at the date of submission of this paper, nothing yet has been legislated, *the Auto*

Green Paper: on the advancement of new energy vehicles in South Africa is currently in the final draft stage of the policy design process. A Green Paper is a government policy discussion paper that details specific issues for public debate and then points out possible courses of action in terms of policy and legislation. It articulates potential solutions for discussion by Cabinet following input from the public. A Green Paper is a precursor to a White Paper which details the official policy position of the government as approved by Cabinet. For instance, the Green Paper establishes challenging goals to lower carbon emissions from vehicles to enhance air quality in urban areas. The Green Paper establishes challenging a goal of a 34% reduction in carbon emissions from the transportation industry by 2030.

The government has implemented a number of programmes and policies to promote green transportation in order to meet this objective. The government made a commitment to increase the usage of renewable energy sources as part of its National Climate Change Response White Paper. Developing alternative energy sources, enhancing public transportation, and encouraging non-motorised modes of mobility including cycling and walking are together important priorities to promote climate resilience in South Africa (Department of Environmental Affairs, 2014). As another incentive, the Department of Transportation has put in place is special tax breaks and refunds for buyers of electric and hybrid vehicles (Department of Transportation, 2020). However, as the previous respondents have indicated, these proposals have not been implemented yet.

The Green Paper proposes a long-term advanced vehicle and vehicle component manufacturing transformation strategy to reposition South Africa's automotive industry transition from ICE technology into NEVs. The Green Paper specifically focuses on creating a high-yielding business environment, including appropriate fiscal and regulatory frameworks for NEV production. Its purpose is to support investment in the expansion and development of NEV and NEV components in new and existing manufacturing plants. This includes the development and investment in NEV component technologies, the expansion of the electric supply chain, transitioning towards cleaner fuel technologies, promoting research and development, and increasing employment in the sector by reskilling and upskilling the design, engineering, and manufacturing workforce. Since three out of every four South African manufactured cars are currently exported to the EU, it is clear that the domestic automotive industry cannot ignore NEVs if it wants to continue exporting to Europe (Department of Transportation, 2021). This is necessary because the implementation of the new Euro 7 emissions standards legislation that

is to be enacted in 2025 could significantly reduce the market for ICE vehicles in the future (Christianson, 2022).

4.5 OPPORTUNITIES AND CHALLENGES FOR SUSTAINABLE GREEN TRANSPORTATION DEVELOPMENT IN SOUTH AFRICA

The current energy crisis has created a new outlook towards green transportation since rising fuel costs are significantly affecting the industry. As one respondent stated *"It is generally true that refuelling conventional gasoline-powered automobiles is more expensive than charging electric ones. The cost of refuelling a gasoline-powered vehicle is substantially higher than the cost of charging an electric vehicle in South Africa, which is estimated by the International Energy Agency to be roughly R2.50 per kilowatt hour"*.]. This drives much of the research and development in the South African transportation industry to focus on developing new technologies for the NEV market. A number of small OEM manufacturers are developing prototype or test versions to experiment with South African road conditions. This is not just for a local market but also for an international market since the favourable structure of the southern African automotive manufacturing sector enables new NEV solutions to be marketed internationally. Hopefully, this will precede investment for full-scale production. As one respondent stated: ["*Several other factors may also contribute to the expansion of green mobility in South Africa. For instance, customers are now more able to afford EV batteries and other clean technology components because of their falling prices. In addition, there will probably be increased demand for these technologies as people become more aware of the advantages of green travel for their health and the environment."*]. Prototyping has been essential in the creation of new mobility solutions in South Africa's setting of green transportation. For instance, the University of Cape Town has created a clean tech incubator that gives businesses working on sustainable transportation ideas access to resources and support (University of Cape Town, 2020). This programme has led to the creation of various cutting-edge prototypes, including electric and solar-powered taxis and buses.

