UNPACKING THE TECHNICAL AND PERCEPTION BARRIERS TO ELECTRIC VEHICLE UPTAKE IN SOUTH AFRICA

BY

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Declaration

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Abstract

The rapid population growth and urbanization on the African continent exert ever more pressure on existing infrastructure, especially energy and transportation infrastructure, which is predominantly fuel-based. This puts a high transport cost burden on citizens and the countries on the continent, due to ever-increasing fuel prices. South Africa urgently needs an alternative transportation system that can offset the fuel cost burden, and reduce carbon emissions through the effective use of its abundant renewable energy resources such as wind and solar.

The main aim of this research is to unpack the technical and perception barriers withholding the mass uptake of electric vehicles in South Africa, assess the opportunities for the innovation and the global growth thereof. The researcher uses quantitative data to address the research objectives by using both primary and secondary research data sources. Using snowball technique and social media platforms, primary data is sourced from experts in the automobile industry, transport departments and the public. Secondary data such as vehicle sales data, and infrastructure development information is obtained from the websites of the various automobile agencies. The World Bank and various automaker associations such as the National Association of Automobile Manufacturers of South Africa (NAAMSA), Nissan South Africa, and BMW South Africa assisted with the secondary data.

The results show that the global transition to electromobility is happening rapidly in China, Europe and the United States, with South Africa far behind when compared to the rest of the world. The results further indicate that electric vehicle technology can offer more benefits such as lowering carbon emissions, stimulation of innovation, decreasing the country's dependence on fossil fuel and fostering economic development by lowering transport costs. However, these technological advantages of electric vehicles over internal combustion vehicles are associated with social challenges, infrastructure challenges, economic challenges and political challenges to both the early adopters and the country in general.

The high purchase cost of electric vehicles results in their high total cost of ownership compared to internal combustion vehicles. On the other hand, electric vehicles have a lower running cost than conventional vehicles in South Africa. Nevertheless, the higher price premium cannot be offset only by lower running costs, but by a combination of lower running cost and incentives such as the provision of capital subsidies on electric vehicle retail prices, and lower import tariffs. It is further recommended that the country needs to intensify its policies, educate the public and create an enabling environment for mass uptake in order to catch up with global developments while attaining its sustainability targets.

Keywords: electric mobility; electric vehicle total cost of ownership; adoption barriers and opportunities; global electric vehicle development.

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Abbreviations

AC	Alternate Current
AEV	All Electric Vehicles
ARPA-E	Advanced Research Projects Agency-Energy
BEV	Battery Electric Vehicle
CCS2	Combined Charging System 2
CEV	Combined Electric Vehicle
CHAdeMO	Acronym for “Charge de Move” or “charge for moving”
CSIR	Council for Scientific and Industrial Research
CV	Conventional Vehicle
DC	Direct Current
DCFC	Direct Current Fast Charging
DTI	Department of Trade and Industry
ECCM	European Commission’s Clean Mobility programme
EPA	Environmental Protection Agency
EU	European Union
EV	Electric Vehicle
EVIA	Electric Vehicle Industry Association
EVSE	Electric Vehicle Supply Equipment
GHG	Green House Gas
GM	General Motors
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
KM	Kilometres
KM/h	Kilometres per hour
KW-hr	Kilowatt-hour
LCV	Low Commercial Vehicle
MW/h	Megawatt/hour
NAAMSA	National Association of Automobile Manufacturers of South Africa
NEC	National Energy Council
NEMMP	National Electric Mobility Mission Plan
NGO	Non-Governmental Organisation
OCPP	Open Charge Point Protocol
OICA	Organisation Internationale des Constructeurs Automobiles
OPEC	Oil Producing Countries

PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
RSA	Republic of South Africa
SAE	System Architecture Evolution
SSA	Sub-Saharan Africa
TCO	Total Cost of Ownership
TCOC	Consumer-based Total Cost of Ownership
UK	United Kingdom
UNIDO	United Nations Industrial Development Organization
VAT	Valued Added Tax
VW	Volkswagen
WHO	World Health Organisation

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Chapter 1: Introduction

1.1 Introduction

The transport sector is a catalyst for economic development and the improvement of the welfare of nations. It provides accessibility, lower production costs and ultimately leads to larger markets. Transport operations and infrastructure are however associated with many externalities such as greenhouse gas emissions, as well as being the sector which consumes the most energy globally. The transport sector alone contributes to a greater percentage of greenhouse gases and is the fastest-growing emissions sector globally (Ritchie & Roser, 2017). With rapid urbanization and car ownership in developing countries such as South Africa, the rate of carbon emission is equally increasing at a higher rate than before. The soaring oil prices, fuel shortages and the impact of climate change have led to global disruption in the transport sector, causing countries and automakers to explore alternative options for sources of fuel such as biofuel, solar and battery-powered vehicles (World Bank Group, 2015). Many countries in the world have started instituting strict policies, even in some cases banning the use of fossil fuel vehicles.

The aim of exploring these alternative options and instituting strict policies is to address externalities associated with the transport sector. The introduction of clean energy mobility such as electric vehicles to reduce fossil fuel dependence and increase reliance on cheaper sustainable and renewable energy sources is considered a good alternative to the dilemma of transport sector pollution. Because of these benefits, electric vehicles have gained popularity on continents such as Asia, Europe, and North America. However, a number of barriers remain that withhold the mass adoption and endorsement of this emerging green transport technology. According to Wang, Yu, Yang, Miao, & Ye (2017), consumer perception of electric vehicle technology is the main barrier to market penetration. The authors postulate that if consumers can obtain an accurate knowledge of electric vehicle technology and experience it regularly, their attitude will change and their willingness to endorse the technology will increase.

There is, however, uncertainty and to some extent, concern over the affordability and the ownership cost compared to conventional vehicles. Cost comparison between a normal conventional vehicle and the electric vehicle counterpart will yield much insight into the current affordability of electric vehicles and the developments that will need to take place to lower the total cost of ownership. Such a cost comparison can also be used to analyse the impact of tax reductions and incentives on the price premium of electric vehicles as well as inform potential consumers about electric vehicle technology and the implications thereof.

This research focuses on assessing the potential opportunities, barriers, development and total cost of ownership in the uptake of electric vehicles in the Sub-Saharan African region, using South Africa as a case study. Over the past decade, the internal combustion engine has entrenched itself in economies and the daily lives of people. It is also very important in the economic sector (a lot of employment), an earner of foreign exchange and inspiring a very strong political lobby group. For a new technology such as electric vehicles to be acceptable, it will have to overcome a lot of technical, economic, social and political barriers (Egbue & Long, 2012).

1.2 The significance of the study

This research aims to provide some information on the adoption barriers and the public perception of electric vehicle technology in South Africa. It is also important as it contributes towards the ongoing conversation of electric vehicle adoption on a wider global scale. On the global level, much research has been conducted on the use of electric vehicles, but limited research has been conducted that relates in particular to South Africa or Sub-Saharan Africa as a whole. To address this gap, the research provides an in-depth analysis of electric vehicle development, adoption barriers, and opportunities that electric vehicle technology will bring to South Africa. It further evaluates the Total Cost of Ownership of electric vehicles compared to internal combustion engine vehicles in South Africa. Therefore, the study is important as it informs consumers and policymakers of the important cost drivers that influence the uptake of electric vehicles. It also outlines the public perception barriers as well as experts' opinions on the uptake of electric mobility in South Africa. These implications of electric vehicle innovation can be useful to automobile industries, fleet purchasers and private owners who are planning to switch to low-emission vehicles.

1.3 Research problem

Globally, poor air quality claims several lives and exposes millions to cardiovascular diseases annually. The greater part of global carbon emissions come from transportation, which is projected to increase due to the high rate of urbanization and car ownership (The World Bank, 2017). In general, the African continent contributes fewer greenhouse gases compared to the rest of the world; however, it is the most vulnerable when it comes to the effect of climate change. Hence, African countries are also committed to cutting emissions on the continent (World Bank Group, 2015).

Switching to a more sustainable form of transport such as electric mobility and investing in renewable energy sources are some possible steps the sub-continent can take to reduce greenhouse gas emissions while honouring its commitment. Electric mobility technology is an opportunity to utilize renewable natural energy such as solar, hydro and wind, readily available at a lower environmental and indeed social cost while decreasing countries' reliance on oil. This results in a reduction in government expenses due to improved balance of payments, reduced transport costs and improved health arising from better air quality (Dane, Wright & Montmasson-Clair, 2018). Before this transition can occur, the barriers that inhibit the uptake of electric vehicles should be acknowledged, understood and addressed. If these barriers are not addressed, it is doubtful whether electric mobility will have the desired positive effect in the country.

1.4 Research aim

The aim of the research is to unpack the perceived technical and social barriers withholding the mass uptake of electric vehicles in South Africa, as well as to assess the opportunities and the ownership cost of both conventional and electric vehicles.

1.4.1 Specific objectives

The research seeks to:

- Investigate the development of electric vehicles and the factors that are driving the development of electric vehicle technology.
- Determine the main cost elements of electric vehicles and compare the total cost of ownership of electric, hybrid and conventional vehicles in South Africa.
- Determine the public perceptions and technical barriers hindering the uptake of electric vehicles.

1.5 Research questions

The following research questions address the research objectives of the study.

- What are the global developments with regard to electric vehicles, and what factors are driving these sales?
- What are the adoption barriers that potential electric vehicle owners may face in South Africa?
- What are the potential opportunities that electric vehicle owners may experience in South Africa?
- What is the total cost of owning and operating an electric vehicle compared to a conventional vehicle in South Africa?

1.6 Methodology and data

The study used quantitative data to attain the research objectives. Primary and secondary research data as indicated in Figure 1.1 was used. The primary data was sourced from experts in the automobile industry and among the public. The experts were from both the private and public sectors in South Africa. These included automobile industries, companies and the Department of Transport. The respondents for the general surveys were sampled by applying authoritative, snowball and convenient sampling techniques using social media.

Secondary data was obtained from various agencies involved in automobility globally. The secondary data included vehicle sales data, infrastructure development information, potential challenges and opportunities available. The World Bank and various automakers associations such as Light Stone Auto, GridCars, National Association of Automobile Manufacturers of South Africa (NAAMSA), United Nations Industrial Development Organization (UNIDO), Electric Vehicle Industrial Association (EVIA), uYilo e-Mobility Technology Innovation and International Energy Agency (IEA) were used.

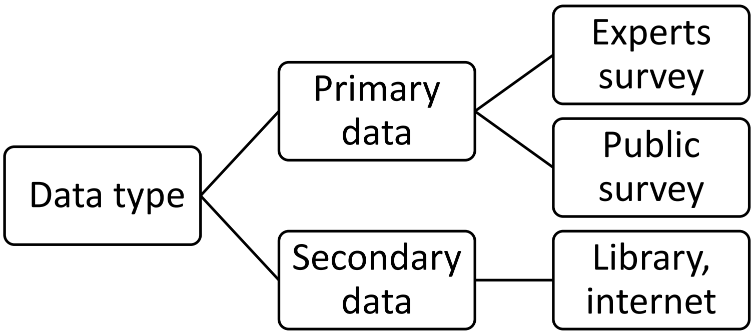

Figure 1.1: Data types and collection techniques

1.7 Outline of chapters

The study consists of nine complete chapters, beginning with the first chapter, which contains an introduction, the purpose of the research, its aims and objectives, and the research questions for the study. Chapter 2 reviews the literature relevant to the study. This covers the evolution of electric vehicles, adoption barriers and opportunities, global electric vehicle developments and the conceptual model of the approach that unveils the topic to realise the set aims and objectives by using the research questions as the watchword.

Chapter 3 deals with the appropriate methods that are applicable to achieving the set aims and objectives. These include the types of data as well as various steps and processes of data collection, capturing and analysis techniques. After the methodology, Chapter 4 outlines the realities of electric vehicles, including types of electric vehicles and charging stations. A modal cost analysis was done in Chapter 5 to compare the cost of ownership between electric and conventional vehicles. This entails a comparison of the daily, monthly and yearly cost of ownership of electric and conventional vehicles respectively. Chapter 6 analyses the data gathered from the expert survey by using descriptive statistics techniques such as graphs and tables. The data obtained from the population survey was also analysed separately in Chapter 7 of the study. An analysis of the findings in Chapters 5 and 6 was done in Chapter 8. This involved making deductions from the data analyses in relation to the research objectives and the relevant literature. The information discovered was meaningfully concluded and the necessary recommendations, as well as future areas of study, were suggested in Chapter 9.

Chapter 2: Literature review conceptual framework

2.1 Introduction

In order to assist in creating a better understanding of the subject matter outlined in the earlier chapter, related themes in the literature are investigated. The literature review begins with the history of electric vehicles internationally and locally. Thereafter current developments in the electric mobility industry are studied. Following this, the opportunities and challenges in the adoption of electric vehicles in South Africa are reviewed. In addition, the total cost of ownership of electric and conventional vehicles in South Africa is included, so that the affordability of electric vehicles can be determined based on the cost of ownership of conventional vehicles.

2.2 Global electric vehicle evolution

In 1889-1891, William Morrison, a chemist from Des Moines, Iowa, created the first successful electric vehicle in the United States (US), which ignited public interest in electric vehicles because of their quietness, absence of pollution and vibration. These characteristics led to many electric vehicles being manufactured in America and the rest of the world. The first electric vehicles looked like carriages (Figure 2.1) and could only travel short distances of about 18 miles (Hutchinson, Burgess & Herrmann, 2014). As years went by electric vehicles from different automakers became common across the US automobile market and were rapidly replacing the fossil fuel vehicles of the early 1900s (Contestabile, Offer, Slade, Jaeger, & Thoennes, 2011). However, because of their short-range capacity, they were used for short trips around city centres and hence were popular among urban residents, especially women.

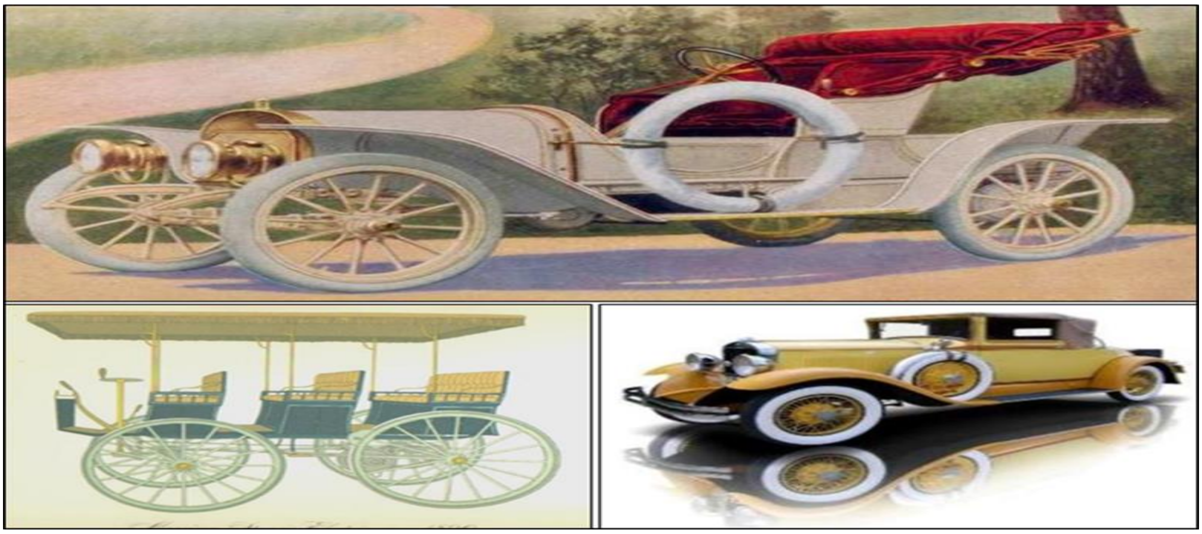

Figure 2.1: First Electric Vehicle – William Morrison
Source: World Economic Forum, 2018

As the electric vehicle technology and transport infrastructure kept on developing, it became easier for electric vehicle owners to travel beyond the city centres, adding to the popularity of these vehicles with all lifestyles in America. The improved technology and the need to reduce emissions led to the mass adoption of electric vehicles globally in the 1910s. In the 1920s, the production of and high demand for electric vehicles declined due to reduced fossil fuel prices and economies of scale of conventional vehicles, which led to conventional vehicles becoming more affordable than electric vehicles. Secondly, improved road infrastructure led to people travelling long distances between cities, and they thus needed longer-range vehicles to commute.

The revival of alternative energy in the transport sector occurred in the 1970s due to global oil shortages, which led to an increase in oil prices as shown in the graph in Figure 2.2. The search for alternative fuel for vehicles in order to reduce dependence on foreign fossil fuels and emissions from vehicles was on again. It was during this time that Battronic produced the first electric truck, with a range of 62 miles and a payload of 2 500 pounds in England. During this period (the 1970s) Battronic also produced passenger buses in England.

Due to the increase in conventional vehicle innovations, range anxiety and cheap global oil prices, the true revival of the electric vehicle market did not happen until the start of the 21st century (Ellram, 1995) and (Reda, Fuad & Aditya, 2017).

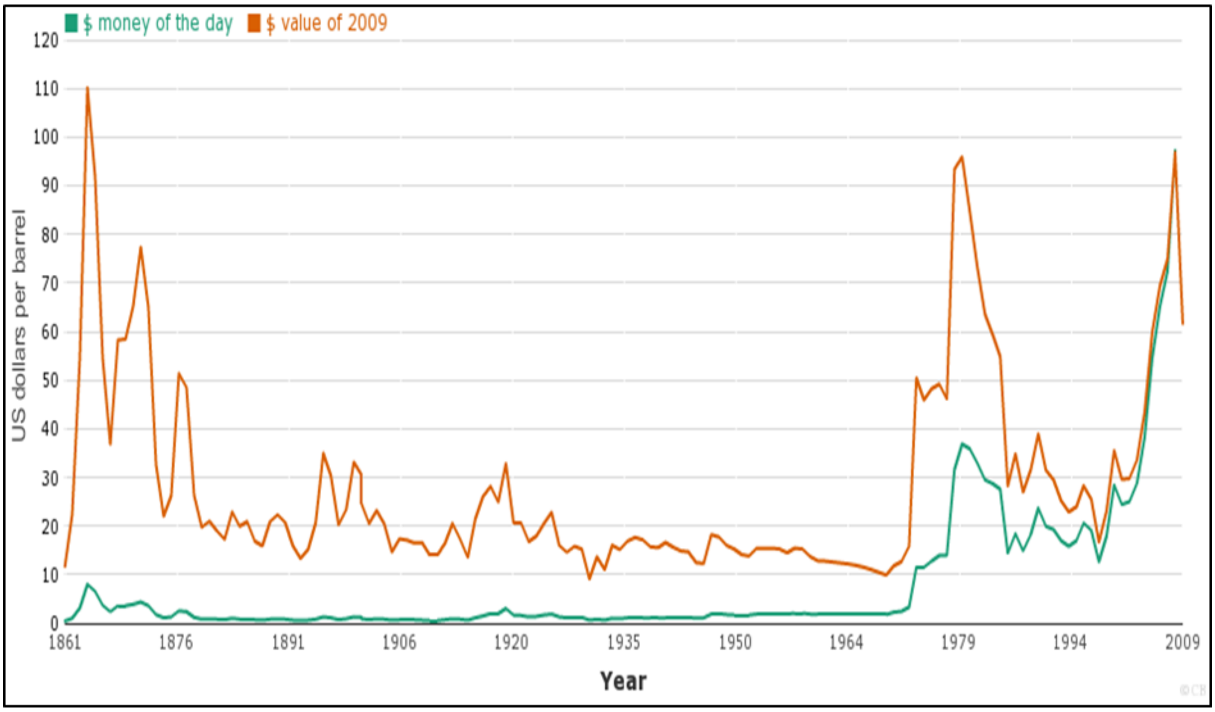

Figure 2.2: Historical crude oil price, 1861 to 2009
Source: International Energy Agency, 2018

The global turning point for electric mobility was reached in the 1990s with the introduction of the Japanese Toyota Prius (hybrid), which became the world's first mass-produced electric vehicle in the year 2000 (Alfaro, Bizuneh, Moore, Ueno & Wang, 2012). Sales in Japan were extremely high, leading to the Prius winning Japan's Car of the year award for 1998. By May 2000, more than 40 000 units had been sold globally and production capacity was increased to 3 000 units per month. The Toyota Prius Hybrid as shown in Figure 2.3 had a driving range of 560 miles and propelled to 62 mph in 13.4 seconds. The combined fuel economy was 57.6 mpg and the power plant produced just 114g/km of carbon dioxide (CO2). The Prius was relatively cleaner and more fuel-efficient than the best-selling conventional cars of that time. After more than 123 000 units had been sold worldwide, production of the first-generation Prius ended in August 2003. It had been the world's most successful hybrid vehicle. It became a popular and very successful car, loved by celebrities. Being loved by celebrities helped to raise the popularity of the whole electric vehicle industry, but could not overcome the forces of resistance created by the fossil fuel industry (Bonilla, Bishop, Axon, & Banister, 2014).