However, smaller niche market OEMs are not necessarily the only avenue for green transportation transitions. As one respondent stated: ["*In South Africa, electric cars are still a very specialised market, although interest is growing. In addition to several smaller, more niche electric vehicle producers operating in South Africa, several significant automakers, like*

BMW and Nissan, offer electric vehicles in their product lines."]. Along with government programmes, a number of businesses in the private sector are actively pushing green transportation in South Africa. Several OEMs and automakers, including Toyota and Volkswagen, have launched EV versions in the South African market. Technology firms like Uber and uYilo are making investments in infrastructure for EV charging stations and ride-sharing services. Energy companies are investing in renewable energy projects that could provide electricity for EV charging stations, including Eskom and independent power suppliers (Eskom, 2020).

The attractiveness of NEVs for future market expansion is due to their low operating and maintenance costs, with one manufacturer stating that: ["*electric vehicles require less maintenance over time than conventional gasoline-powered vehicles since they have fewer moving parts. This may also assist in lowering the total cost of ownership of an electric vehicle* "]. This requires the development of workable prototypes that can be commercialised in order to reach the market. Although NEVs compete with ICEs, there are strong existing production and distribution networks in the currently established ICE automotive manufacturing sector (Isaksen and Dorval, 2018). There are a number of effective instances of green transportation options in South Africa that have reached a level of commercialisation. Uber is one such example. In key cities all around the country, Uber has added a variety of electric and hybrid vehicles to its fleet. Additionally, a number of regional businesses produce electric bikes and scooters, offering a cost-effective and practical substitute for owning a personal vehicle. A good example is Khaltsha Cycles, a social enterprise encouraging non-motorised transportation (NMT) by providing selling, training, and maintenance of electric motor bicycles, stating that: ["*it is important to be able to make mistakes and be able to try out, you know, innovative ideas around mobility and not be afraid to fail and learn from failures. And I think our cities are not flexible enough…. And I don't think that's the way to deal with current problems right now."*]

However, smaller innovators experience much frustration at civil officials sticking to relevant standards and legislation, with no room for flexibility, with the most restrictive conditions for green transportation held by the South African Road Classification and Access Management Manual and Centre for Scientific Research (CSIR) Guidelines for human settlements and design (commonly known as the Redbook). There seems to be a lag or disconnect between what planners are envisioning for their built environment, and the design standards and legislation implemented on the ground. While on the surface, what's envisioned in a planning

or strategy document like the Redbook might seem to be more ambitious, outlining a future where EVs make up a significant portion of the vehicle fleet, supported by extensive charging infrastructure and powered by a grid that's predominantly powered by renewable energy, the inflexibility of their policies, and the limited scope for changing regulations once it is codified in the Redbook, means that most of the diatribes about accommodating green transportation are merely a smokescreen. The difference between what the legislation permits of electric vehicles in South Africa in practice and what is envisioned in the Redbook is that the legislation developed from the regulations in the Redbook is currently more restrictive than the vision of the Redbook. For example, the legislation currently requires that all-electric vehicles regardless of their size be registered with the South African Revenue Service (SARS), while the Redbook does not require this. Additionally, the legislation currently imposes a number of taxes on electric vehicles, while the Redbook does not envision any taxes being imposed on electric vehicles. The sentiments and viewpoints from respondents indicate that the biggest challenge in this industry is the lack of policy flexibility and responsiveness in different sectors of government within a rapidly evolving market and technologies.

Looking ahead, there are a number of recent developments in green transportation technologies that have enormous potential to revolutionise the market. The development of autonomous vehicles is one such trend that has the potential to reduce emissions and enhance road safety (KPMG, 2020). Another development is the optimisation of route planning, traffic management, and maintenance scheduling through the integration of artificial intelligence and machine learning algorithms. Nevertheless, if green mobility is to become a common practice in South Africa, there are still a number of important issues that need to be resolved. The high cost of technology, a lack of infrastructure, and low customer awareness are some of these issues (PwC, 2020). Collaboration between governmental organisations, commercial enterprises, and civil society organisations will be crucial to overcoming these challenges. A sustainable future requires green transportation, and South Africa is leading the charge in this revolution. The nation may move towards a more ecologically friendly and equitable transportation system through utilising innovation, technology, and governmental policies. Even if there are obstacles to overcome, there are many chances for growth and development in the green transportation sector in South Africa in the future.