Figure 2.3: The first-generation Toyota Prius
Source: Global EV outlook, 2018

The recent public awareness of the externalities of internal combustion engine vehicles – especially with regard to climate change – has increased the demand for alternative transport technology such as electric vehicles. Many automakers around the world are manufacturing different types of electric vehicles to meet the demand for electric vehicles globally. To help achieve the global emissions-free goals, President Barrack Obama in 2012 launched an Energy Department initiative that brought together America's best and brightest scientists, engineers and businesses to find ways and means to increase the production of electric vehicles as affordable as today's conventional vehicles are by 2022 (US Department of Transport, 2017).

Madina, Zamora and Zabala (2016) confirm that the Advanced Research Projects Agency-Energy department (ARPA-E) in the US is progressing with changing technologies that could alter the public's perception of electric vehicles through investing in new types of batteries that are affordable and could go further on a single charge. ARPA-E's projects could transform the electric vehicles market through its cost-effective materials critical to the battery cost and the total cost of ownership of electric vehicles.

Today, electric mobility is not a country-based issue but a global one. It has become the main priority in many nations such as China, Norway and the Netherlands. According to Palmer, Tate, Wadud, & Nellthorp (2018), China, France, the United States of America (California) and the United Kingdom are working on an outright ban of fossil fuel-powered vehicles in order to reduce air pollution. Bonilla *et al.* (2014) and Bickert, Kampker, and Greger (2015) state that the European Union will be implementing more serious carbon emission limits in 2020 to reduce emission. These will have a great positive influence on electric vehicle development and adoption in Europe and many other parts of the world.

However, this transition comes with opportunities and challenges that require proper urbanization policies that will have a positive impact on inclusive transport needs and the necessary infrastructure. Urbanization policies should include the introduction of clean energy fuel policies, public transport systems and infrastructure development plans that will encourage the use of alternatives such as electric vehicles to reduce carbon emissions in city centres (World Economic Forum, 2018).

2.3 South Africa's electric vehicle roadmap

Holley (2017) indicates that, as countries develop, the impacts on global energy consumption and greenhouse gas emissions become substantial and the transport sector, particularly in developing countries, plays a critical role in global energy consumption and strategies to reduce greenhouse gas emissions. As a result, South Africa committed to cutting emissions by 34% by 2020 and 42% by 2025 in the Copenhagen Accord aimed at reducing greenhouse gases through various means such as alternative transportation (World Bank Group, 2015). The Copenhagen Accord resulted from the United Nations Climate Change Conference held in Copenhagen, Denmark from 7-19 December 2009, where countries including South Africa agreed to cut down greenhouse emissions within some specific periods.

To achieve this carbon emission commitment, the electric vehicle innovation continued locally with individuals such as Kobus Meiring of Optimal Energy (Edwards, 2011). Meiring developed a local all-electric vehicle called Joule, as shown in Figure 2.4 It was environmentally friendly, with zero-emission. The same reasons such as fuel price increases and rising air pollution levels had caused Optimal Energy to embark on the production of a vehicle that could meet these needs. The Joule was an electric five-seat passenger car produced by Optimal Energy, a South African company based in Cape Town. The car had a driving range of 150 km and a top speed of 135 km/h. The Joule was first unveiled to the public at the 2008 Paris Motor Show and again at the 2010 Geneva Motor show.

Figure 2.4: Optimal Energy Joule
Source: EVIA, 2017

At the United Nations Climate Change Conference (COP17) held in Durban, South Africa in 2011, many role players in the automobile industry such as BMW and Nissan displayed their electric vehicle (EV) innovation with the aim of bringing electric mobility to the country. Some zero-emission electric vehicles that were on display included the BMW Mini E and Nissan Leaf (United Nations Environment Programme, 2017). Unfortunately, the mass production of electric vehicles in South Africa coincided with the global market recession that negatively affected investor confidence, import of key components and consumer demand for electric vehicles. Therefore, no electric vehicle including the Joule was released commercially in South Africa and eventually the idea and interest of electric vehicle innovation disappeared (EVIA, 2017).

2.4 International electric vehicle development

According to the analyst Ritu Shah, (2019) in 2018 alone, about 1.6 million electric vehicles were sold in the United States, Europe and China, and the uptake is set to increase in the coming years. The most rapidly growing electric vehicle markets globally include the People's Republic of China, Germany, Netherlands, Norway, Sweden, United Kingdom and the United States. These countries are currently active in electric vehicle production and account for high global electric vehicle sales, as indicated in Figure 2.5.

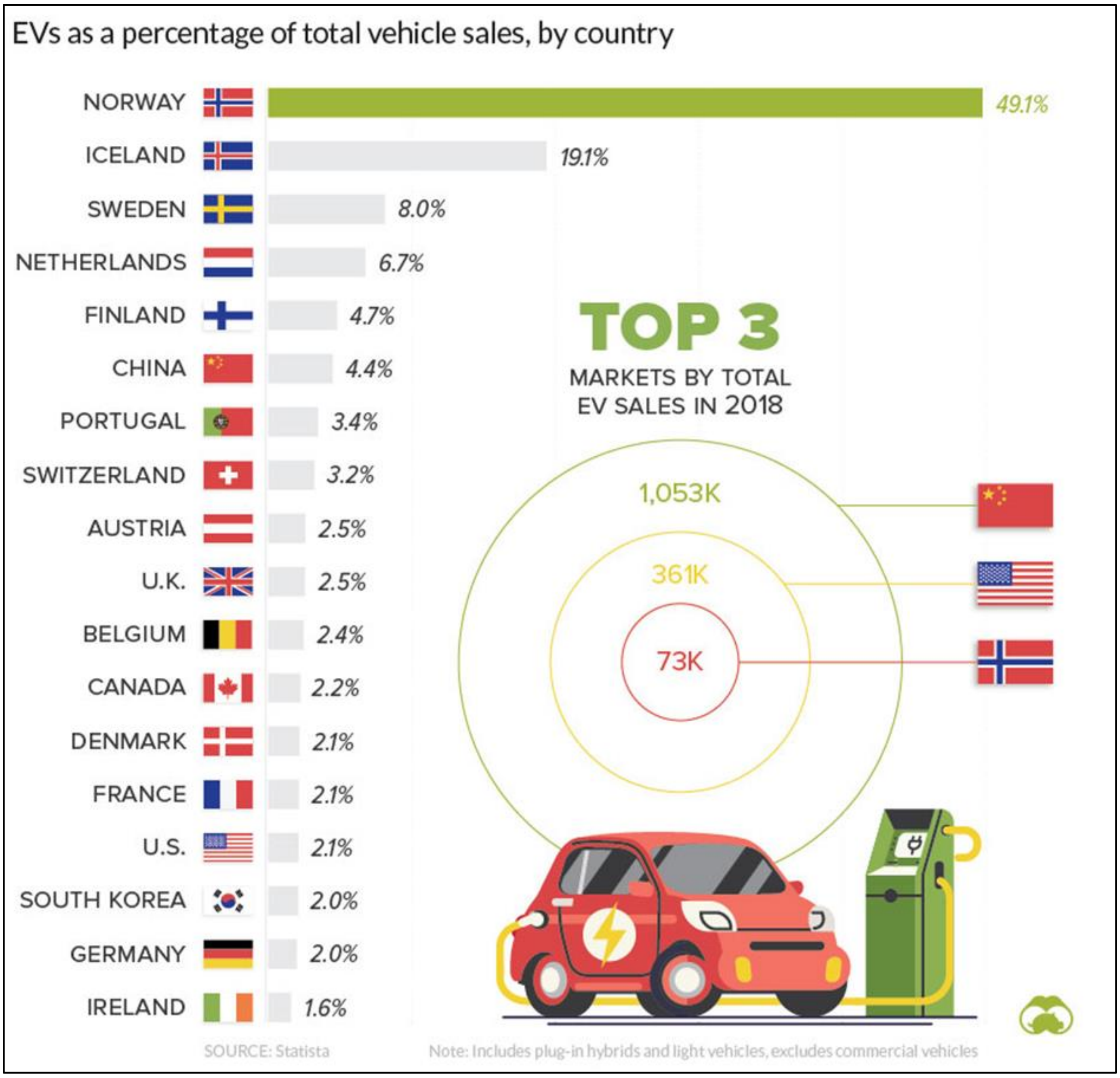

Figure 2.5: Global Electric Vehicle Sales
Source: International Energy Agency, 2018

For instance, Berkeley, Bailey, Jones and Jarvis (2017) indicate that the Kia e-Niro (EV) in Figure 2.6 topped its fossil fuel rivals to win the top prize at a ceremony in London in 2018 signalling the beginning of electric vehicle popularity after years of consumer concerns over travel range and high initial cost. The Kia e-Niro has a 64 kWh battery, 375 km range with energy consumption of 17.1 kWh per hundred kilometres. It cost about £32 995 in the UK and €42 510 in the Netherlands.

Figure 2.6: Kia e-Niro – 64 kWh
Source: Global Electric Vehicle Outlook, 2018

2.4.1 The United States electric vehicle market

In April 2018, the United States Environmental Protection Agency (EPA) announced a change in the greenhouse gases (GHG) emission standards for new light-duty vehicles sold in the United States between 2022 and 2025. According to The United States Environmental Protection Agency (2017), vehicles with the model year of 2017 and beyond are to reduce GHG emissions at a rate of 4.9% per year for light-duty vehicles and about 4.5% per year for light trucks. This is to confirm the country's commitment to the GHG emission standards for the 2017-2025 period and to induce the mass uptake and consumer adoption of efficient technologies. This propelled the electric vehicle market in the US to be one of the fastest markets in the world, with 81% more electric vehicle sales in 2018 than in 2017 (Table 1.1) and the highest growth rate since 2013. These vehicles included pure battery electric vehicles (BEVs), which accounted for 66% of the total vehicle sales, with the remaining 15% being hybrid (HEV) and Plug-in Hybrid (PHEVs) electric vehicles. Tesla electric vehicles accounted for more than half of all plug-in sales in the US (Palmer *et al.*, 2018).

Table 1.1: US electric vehicles sales in 2018

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOT
2018	12009	16845	26443	19623	24307	25029	29598	36347	44544	34074	42588	49900	361307
2017	11004	12375	18542	13367	16596	17046	15540	16514	21242	14315	17178	26107	199826

Source: United States Environmental Protection Agency, 2017

The International Energy Agency report also confirms that increased sales volumes of EVs together with growing competition in the development of new technologies will contribute to continuous reductions in the cost of manufacturing batteries, which is the most important cost component for EVs. It further states that Norway has the world's highest EV share (Figure 2.5), but major developments regarding EVs happen in China, Europe, India and the US. About 40% of the global electric vehicle fleet is in China, while the European Union and the United States each account for about a quarter of the global total (International Energy Agency, 2018).

2.4.2 European electric vehicle market

As part of the European Commission's Clean Mobility programme (ECCM), the carbon emission standards for new passenger cars and light commercial vehicles (LCVs) have been updated to 2030. The Clean Mobility Package includes new carbon emission standards to help manufacturers to embrace innovation and supply low-emission vehicles to the automotive market. It is also meant to promote clean mobility in an action plan for alternative fuel energy in Europe. The ECCM's new target includes a 15% reduction in CO2 emissions per kilometre (km) for new vehicles in 2025 and a 30% reduction in 2030. The new regulation allocates specific emission targets to each manufacturer and a penalty for those that exceed the target for each newly registered vehicle (Berkeley *et al.*, 2017). This is to discourage and limit the production of conventional vehicles in Europe by 2030.

According to new registration data from the European Automobile Manufacturers Association, the electric vehicle market is growing rapidly in most of the countries in the European Union, including Norway and Switzerland. Plug-in vehicle sales in Europe reached 259 000 units in the first half of 2019, 34% higher than those of 2018. These include all Battery Electric Vehicles (BEV) and Plug-in Hybrids (PHEV) in the European Union (EU) and European Free Trade Association (EFTA) countries, passenger cars and light commercial vehicles. The plug-in share of the European light vehicle market reached 2.9% in June. The trend is forecast to increase by 33% for the entire 2019 to reach a total of 540 000 units. The rate of EV uptake reflects the introduction of more stringent regulations for fuel economy ratings as well as changes in incentives packages to promote more battery electric vehicles and a better supply of long-range electric vehicles (International Energy Agency, 2019). According to the first quarter's statistics in Figure 2.7, Germany and the Netherlands are the highest growth contributors in Europe in terms of volumes. Germany has the largest market for plug-ins in Europe, displacing Norway for the first time. Norway is still the world leader in electric vehicle uptake, with about 47% in light electric vehicle sales, which are up by 10% from 2018 (Alegre, Míguez & Carpio, 2017).

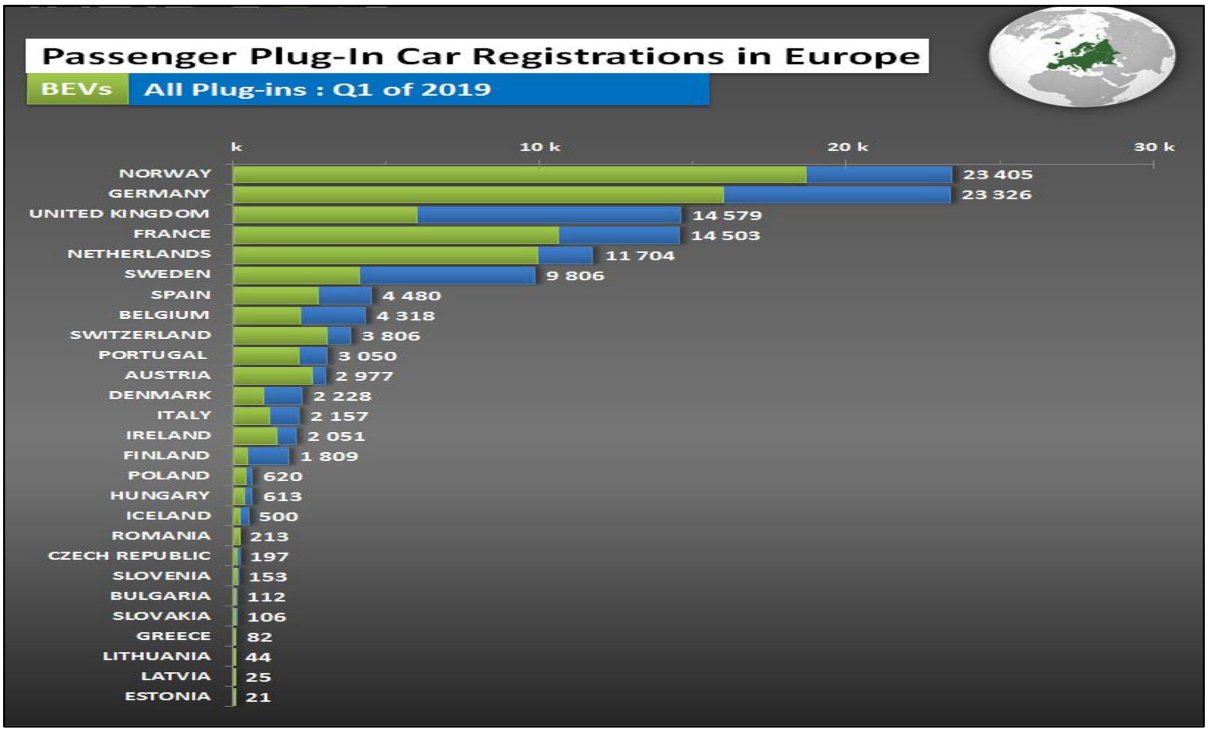

Figure 2.7: European Electric Vehicle 2019 Report
Source: BloombergNEF, 2019

2.4.3 Asia (China) electric vehicle market

The study done by Lin and Wu (2018) focused on the electric vehicle market in China, based on the key manufacturers, vehicle type (passenger cars and commercial vehicles), and policies. According to the authors, the Chinese government issued a directive that set a minimum carbon emission requirement for the production of new energy vehicles such as PHEVs, HEVs and BEVs in China. The regulation requires 10% of automobile manufacturers' annual sales to be electric vehicles by 2019 and 12% in 2020. In addition, some major cities such as Beijing have stringent restrictions to discourage people from buying conventional vehicles. For instance, Beijing issued only ten thousand (10 000) permits for conventional vehicles per month in order to encourage residents to switch to electric vehicles.

In 2010 the government introduced a subsidy for all types of electric vehicles, with the aim of inducing electric vehicle uptake while reducing carbon emissions. However, since 2016 the government has been gradually withdrawing the subsidy to encourage manufacturers to depend on innovation and not government assistance. Currently, subsidies in China depend on a vehicle's travel range and battery efficiency. In order to qualify for any subsidy, the electric vehicle needs to have a range of at least 250 km. These changes are intended to push electric vehicle manufacturers to invest in manufacturing vehicles with ranges that are closer to those of engine vehicles and with less emission. Despite the gradual withdrawal of government subsidies, electric vehicle market growth in China is still encouraging, as can be seen in Figure 2.8.

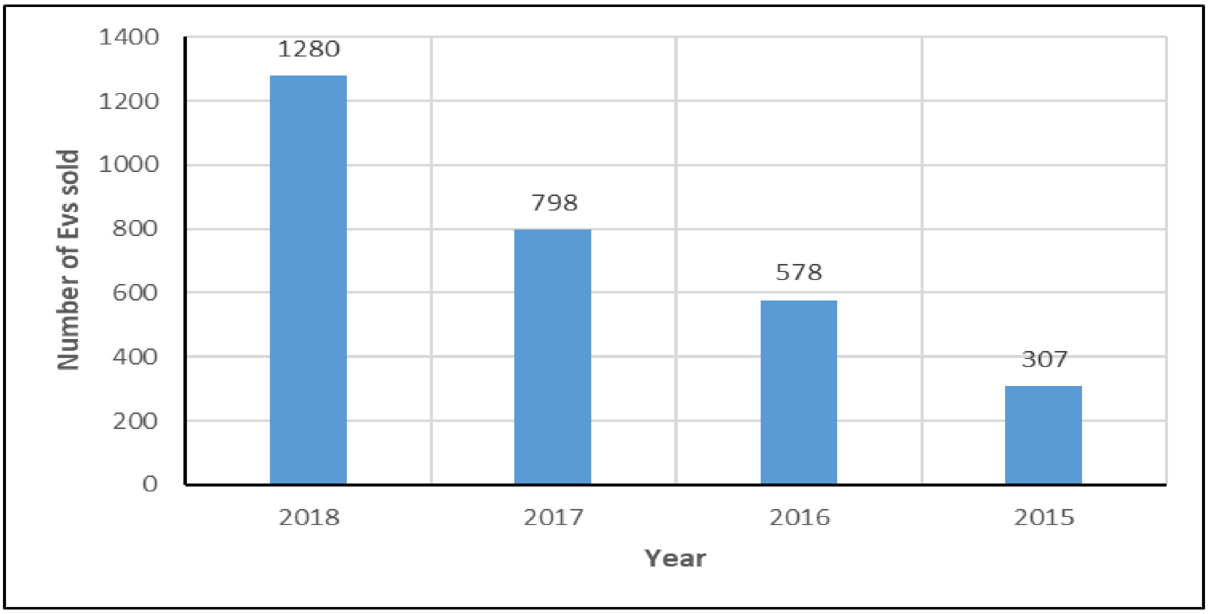

Figure 2.8: EV sales in China, in thousands (000s) 2015-2018
Source: OICA, 2017

2.4.4 South Africa's electric vehicle market as of 2018

South Africa's electric vehicle market as shown in Figure 2.9 is very small compared to other countries in the Western world. According to the Department of Transport, (2018), there are only 867 electric vehicles on South African roads, with the majority of these vehicles in the Gauteng and the Western Cape provinces. Nevertheless, many projects and demonstrations are going on to help the country to catch up with global uptake trends. The following are some of the developments in South Africa to help roll out electric mobility in the region.