4.6 CONCLUSIONS

In conclusion, transit is a crucial component of South Africa's economic growth and social mobility. The historical reliance on fossil fuels has increased greenhouse gas emissions and harmed the environment. The government may potentially reduce the sector's carbon footprint and enhance air quality by supporting green transportation options, such as electric and hybrid automobiles, and increasing public transit services, however, there are still a number of regulatory and implementation obstacles to its widespread acceptance. Section 4.2 highlighted that the major challenge in adopting green transportation is not the infrastructure so much, but the cost of maintenance in a country with a severely declining road infrastructure. Although bus operators are very open to switching over to NEVs, the threat of public disturbances such as riots and the vandalism of vehicles makes cheaper ICE vehicles preferable. There is a lot of pushbacks from the local taxi industry, which does not permit any vehicles, particularly not green buses from operating in the townships. Moreover, many potential consumers still have a misapprehension about the range and reliability of NEVs. This is exacerbated in the South African urban form, in which the daily driving distance between residents and place of work is relatively high due to the highly decentralised structure of our cities.

Another major challenge respondents face is the challenge of adapting the existing transportation policy environment to the needs of a very dynamic and rapidly developing green transportation sector. While higher-tier policies universally support green transportation initiatives, these initiatives are not devolved into lower-tier design regulations and planning bylaws, limiting the adoption of NEVs in transportation systems. The planning environment is still highly constrained by an antiquated set of bylaws and a restrictive infrastructure environment. This has not been effectively implemented in creating a common standards platform through the SABS, nor through a more sustainable energy mix in the country's energy grid. While transportation, production, and value chain development should be technology-agnostic, the inflexible policy environment limits the adaption to NEVs. There is one positive trend and that is the development of green transportation technologies in tertiary education institutions.

Section 4.3 highlights the uncertainty of sustainable green transportation regulations. While South Africa has an increasing number of high-level incentives and laws aimed at increasing opting for green transportation technologies, it is still hamstrung by vague regulations in terms of taxes, subsidies, and levies. The incompatibility of current vehicle import tax regulations stifles green technologies rather than incubates green industries. On paper, the South African

government has put in place a number of policies and laws to encourage environmentally friendly transportation, such as proposals for tax breaks for organisations purchasing electric vehicles, funding for the development of EV charging infrastructure, community outreach programmes, and investments in public transportation (Department of Transportation, 2020). However, in practice, the various tax structures in place NEVs in a higher cost category, often increasing the price of the vehicle by over 50%. Added to that is higher of vehicle registration costs and the challenge of aligning NEVs with ICE vehicle classification and registration processes. Additive these are the higher insurance premiums that NEVs receive due to the non-standard nature of these vehicles. These challenges limit the development of green transportation technologies and the growth of the green transportation industry, especially when far cheaper ICE alternatives are available in the market. However, the South African government is currently reviewing its legislation on electric vehicles and introducing new legislation that is in line with green transportation guidelines following international best practices.

Section 4.4 indicates that the green transportation industry is presenting a strong business case before the government to stimulate demand for NEVs. The argument is based on the environmentally friendly nature of NEVs and their ability to run on renewable energy sources. This is primarily focused on the manufacturing sector since the growth in the export of NEVs will reduce the cost of NEVs domestically. However, that requires lower due to rates for unique NEV production inputs such as value-added local assembly credits, production rebate certificates, and a sunset clause to gradually strengthen the cost competitiveness of the industry. This will probably greatly improve the financing of this industry since this industry attracts a high level of capital investment.