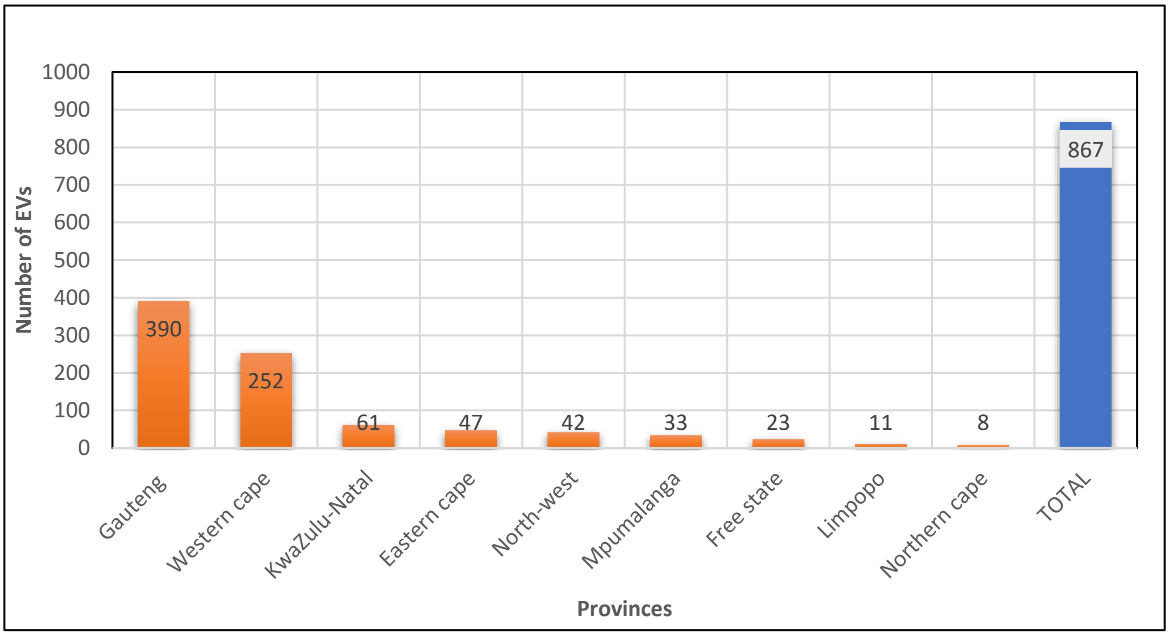

Figure 2.9: South Africa's EV development 2018
Source: Department of transport, 2019

2.4.4.1 Department of Transport (DoT) Green Transport Strategy

The DoT's 'Green Transport Strategy 2018-2050' is the first national policy document promoting electric vehicle adoption in the country. It is committed to providing a world-class transport system that reduces both the cost of transport and the emission of greenhouse gases in South Africa (Department of Transport, 2018). This strategy entails a number of electric vehicle policies which could enable mass adoption in the country. Such policies include the reduction of import tariffs on electric vehicles, and incentivising the electric vehicle market to make it affordable and attractive to both the local and international market. It is also committed to working with research institutions and battery manufacturing companies to create an enabling environment for mass production (Department of Transport, 2018).

Other public and private organizations such as the South African Energy Development Institute (SANEDI), United Nations Industrial Development Organisation (UNIDO), National Association of Automobile Manufacturers of South Africa (NAAMSA) and Greencab are some of the promoters of electric mobility in South Africa.

2.4.4.2 South African Energy Development Institute (SANEDI)

SANEDI's main objective is to drive the country's energy development journey into clean technology advancement and to enable South Africa to take full advantage of its energy resources and associated infrastructure development. SANEDI's ongoing programme such as Cleaner Mobility, Cleaner Fossil Fuels Working For Energy, Smart Grid and Energy Efficiency are some of the projects promoting the uptake of electric vehicles in the country (Sanedi, 2019).

2.4.4.3 BMW ChargeNow project

The BMW group's communication manager for South Africa and Sub-Saharan Africa Hailey Philander confirms that the company has 57 "ChargeNow" charging stations in South Africa and is hoping to expand the number by adding an additional 30 "ChargeNow" stations to the existing charging network by the end of 2019 (Sector, 2019). The stations can be accessed using a "ChargeNow" card at no cost to owners and drivers of all types of electric vehicles (Vermeulen, 2018). The map in Figure 2.10 shows the growth of public charging stations between 2017 and 2019 (GreenCape, 2019).

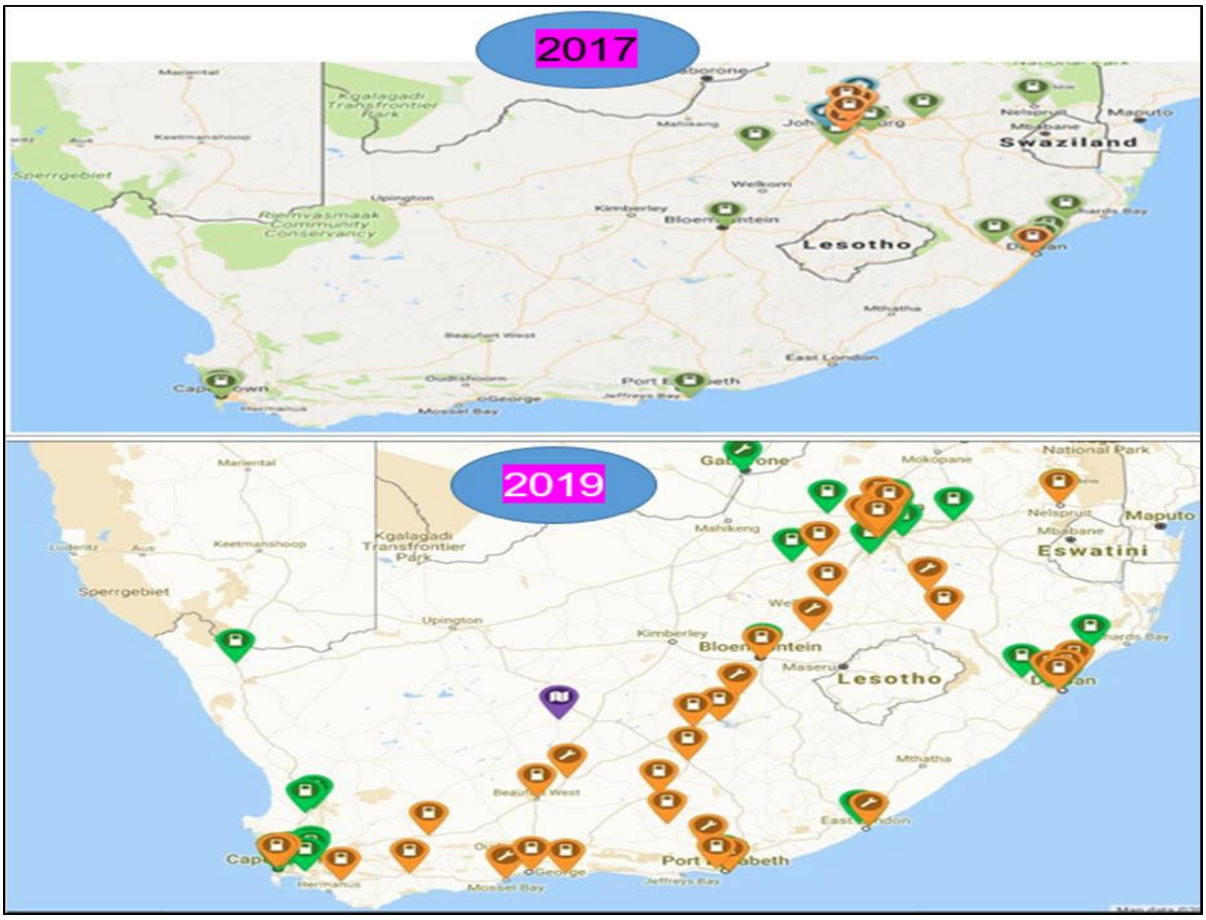

Figure 2.10: Charging infrastructure development
Source: Sanedi, 2019

2.4.4.4 Jaguar Land Rover

According to Reuters (2017), Jaguar Land Rover in conjunction with GridCars, which is an electric vehicle charging service and equipment company, has made an investment of R30 million into an electric vehicle infrastructure project known as Jaguar 'Powerway', a network of public charging stations being developed in South Africa. This will include about 80 charging points, some of which will be located at Jaguar Land Rover dealerships and at shopping centres around the country. Twenty-two (22) of the charging stations will be along the N3 between Gauteng and Durban and the N1 between Gauteng and Cape Town. In addition, Cape Town will be connected to East London through the Garden Route (N2) with a number of charging stations.

2.4.4.5 GridCars

A report published by EVIA (2017) also indicates that CSIR-based GridCars and Mellow Cabs have plans to build small electric people transporters that can be used in city centres and other public places such as airports and hospitals in South Africa. These will be three-wheel, two-seater commuter cars as shown in Figure 2.11, with an 80 km range, and a light electric utility (EVIA, 2017). In addition, the Pretoria automobile company 2Life is undertaking a similar project in manufacturing two-seater and four-seater electric vehicles with 80% local parts. The company plans to build all-weather and environmentally friendly six-seater vehicles for airports and the hospitality industry in South Africa (EVIA, 2017).

Figure 2.11: People Transporter
Source: EVIA, 2018

2.4.4.6 uYilo e-Mobility Technology Innovation Programme

Another organization championing electric mobility is the Nelson Mandela Metropolitan University's uYilo e-Mobility Technology Innovation Programme. It has a team of engineers and scientists with the main aim of creating an enabling environment for electric vehicle infrastructure and battery technology development in South Africa. This includes solar electric vehicle charging, second-life EV battery storage systems, alternating current charge points, direct current fast chargers and smart grid technology. The uYilo smart grid facility is a technology that uses second-life batteries from electric vehicles combined with a solar system to store energy during the day to support homes and the national power grid (Figure 2.12). Currently, the pilot programme produces about 128 kW electric vehicle charging capacity (Theron, 2019).