Unfortunately, some of the main programmes such as the APDP, SAAM, and PPPFA which promote local inputs and domestic value chains, hinder the growth of the NEV industry which is still primarily dependent on imports. Instead, the government should employ a technology-agnostic approach that benefits both the existing ICE industry and fledgling NEV producers, something for which the current policy environment is not geared for. It requires the wholesale replacement of existing legislation. This is the impetus from the new transportation Green Paper, which specifically aims to lower carbon emissions by promoting green transportation. In the future, the Green Paper envisions creating a high-yielding business environment with appropriate fiscal and regulatory frameworks to create a sustainable NEV supply chain,

reskilling the manufacturing sector and transitioning to cleaner fuel technologies, especially for the export market.

Section 4.5 concludes the analysis by evaluating the changing outlooks toward green transportation, which is driven by a high level of research and development in the local transportation industry. Very encouraging is the entrance of the small number of manufacturers that are developing new prototypes specifically designed for South African road conditions. This is occurring hand in hand with green transportation transitions in the traditionally ICE-producing companies. Due to their lower maintenance and operation costs, these firms are experimenting with NEVs, and opening up the field for new fledgling NEV companies to enter the market. This is despite the frustration with local regulations and guidelines that have ambitious goals for green transportation energy but do not allow modifications of their design standards to adapt to new technology.

CHAPTER 5: CONCLUSIONS

The paper evaluates the challenges the green transportation sector faces in South Africa, focusing on infrastructure and planning considerations, transportation policies that affect the transition towards green infrastructure, and the major concerns of manufacturers and users of NEVs. This is in light of the unprecedented crisis in the form of climatic changes and the role of the transportation sector in contributing to greenhouse gases.

The transition to green transportation is a complex and multifaceted issue. It requires a coordinated effort from governments, businesses, and individuals. The notion of green transportation in planning represents equitable and environmentally friendly traveling modes with low emissions, low energy consumption, and low pollution levels in terms of noise, air, and chemical run-off. The transition to green transportation presents an ontological argument for more human-scale development orientation in the built environment fields. Human-scale development in this context, reflects an orientation towards higher densities, developing an urban design conducive to green transportation and micro-industries that stem from its use. As South Africa is participating in the transition to green transportation, the research intended to use Cape Town as a case study to understand the dynamics of this transition with responses from stakeholders in government, civil society, and the private sector.

The problem statement for the study was to identify the challenges and opportunities of the transition to green transportation in South Africa. The study has successfully identified a number of challenges and opportunities, and it has also provided some recommendations for how to address these challenges. The study has contributed significantly to the understanding of the transition to green transportation in South Africa, and it has also provided some useful insights that can be applied to other cities around the world.

The study conducted in Cape Town, South Africa, has provided valuable insights into the challenges and opportunities of this transition. These include the need for coordination between different stakeholders is essential for the successful transition to green transportation. It also highlights that the high tax costs and the poor development of insurance and registration standards for green transportation is a major barrier to adoption, especially in South Africa. However, the development of new green energy technologies is an important opportunity for the transition to green transportation. The increasing demand for cheap sustainable transportation is a positive trend that can help to drive down the cost of green transportation.

One of the key challenges identified in the study is the lack of coordination between the different tiers of policies. Antiquated regulations and the poor devolving of regulations to the everyday planning bylaws and automotive industry regulations limit the effective use of enabling policies at the higher level. There is also uncertainty as to how to register and classify green transportation due to their disproportionately powerful powertrains relative to ICE vehicles. The study also highlighted the need for a common standards platform through the SA Bureau of Standards (SABS). It's not that there is a lack of enabling policies at the higher level, but the challenge is aligning the myriad of lower-level policies to the transition to a green transportation agenda. While public transportation providers struggle to find tax breaks to fund public transportation, the SABS struggles to create her common standards platform for the different technologies, planners struggle to effectively create regulatory bylaws that can be adapted to new technologies, and the national government struggles to provide an energy mix that can support NEVs and maintain the roads and lawn order for these vehicles to operate. All these myriads of minor obstacles contribute to the high cost of green transportation and makes it difficult for consumers to transition to green transportation vehicles, limiting the demand for these vehicles.

From the statements from respondents, it seems there may be a lag or disconnect between what planners are envisioning for their built environment, and the design standards and legislation implemented on the ground. More coordination and facilitation, with enterprises and civil society, should be encouraged to bring out more bottom-up solutions. There also seems too much confusion from the public as to green transportation because the public is generally misinformed about the utility, reliability, and convenience of green transportation technology. Moreover, the most poignant viewpoint from the majority of respondents is that the current legislation intersecting with green transportation technology is currently too vague and uncertain on key issues to attract active participation and investment in green transportation in South Africa. The issues include taxes, subsidies, levies, infrastructure, and local assembly and manufacturing regulations. The findings of this study reveal a disconnect between the visions of urban planners for green transportation in the built environment and the actual implementation of adapting design standards and legislation to the real demand for NEVs. This gap underscores the need for greater coordination and facilitation among enterprises, civil society, and government to foster bottom-up solutions. Public confusion and misinformation about green transportation technology also emerged as significant barriers to the transition. The

public's understanding of the utility, reliability, and convenience of green transportation technology needs to be enhanced to foster acceptance and adoption.

The most onerous challenge to adopt green transportation is the Ad Valorem duty tax on imports which makes NEV unaffordable for most South Africans. Respondents suggest temporarily reducing duty taxes and tariffs to reduce the initial capital cost of green transportation to boost the nascent green transportation industry in South Africa. This ought to address the issue of registering and classifying green transportation due to their disproportionately powerful powertrains relative to Internal Combustion Engine (ICE) vehicles. The rapid replacement of older legislation such as the Automotive Production and Development Programme (APDP), the South African Automotive Masterplan (SAAM), and the Procurement Policy Framework Act (PPPFA) could significantly benefit NEV manufacturing and assembling industries in South Africa for exports and local adoption. While these policies favourably view green transportation technologies, they are not designed to promote these technologies. Whilst amendments are still in the draft stage, the Green Paper may significantly change these policies in the immediate future. This includes a long-term advanced vehicle and vehicle component manufacturing transformation strategy to reposition South Africa's automotive industry transition from ICE technology into electro-mobility technologies. It specifically focuses on creating a high-yielding business environment, including appropriate fiscal and regulatory frameworks for NEV production. The South African Automotive Masterplan (SAAM) proposes a one-tariff regime across all light vehicles and green transportation modes to address the high import duty challenge.

Despite these challenges, there are also a number of opportunities for the transition to green transportation. One of the biggest opportunities is the development of new technologies, especially in tertiary education institutions. New technologies, such as electric vehicles and solar-powered buses, are becoming more accessible and efficient, if not currently affordable. Civic groups especially within the green transportation industry are actively lobbying the government to coordinate transitions. They highlight that these technologies have the potential to make a difference in the South African automobile manufacturing sector since this has a strong, ready market in the EU and will enable the local market to acquire cost-efficient vehicles. This includes small niche market innovative firms, as well as larger vehicle producers who are shifting to green transportation technology. This increasing demand can create a market for green transportation, which can help to drive down the cost of these vehicles.

The study suggests major initiatives to improve green transportation transitions in urban planning, including establishing coordination teams or working groups between the government, and the private sector, particularly in the green transportation sector and civil society. These teams would coordinate green transportation planning, investment, construction, and management initiatives and adapt local regulations to the needs of green transportation transitions. The goal of these actions is to enable a just transition to green transportation technology and manufacturing sector that could create additional jobs, stimulate local industries, and generate new markets for NEVs, thereby overcoming the negative effects of the declining demand for ICE technologies. Green transportation can develop local micro-economies generating business opportunities for the private sector and employment creation in the public sector, as well as transition large ICE OEMs into green transportation technology.