Figure 2.12: uYilo SmartGrid Facility
Source: EVIA, 2019

All these entrepreneurial skills and opportunities are bringing innovation, technology, invention, economic growth and job creation coupled with numerous environmental advantages and climate change solutions in South Africa.

Behind all these organizations is the United Nations Industrial Development Organisation (UNIDO). UNIDO is an agency of the United Nations that promotes industrial development for poverty reduction, inclusive globalization and environmental sustainability. It is fully committed to supporting member states through projects to achieve sustainable industrial development.

2.5 Global automobile industries commitments

It can be seen from this related literature that the global EV deployment targets are complemented by government actions and commitments such as setting limits on emissions, policies to support EV development, lower taxes, and subsidies. All these strategies are motivating electric mobility development by de-incentivising the carbon emission vehicles. In support of these national commitment made by various countries in rolling out EV technology, almost all the big global brands in the automobile industry have also outlined their commitments, and plan to produce and deliver electric vehicles in the years ahead. This is in pursuit of the global GHG policies in the era of electric mobility and tighter emission regulations. If their promises are materialized, the world including South Africa will see a major shift in innovation, production and transition to electric vehicles in the next decade (Witkamp, 2016). The following are some of the global brands' plans and commitments for taking electric vehicle development to a higher level in the next decade:

General Motors (GM) has plans to revisit EV technology by phasing out conventional vehicles for electric vehicles by the year 2023 (Holley, 2017). Not only GM but also Ford has created an electric vehicle dedicated team called Team Edison to focus specifically on the development of all-electric cars. The automaker has also pledged to invest $11 billion over the next five years in new all-electric and hybrid vehicles. This implies that the project will be rolled out by the year 2023 (Lienert, 2017).

Toyota and Mazda, on the other hand, have announced their alliance to manufacture auto-parts beyond those of their first and famous electric Toyota Prius line. This will create a big company to develop basic electric vehicle technology for use across all types of models (Williams, 2017). The two major Japanese automakers have pledged to build a massive $1.6 billion electric and hybrid vehicles plant in the US by 2021 (LeBeau, 2017).

Daimler, the mother company of Mercedes-Benz has also committed to building an all-electric vehicle plant in Alabama to produce EV SUVs and battery facility. It has plans to electrify its entire range of vehicles by 2022, proposing 50 different electric and hybrid models in the global automobile market (LeBeau, 2017).

The Renault, Nissan, and Mitsubishi alliance have plans to come up with a brand new approach to develop new systems across their vehicle line, which will focus purely on all-electric vehicles like the Nissan Leaf which is already in the market. The global vehicle manufacturer (Nissan) has plans to release 12 different all-electric models to the market by 2022 under the Nissan, INFINITI and Datsun brands (Nissan Motor Corporation, 2017). In the same vein, Jaguar Land Rover (JLR) plans to come out with a new powertrain ranging from mild hybrid to all-electric systems. Its promises to electrify its entire vehicle line-up by 2020 (Reuters, 2017). Not only the above but also Volvo will electrify its entire vehicle lineup by the year 2019, with five all-electric models to come out between 2019 and 2021. It hopes to sell a million of both hybrid and electric vehicles by 2025 (Schroeder, 2017).

The Volkswagen (VW) Group that comprises Volkswagen, Audi, and Porsche will invest $84 billion in electric vehicle development. About $60 billion of the investment will be dedicated to battery production, which is the greater part of EV production costs. Volkswagen's ultimate goal is to reach 1 million annual EV sales by 2025 (Ho, 2017).

2.6 Benefits of electric vehicles

Although South Africa's electric vehicle market is below par compared to countries in the Western world, there are still opportunities for entrepreneurs to realise their dreams and help stimulate industrial development while reducing oil imports, saving foreign exchange and improving urban air quality. These will bring economic, environmental and health benefits.

2.6.1 Economic benefits

Vassileva and Campillo (2017) maintain that many features make a country suitable for large-scale uptake of EVs, among other things its share of renewable energy sources and the environmental awareness of its citizens. Based on this, South Africa can offer fertile ground for EV technological innovation due to the availability of enormous renewable energy such as solar energy in the country. EV technology depends mostly on metals such as cobalt, nickel and uranium for the manufacturing of batteries, and this makes Africa as a whole a better place for EV innovation because countries such as DRC, Zambia and Zimbabwe are rich in those minerals and can bring massive economic growth to the region (World Economic Forum, 2018). The continent has all the scarce resources required for economic development and growth, including land, labour and capital. So while Africa does have the land (which includes the minerals) it should invest the labour (skills), provide capital (government or private) and support entrepreneurship in the industry.

A report by Sub-Saharan Africa Automobile Business (2017) also confirms that many African countries do not have any reliable mode of public transport in place, apart from road transport. However, the unappealing condition of the public transport systems in South Africa has resulted in extensive private car ownership. Those who cannot afford their own transport, have little means of transport and entrepreneurs could take advantage of this dormant public transportation demand to induce mass adoption of EVs.

Berckmans, Messagie, Smekens, Omar, Vanhaverbeke and Mierlo (2017) emphasise that electric vehicle innovation comes with many job opportunities such as for technicians in the battery manufacturing and charging industry. It also creates an opportunity for investors to invest in battery manufacturing and charging facilities driving the electric vehicle revolution. The Sub-Saharan Africa Automobile Business report (2017) agrees that with private organizations involved in public electric vehicle battery and infrastructure development, the possibility of South Africa becoming a globally competitive electric vehicle market is high.

2.6.2 Environmental benefits

Ahmadi, Yip, Fowler, Young and Fraser (2014) researched the feasibility of re-using electric vehicle batteries in China. Their study indicates that the life of a lithium-ion battery of an electric vehicle is long enough for it to be re-used in power storage to support the utility grid during peak hours. The advantage of battery re-use is that it is possible to reduce up to about 56% of carbon emissions – compared to using normal gas fuel – when the electric vehicle battery is re-purposed to store clean electricity during off-peak times to supplement peak demand.

The study further shows that the amount of carbon emission prevented through battery re-use is similar to switching from using an internal combustion engine vehicle to using an electric vehicle, meaning that the benefit of using an electric vehicle is doubled by using off-peak low-cost clean electricity instead of gas or coal.

The International Organization of Motor Vehicle Manufacturers (2014) ascertained that human activities bring about climate change, and the global automobile sector wants to be part of the solution. CO2 is associated with climate change and human activities such as transportation and manufacturing raise the level of CO2 in the atmosphere, which contributes to rising global temperatures and affects the climate. The road transport industry alone contributes about 16% of global carbon emissions as shown in Figure 2.13. This means a transition to e-mobility and the reuse of electric vehicle batteries through smart-grid technology can significantly reduce the amount of carbon emission from the transport sector. On the other hand, electric vehicles do not have exhaust pipes and therefore do not cause noise pollution. The combination of being emission-free and quiet gives EVs many environmental benefits over conventional vehicles.

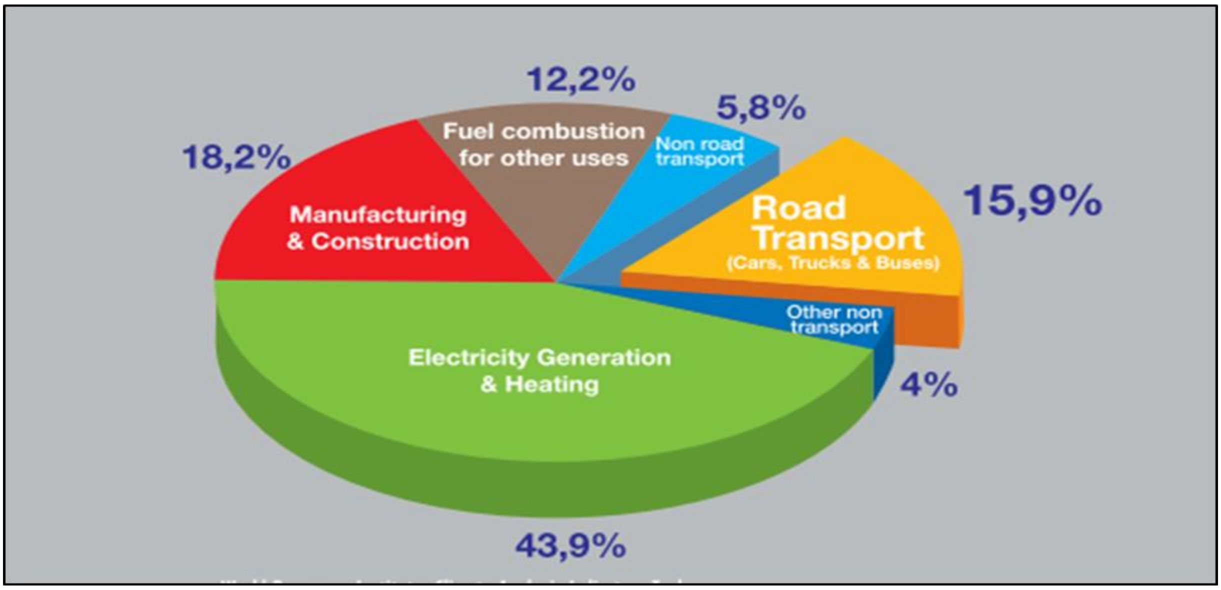

Figure 2.13: Emission share of road transport
Source: World Bank Group, 2018

A study done by Stefan Bickert on CO2 emission and costs for small electric and conventional vehicles in Germany shows that, in the production phase of various vehicle types, electric vehicle emissions exceed those of conventional vehicles, but during their operation, the conventional vehicles cause more emissions than electric vehicles. Secondly, the private cost of electric vehicles exceeds that of conventional vehicles but the external costs of conventional vehicles are higher than those of electric vehicles (Bickert *et al.*, 2015).