In conclusion, the transition to green transportation in South Africa is fraught with challenges. However, with coordinated efforts among various stakeholders, clear and supportive legislation, and public education about the benefits of green transportation, these challenges can be overcome. This study provides valuable insights into the dynamics of this transition and offers practical recommendations for facilitating the shift toward a more sustainable and equitable transportation system. The transition to green transportation, characterised by low emissions, low energy consumption, and minimal pollution, is a critical step towards achieving sustainable urban development. This shift not only addresses environmental concerns, but also promotes equitable access to transportation. However, the transition is not without its challenges, particularly in developing nations like South Africa. This study aimed to delve into these challenges to understand the dynamics of this transition from the perspectives of various stakeholders in government, civil society, and the private sector.

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APPENDICES

APPENDIX A

Interview questions

1. How do you interact with the informal transport sector with regard to green transportation?
2. What is the capacity for your current role?
3. What is the current regulatory landscape for green transportation in South Africa
4. What are the stakeholder dynamics in this space and their motivations?
5. Who is responsible for steering the transition to green transport?
6. What are the socio-economic and perception barriers to green transportation uptake?
7. What are the policy gaps in the current legislation for green transportation for effective uptake?
8. Does citizen engagement and participation affect and influence green transportation initiatives?
9. How do you measure green transportation uptake?
10. What would proactive policy planning for green transport potentially achieve?
11. What role does local government have in fostering green transportation initiatives?
12. Is public-private partnerships an adequate vehicle to facilitate this transition?
13. What role do the industry, civil society and academia have in fostering green transportation initiatives?
14. How effective is the current legislation around green transportation in fostering growth in the industry?
15. What is the sustainability of green transport initiatives in Cape Town?
16. What are the international best practices?
17. Urban and regional planning and urban design suggestions?

APPENDIX B

UNIVERSITEIT STELLENBOSCH UNIVERSITY

CONDITIONAL APPROVAL GRANTED

REC: Social, Behavioural and Education Research (SBER) - Initial Application Form

5 August 2021

Project number: GEO-BA-2021-22359

Project title: The challenges of a developing nation transitioning to green transportation: A Cape Town case study.

Dear Mr ET Malebo

Your REC: Social, Behavioural and Education Research (SBER) - Initial Application Form submitted on 29/06/2021 12:09 was reviewed by the REC: Social, Behavioural and Education Research (REC: SBE) on and approved with certain conditions.

This conditional approval means that the researcher may proceed with the envisaged research provided that they respond or adhere to the stipulations/conditions.

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
5 August 2021	4 August 2024

REC STIPULATIONS/CONDITIONS:

The researcher intends to interview personnel at the Transport department at national level and City of Cape Town. No institutional permission submitted. The researcher should ensure that institutional permissions are obtained before they proceed with interviews. The researcher is reminded to obtain permission from the participating organisation(s) before recruitment and/or data collection may commence. Proof of permission should be uploaded to the REC online application once received [ACTION REQUIRED]

HOW TO RESPOND:

Some of these stipulations/conditions may require your response. Where a response is required, you must respond to the REC within **three (3)** months of the date of this letter.

Your conditional approval will lapse automatically should your response not be received by the REC within 3 months of the date of this letter.

For instructions on how to respond to these stipulations, please download the FAQ on how to edit your application and follow the steps carefully: HOW TO RESPOND TO REC FEEDBACK.

Where revision to supporting documents is required, please ensure that you replace all outdated documents on your application form with the revised versions.

INVESTIGATOR RESPONSIBILITIES

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: SBE, the researcher must notify the REC of these changes.

Please use your SU project number (22359) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the REC: SBE before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary)

Included Documents:

Document Type	File Name	Date	Version
Informed Consent Form	Informed consent form for green transport study-19217471	28/06/2021	2
Research Protocol/Proposal	TEM_MPHIL_MURP_Proposal_V2	28/06/2021	2
Data collection tool	Research_questions_2	28/06/2021	2

If you have any questions regarding this application or the conditions set, please contact the REC Secretariat at cgraham@sun.ac.za.

Sincerely,

Clarissa Graham
Secretariat: Research Ethics Committee: Social, Behavioural and Education Research (REC: SBE)

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.
The Research Ethics Committee: Social, Behavioural and Education Research complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. Annually a number of projects may be selected randomly for an external audit.

Principal Investigator Responsibilities

Protection of Human Research Participants

As soon as Research Ethics Committee approval is confirmed by the REC, the principal investigator (PI) is responsible for the following:

Conducting the Research: The PI is responsible for making sure that the research is conducted according to the REC-approved research protocol. The PI is jointly responsible for the conduct of co-investigators and any research staff involved with this research. The PI must ensure that the research is conducted according to the recognised standards of their research field/discipline and according to the principles and standards of ethical research and responsible research conduct.

Participant Enrolment: The PI may not recruit or enrol participants unless the protocol for recruitment is approved by the REC. Recruitment and data collection activities must cease after the expiration date of REC approval. All recruitment materials must be approved by the REC prior to their use.

Informed Consent: The PI is responsible for obtaining and documenting affirmative informed consent using **only** the REC-approved consent documents/process, and for ensuring that no participants are involved in research prior to obtaining their affirmative informed consent. The PI must give all participants copies of the signed informed consent documents, where required. The PI must keep the originals in a secured, REC-approved location for at least five (5) years after the research is complete.

Continuing Review: The REC must review and approve all REC-approved research proposals at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the REC approval of the research expires, **it is the PI's responsibility to submit the progress report in a timely fashion to ensure a lapse in REC approval does not occur.** Once REC approval of your research lapses, all research activities must cease, and contact must be made with the REC immediately.

Amendments and Changes: Any planned changes to any aspect of the research (such as research design, procedures, participant population, informed consent document, instruments, surveys or recruiting material, etc.), must be submitted to the REC for review and approval before implementation. Amendments may not be initiated without first obtaining written REC approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the REC should be immediately informed of this necessity.

Adverse or Unanticipated Events: Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research-related injuries, occurring at this institution or at other performance sites must be reported to the REC within **five (5) days** of discovery of the incident. The PI must also report any instances of serious or continuing problems, or non-compliance with the RECs requirements for protecting human research participants.

Research Record Keeping: The PI must keep the following research-related records, at a minimum, in a secure location for a minimum of five years: the REC approved research proposal and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence and approvals from the REC.

Provision of Counselling or emergency support: When a dedicated counsellor or a psychologist provides support to a participant without prior REC review and approval, to the extent permitted by law, such activities will not be recognised as research nor the data used in support of research. Such cases should be indicated in the progress report or final report.

Final reports: When the research is completed (no further participant enrolment, interactions or interventions), the PI must submit a Final Report to the REC to close the study.

On-Site Evaluations, Inspections, or Audits: If the researcher is notified that the research will be reviewed or audited by the sponsor or any other external agency or any internal group, the PI must inform the REC immediately of the impending audit/evaluation.

APPENDIX C

Informed consent form for Green transportation stakeholders

PERMISSION FROM PERSONS IN INFORMAL SETTLEMENTS AS PARTICIPANTS IN RESEARCH

My name is Tumelo Malebo (student number 19217471) from the University of Stellenbosch and I am officially registered for the MPhil in Urban and Regional Planning. I would like to request your permission to assist me in a research project entitled: The Challenges of a Developing Nation Transitioning to Green Transportation: A Cape Town Case Study.

1. PURPOSE OF THE STUDY

The study aims to gain deeper insights into the challenges and shortcomings in the green transport transition for a country such as South Africa. This research topic explores green transportation transitions in Cape Town, with a particular focus on the intersection between privately funded initiatives and local government in Cape Town. The research seeks to understand the viewpoints and sentiments of whether the current regulations surrounding green transport in South Africa are conducive to the incremental transition to green transportation in South Africa.

2. WHY YOU HAVE BEEN SELECTED FOR THIS INTERVIEW

You have been selected because you have experience with the green transport industry in South Africa, either from the government, the private sector, or civil society. The study intends to learn from your experience to understand the challenges in the green transportation industry in South Africa and possible remediations thereof.