2.6.3 Health benefits

Mitchell House and David Wright of the University of Ottawa, Canada, also confirm that switching from internal combustion engine vehicles that use fossil fuels to electric vehicles could significantly reduce the incidence of cardiopulmonary illness due to air pollution. This would lead not only to less employee absence from work through illness but also lead to broad improvements in quality and length of life. Their study compares the financial costs of building electric vehicle charging infrastructure using empirical data with health costs to see if there is a net benefit (House & Wright, 2019). Taking the House and Wright study further, research findings from the Centre for Air Quality, Climate, and Energy Solutions (CACES) at Carnegie Mellon University show significant human health benefits when air quality is improved to levels better than the current air quality in California. The study indicates that more than thirty thousand lives could be saved and life expectancy could be increased by 0.3 years, which is equal to the annual deaths from car accidents in California (Kulick, 2019).

The studies examined US mortality related to fine particulate matter pollution (PM2.5). Particulate matter pollution is a mixture of extremely small particles and liquid droplets that can penetrate deeply into the lungs to cause respiratory and cardiovascular diseases and premature deaths. The present annual average of PM2.5 in the US is 12 micrograms per cubic meter of air. The study used public data from 28 years of National Health Interview Surveys linked with the National Death Index to create a representative group of 1.6 million US adults together with 18.4 million cardiorespiratory deaths from 1999 to 2015 sourced from the Health Statistics of the US. The findings indicate that there are significant public health benefits to improving air quality, even in locations where PM2.5 levels are below 12 micrograms per cubic meter.

2.7 Barriers to electric vehicle adoption

Uptake of any innovation comes with opportunities and challenges hence public-private collaboration is very important in achieving green mobility aims in a country. Concerning the uptake of electric vehicles, different studies have looked into the various barriers that prevented early adoption globally, and which still need to be overcome before the technology can be successful. The following literature looked into various categories of adoption barriers.

2.7.1 Activity and social barriers

As travel is a derived demand, derived from the need to participate in spatially dispersed activities, it is the layout of the cities and the spatial pattern of land uses that will determine travel needs such as modes used, trip distance and routes taken. While a lot of research has been done on activity-based travel demand models, limited research has been done on the impact of activity demands on electric vehicle choice (Arentze, Dijst, Dugundji, Joh, Kapoen, Krygsman, Maat, Timmermans & Veldhuisen, 2001; Daina, Sivakumar & Polak, 2017). Households facing complex activity demand may be reluctant to adopt electric vehicles.

Barth, Jugert and Fritsche (2016) investigated whether social norms predict electric vehicle acceptance in Germany by exploring the beliefs of experts and non-experts through using surveys. Their study tested whether cost-related advantages and disadvantages influence consumer acceptance. Results from the study suggest that the adoption of alternative fuel vehicles is controlled by social acceptance by consumers and cost-related factors such as purchase cost and maintenance cost. The cost-related factors are much more important than social factors. This social acceptance factor includes the changes the innovation makes in society, such as with charging behaviour and travel patterns. With conventional vehicles, consumers are used to driving a long distance or for days before refuelling their vehicles. However, with the electric mobility innovation, they probably have to charge their vehicles for a specific driving distance or charge them at home every day.

Han, Wang, Zhao and Li (2017) also examined consumers' intention to adopt electric vehicle transport from two perspectives. The first one is the consumption value perspective taken from consumption value theory, which includes functional values such as monetary, performance and convenience values. The second perspective is non-functional values, which are emotional and social values. Through a survey, 607 drivers in Hefei, China completed some questionnaires and the responses empirically test the relationship between functional and non-functional. The results indicated that the perceived functional value has both direct and indirect effects on the adoption intention of consumers, which is greatly facilitated by consumers' attitudes while the non-functional value has only indirect effects on the adoption intention. In the same vein Li, Long, Chen and Geng (2017) studied the factors that influence consumers' intentions to adopt battery-electric vehicle transport in China by using peer-reviewed journals. The study systematically peer-reviewed and analysed 40 journals in detail. The findings categorised the influencing factors into demographic factors such as individual family size, situational factors, which include purchase cost and policies, as well as psychological factors such as attitude and emotions as the main factors that influence electric vehicle adoption.

Schmalfuß, Mühl and Krems (2017) conducted research to address the relationship between consumers' attitudes and their purchase decisions. An online survey (N = 286) and a 24-hour field test drive (N = 30) in Germany was used to assess the relationship between the variables. Both studies exhibited several experience-based differences in estimating battery-electric vehicle attributes, attitude and purchase decision. Most battery-electric vehicle attributes were more when respondents had hands-on experience. The study concluded that short-term practical experience with battery-electric vehicles had the potential to change consumers' psychological factors relevant to purchase decisions.

2.7.2 The competitive advantage of conventional vehicles

Hosseinpour, Chen and Tang (2015) did research on the barriers to the widespread adoption of electric vehicles in the US by using literature review based discussions. Upon their analysis of several historical pieces of literature on electric vehicles, the study concluded that conventional vehicles have a competitive advantage over electric vehicles in the global automotive market. Therefore, to assist with the mass adoption of electric vehicles, the lock-in resistance forces such as technological, social, economic, and political environments created through developments in the conventional vehicle market need to be addressed in order to help diffuse electric vehicles into the automobile market successfully. The authors further concluded that to deal with the lock-in resistance factors, there should be clear communication of electric mobility advantages and disadvantages through researches and independent organizations.

Egbue and Long (2012) also researched consumer attitudes and perceptions in the US. Their study used an internet-based survey to collect data from a sample population of 481 respondents for the analysis. The study identified socio-technical barriers such as battery technology, battery costs and lack of charging infrastructure as the main elements in the negative perception that consumers have of electric vehicles. The authors further determined that sustainability issues such as pollution influence consumers' decisions to buy electric vehicles, but the initial advantages gained from a conventional vehicle have a very negative effect on electric vehicles adoption. For the past decade, the development of conventional vehicles has created a strong economic and political bond that EVs need to overcome in order to be successful in the automobile industry.

2.7.3 Infrastructure barriers

As the electric vehicle market grows, its charging infrastructure remains the major issue that many consumers in South Africa ask questions about. Wang investigated the barriers to the widespread adoption of electric vehicles in Shenzhen, China. About 406 approved questionnaires among 500 participants were used to gather information from respondents. The study ascertained that the mass uptake of electric vehicles depended on how accessible charging facilities are in the community and workplace. The study further found that a drop in financial incentives in China would not have a significant effect on electric vehicle adoption in future, as long as the necessary infrastructure is available for consumers (Wang *et al.*, 2017).

A similar study that was done in St. Gallen, Switzerland on policy measures to promote electric mobility also showed that the installation of a charging network on freeways is an absolute necessity for global adoption of electric mobility. The study was conducted in 20 countries on five continents through surveys. Cash incentives had a positive impact on adoption; however, combinations of cash incentives and charging facilities resulted in a higher adoption rate for each of the twenty countries studied (Lieven, 2015).

Andersen, Mathews and Rask (2009) also investigated the best strategy for creating intelligent recharging grids for electric vehicles in Denmark. The study developed a new business model to introduce electric vehicles into a private transport system through an Electric Recharge Grid Operator (ERGO). The ERGO business model created a market for the production and consumption of renewable energy in the electromobility industry in Denmark. The study advocated for nationwide infrastructure development, such as charging stations where electric vehicles' batteries may be changed or replaced easily and quickly instead of concentrating on the electric vehicle, or the batteries' development.

Morrissey, Weldon and O'Mahony (2016) explored future standard and fast-charging infrastructure by analysing electric vehicle charging behaviour in Dublin, Ireland. Data on usage patterns in electric vehicle charging for the entire island of Ireland since the rollout of infrastructure began was used for this study. The study found that electric vehicle users preferred to charge their electric vehicles at home in the evenings, but during the period of highest demand on the electrical grid. Public car park locations were also the most popular location for public charging, with fast chargers recording the highest usage indicating that fast-charging infrastructure in public places is most likely to become viable in Ireland.

Madina, Zamora & Zabala (2016) assessed electric vehicle charging infrastructure business models in Spain. The study found that a lack of accessible charging infrastructure at home, in the community or at the workplace is a serious adoption barrier hampering market penetration. When these barriers are dealt with, then consumers' attitude and willingness to buy electric vehicles will increase. A similar survey conducted by Lieven (2015) in the United States of America confirmed that out of 250 consumers 81% preferred to charge their electric vehicles at home, and 19% at work. Among the same respondents, 54% were not willing to buy electric vehicles unless charging infrastructure was as accessible as gas fueling stations.

2.7.4 Technological issues

A study that was done by Albertus, Babinec, Litzelman and Newman (2017) in Germany concedes that battery technology has been a major adoption barrier since the evolution of electric vehicles because of the limited distance an electric vehicle travels per charge and the poor performance of batteries at very low and high temperatures. In addition, the long charging time of electric vehicles, particularly pure battery electric vehicles (BEV) makes them less attractive to consumers. The study summarizes the state of research and commercial efforts in Germany in terms of key performance parameters. It advocates for the use of limited lithium (≤30 μm) to ensure early identification of technical challenges associated with stability and a more rapid transition to commercially relevant designs in the battery manufacturing industry. The study shows that an increase in the driving range of EVs will require a larger and heavier battery at a higher cost and a longer charging time. It further concedes that weather conditions affect battery performance – at very low temperatures heating is required while hot conditions may demand the use of air conditioning, which consumes more battery power. This has resulted in low customer value for the EVs in countries with extreme cold and hot seasons. Plötz, Schneider, Globisch and Dütschke (2014) also confirm that improvements in electric vehicle technology are imperative to decrease cost, increase driving range and improve charging time and infrastructure. The German experts agree that such adoption barriers still need to be overcome before EVs can really challenge internal combustion cars.

2.7.5 Economic issues

Electric vehicles may have a significant impact on the way people travel. It may also affect the transport expenses of households such as higher capital outlays but less fuel and maintenance charges. What is less well understood is the impact on the road generated revenue, or the fuel tax and other charges based on fuel use? (Van Rensburg & Krygsman, 2015; Van Rensburg & Krygsman, 2019).

On the economic point of view, Letmathe and Suares (2017) investigated the consumer-oriented total cost of ownership model for different vehicle types in Germany. The study was done in eight key European vehicle segments (small, medium, and large) taken from the German Federal Motor Transport Authority statistics that reflected 94% of the newly registered passenger vehicle models. The results revealed that only a few battery electric vehicles and hybrid electric vehicles were economical without subsidies when compared with internal combustion engine vehicles, while the small and the medium vehicle segment remained uneconomical in all tested scenarios. The study concluded that subsidies support the competitiveness of battery electric vehicles, which do not automatically lead to the lower total cost of ownership of electric vehicles.