3. WHERE INTERVIEWS WILL TAKE PLACE AND HOW LONG INTERVIEWS ARE EXPECTED TO LAST

Interviews will take place at any location you choose, whether at home, and a public space, or at the place of work. The interviews will occur between a space of 15 minutes to an hour depending on how on the length of the answers given. The interview will take place telephonically, via Microsoft Teams or Zoom. You will not be expected to answer all the

questions, only those questions that are deemed relevant to your circumstances and level of knowledge.

4. WHAT WILL BE ASKED OF ME?

1. How do you interact with the informal transport sector with regard to green transportation?
2. What is the capacity for your current role?
3. What is the current regulatory landscape for green transportation in South Africa
4. What are the stakeholder dynamics in this space and their motivations?
5. Who is responsible for steering the transition to green transport?
6. What are the socio-economic and perception barriers to green transportation uptake?
7. What are the policy gaps in the current legislation for green transportation for effective uptake?
8. Does citizen engagement and participation affect and influence green transportation initiatives?
9. How do you measure green transportation uptake?
10. What would proactive policy planning for green transport potentially achieve?
11. What role does local government have in fostering green transportation initiatives?
12. Is public-private partnerships an adequate vehicle to facilitate this transition?
13. What role do the industry, civil society and academia have in fostering green transportation initiatives?
14. How effective is the current legislation around green transportation in fostering growth in the industry?
15. What is the sustainability of green transport initiatives in Cape Town?
16. What are the international best practices?
17. Urban and regional planning and urban design suggestions?

5. POSSIBLE RISKS AND DISCOMFORTS

While the study should not pose any risks or discomforts to yourself, we need to ensure the safety of interpreters. However, you are welcome to seek assistance from someone who is 18 years or older to assist during the survey.

6. POSSIBLE BENEFITS TO PARTICIPANTS AND/OR TO THE SOCIETY

The study aims to gain deeper insights into the challenges and shortcomings in the green transport transition for a country such as South Africa. This research topic explores green transportation transitions in Cape Town, with a particular focus on the intersection between privately funded initiatives and local government in Cape Town. The research seeks to understand whether the current regulations surrounding green transport in the South are conducive to the incremental transition to green transportation in South Africa.

7. PAYMENT FOR PARTICIPATION

Since this is an academic research study adding to the existing body of knowledge with regard to land use regulation, the interviewees will not be financially compensated for participating in the study. The translators will however be paid for assisting the researcher in collecting the data.

8. PROTECTION OF YOUR INFORMATION, CONFIDENTIALITY AND IDENTITY

Any information you share with me during this study that could identify you as a participant will be protected. Neither your name, location, nor address will be requested. You will not be required to provide any specific information on any specific event or person. Rather, you will merely be requested to provide information regarding the normal processes followed within the community with regard to regulating land uses. During data analysis and writing up of findings, the identifiers will be replaced by codes which will prevent any of the participants from being identified.

9. PARTICIPATION AND WITHDRAWAL

Should the interviewee decline to participate at any time, the rights of the interviewee are maintained to withdraw any information revealed in the interview.

10. RESEARCHERS' CONTACT INFORMATION

If you have any questions or concerns about the research, please feel free to contact the researcher and project coordinator: Tumelo Malebo, 19217471, 19217471@sun.ac.za, 0786368415

Supervisor: Herman Geyer, hsgeyerjr@sun.ac.za

11. RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a participant, contact Ms Maléne Fouché

[mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

12. DECLARATION OF CONSENT BY THE INTERVIEWEE

As the interviewee, I confirm that:

I have read the above information and it is written in a language that I am comfortable with.

I have had a chance to ask questions and all my questions have been answered.

All issues related to privacy, and the confidentiality and use of the information I provide, have been explained.

By signing below, I _____grant permission for the interview.

_____ _____

Signature of Representative Date

DECLARATION BY THE PRINCIPAL INVESTIGATOR

As the principal investigator, I hereby declare that the information contained in this document has been thoroughly explained to the participant. I also declare that the participant has been encouraged (and has been given ample time) to ask any questions.

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Signature of Principal Investigator Date