Mersky, Sprei, Samaras and Qian (2016) analysed the effectiveness of incentives on electric vehicle adoption in Norway by using sales of electric vehicles on a regional and municipal basis in the same country, and then cross-analysed them against the corresponding local demographic data and incentive measures to determine which factors led to higher battery electric vehicle adoption. The study investigated only freeway legal battery-operated passenger electric vehicles, with short-range vehicles those with a range of 100 km or less, and long-range vehicles those that exceeded 100 km. It was concluded that access to battery electric vehicle charging infrastructure in major cities, and regional incomes had the greatest impact on electric vehicle sales and adoption. It was concluded that short-range vehicles had a more positive impact than long-range vehicles. Toll exemptions and the right to use bus designated lanes had a statistically significant impact on battery electric vehicle sales.

The global electric vehicle outlook for 2018 was developed and prepared by the energy technology policy division of the directorate of sustainability, technology and outlook of the international energy agency under the directives of Dave Turk. Through several in-depth interviews on specific topics, the report established that potential electric vehicle customers would prefer conventional vehicles to any alternative fuel-efficient vehicle if that alternative is not competitive enough. The study concluded that if the price range between conventional vehicles and battery electric vehicles can be 20% accompanied by 60% access to electric vehicle charging stations, the battery electric vehicle could be more competitive against the conventional vehicle (International Energy Agency, 2018).

A study by Sierzchula, Bakker, Maat and Van Wee, (2014) in the Netherlands investigated the influence of financial incentives and other socio-economic factors on electric vehicle adoption. The study determined the relationship between consumer financial incentives and electric vehicle adoption based on the existing literature of the time. The study collected and analysed data from 30 countries to examine the relationship between financial incentives and electric vehicle market share for the year 2012. Using multiple linear regression analysis, the model showed that financial incentives, charging infrastructure and the presence of local electric vehicle production facilities were positively correlated to a country's electric vehicle market share.

Enang and Bannister (2017) presented a comprehensive review of works of literature, focusing primarily on contributions on the aspect of parallel hybrid electric vehicle modelling and control in the UK by using linear programming, dynamic programming, stochastic control strategy and optimisation-based control strategies. The results showed that the global oil price is another factor that influences consumers' adoption decisions. As the price of fossil fuel increases the demand for alternative energy sources increases, and as the price decreases the opposite happens.

Reda, Fuad and Aditya (2017) researched the energy transition beyond 2040 by using adoption scenarios. The study projected vehicle ownership using the growth rate of vehicles at the beginning of the 20th century to project the rise of electric vehicles starting from 2017. The analysis suggests that oil as the main source of fuel for transportation could have a much shorter life span left than commonly assumed. In the fast adoption scenario, oil prices could drop as low as about $15 per barrel by the early 2040s. The study further stated that governments around the world but especially in the developing countries might lose out on billions in tax revenue from road fuel sales by the year 2030. The fear of losing revenue gained from fossil fuels such as through a fuel levy makes many governments less committed to promoting electric vehicle adoption.

Bubeck, Tomaschek and Fahl (2016) studied the total cost of ownership of electric vehicles in Germany. To represent the electric vehicle market in Germany the study investigated different vehicle sizes, user and drive technologies as well as the CO2 reduction offered by different electric vehicle types. The study analysed buyer's bonuses as an incentive for the mass uptake of electric vehicles in German. The results showed that even without incentives all-electric vehicle types are already an economical option for a wide range of vehicle sizes and user types. Nevertheless, to achieve cost competitiveness for electric vehicles, incentives are necessary.

2.7.6 Policy issues

Global electric vehicle deployment targets have been complemented by several governments announcing policies and intended restrictions on conventional vehicles. Holtsmark and Skonhoft (2014) discussed whether the Norwegian support and subsidy policy with regard to electric vehicles should be adopted or rejected by other countries. The policies include exemption from VAT and other car purchases and sales taxes, free parking in public parking spaces and free tolls for electric vehicles. The company car tax is 50% lower on electric vehicles and free charging at public charging stations. The study states that these policies give Norwegian households incentives to purchase electric vehicles. Again it is encouraging the use of private cars instead of public transport and cycling. The effects of these policies are analysed based on the possible greenhouse gas (GHG) emission benefits as well as other possible benefits of utilizing electric vehicles versus conventional vehicles. The results made the researchers do concede that these policies should not be emulated by any other country and should be ended as soon as possible.

In the same vein, Aasness and Odeck (2015) investigated the increase of electric vehicle usage and incentives and the adverse effect that had in Norway. The study analysed some secondary data sourced from the Norwegian electric vehicle policy document. It used relatively simple statistical methods to examine the adverse effects of those incentives and used the Oslo toll ring as a case study. The results showed that the rapid increase in the use of electric vehicles is as the result of the various economic incentives such as free tolls, free charging and tax exemptions. Though the increase in electric vehicles has led to a reduction in CO2 emissions, some of the incentives have adverse effects such as loss of toll revenue. The study concludes that the Norwegian approach should not be followed by other countries without due consideration of the adverse effects and of how electricity is produced in that particular country.

Bonilla *et al.* (2014) also argued that innovation activities in engine efficiency are affected by market size, oil prices and taxes. Innovation is positively influenced by past transport research and development. The study used secondary data from 1974 and 2010, from mostly Japan, the EU and the US, averaging 693 official documents a year. It used econometric analysis to conclude that on average, engine efficiency innovations accounted for 79% of all diesel vehicle purchases at a time when oil prices were $33 a barrel (average diesel price $0.94 a litre); and an average of two million trucks were sold in Japan and 5.8 million in the US. On average, 23% of passenger car sales in Europe were diesel based. A major benefit of rapid innovation is that the costs of climate policy for the transport sector can be lower than costs in the absence of innovation. Innovation can turn energy-efficient engines into a cost-effective investment.

Palmer *et al.* (2018) investigated ownership cost and market share for hybrid and electric vehicles in the UK, US and Japan by using cost comparisons between HEV, PHEV, and BEV across four different geographical regions. By using regression analysis the result showed that market share was found to be strongly linked to Hybrid Electric Vehicle Total Cost of Ownership through a panel. Financial subsidies have enabled Battery Electric Vehicles to reach cost parity in the UK, California and Texas, but the Plug-in Hybrid Electric Vehicles did not receive much financial support. The study further confirms that the European Union is planning to implement serious carbon emission limits in 2020, which will have a great positive influence on global electric vehicle adoption.

The International Energy Agency (2018) report also indicates that changes in the cash incentives provided for electric vehicles in the Netherlands resulted in a significant decline in the market share of plug-in electric vehicles. In the same way, changes to the vehicle registration tax for battery electric vehicles in Denmark in 2016 led to a decrease in cost competitiveness, leading to a significant drop in electric vehicle sales that year. Lieven (2015) investigated policy measures to promote electric mobility in Gallen, Switzerland. The study was conducted in 20 countries on five continents through surveys. The results showed that cash incentives had a positive impact on adoption; however, combinations of cash incentives and charging facilities resulted in a higher adoption rate for each country.

Tietge, Mock and Lutsey (2016) compared electric vehicle policy and deployment in five leading countries in Europe. The study investigated incentives for electric vehicles in the five largest electric vehicle markets in Europe. These included Germany, the United Kingdom (UK), France, the Netherlands, and Norway, in order of passenger car market size in Europe. The study concluded that policies have a significant influence on electric vehicle adoption.

Soltani-Sobh, Heaslip, Stevanovic, Bosworth and Radivojevic (2017) analysed Electric vehicle adoption across the United States of America. This study is based on a cross-sectional/time-series (panel) analysis. The developed model is an aggregated binomial logit share model that estimates the modal split between electric and conventional vehicles for different US states from 2003 to 2011. The results established that electricity prices were negatively associated with electric vehicle use, while urban roads and government incentives were positively correlated with states' electric vehicle market share.

Held (2019) investigated urban electric mobility policies in 15 European cities. Using qualitative comparative analysis the study postulates that policies that have a strong impact on the total cost of ownership of electric vehicles include incentivising charging infrastructure at home, workplace and public places. The study further indicates that any de-incentivize policy such as strict regulation on the use of fossil fuel increases the uptake of electric vehicles.

Yong and Park (2017) also analysed factors affecting the uptake of electric vehicles across Europe by using the fuzzy-set qualitative comparative analysis methodology. Their study compared the factors affecting the mass uptake of electric vehicles and the policy implications for promoting the uptake. Their results indicate some potential policies to include tax exemption and purchase subsidies. The study further indicates that policies can significantly increase the uptake of electric vehicles; however, no single effective policy tool can promote mass uptake of an electric vehicle. To induce electric vehicle uptake it is necessary to promote a policy mix that is in line with the country's needs and available resources.

2.7.7 Africa specific issues

Bonilla *et al.* (2014) state that fuel taxes are a source of revenue for many countries around the world and they may stand to lose out in tax revenue from road fuel sales. Bonges and Lusk (2016) also confirm that many countries in Sub-Sahara Africa get funds from fuel taxes for running and upgrading their transport infrastructure and for operations, and governments will have to find alternative sources of revenue to meet their financial needs. To mitigate this significant impact on transport infrastructure development especially in developing countries such as South Africa, alternative road use tax such as per kilowatt-hour excise tax for charging at non-residential charging stations and pay by distance per kilometre travel are some practical ways to fund transport infrastructure and operations.

Secondly, lack of financial support for the emerging technical expertise in the e-mobility industry results in a brain drain of Africa's entrepreneurs to the western world. Such entrepreneurs include Sangulani Chikumbutso, the first Zimbabwean to design and make an electrically powered vehicle and a hybrid helicopter among other gadgets, as shown in Figure 2.14 (Africa Growth Initiative, 2017). The brain drain in Africa is aggravated by a lack of financial support and centres of excellence to establish technical know-how on the continent. These make Africa a continent of technology consumers instead of producers.

Figure 2.14: Hybrid helicopter by Sangulani Chikumbutso
Source: Africa Growth Initiative, 2017

Thirdly, high poverty levels and low-income rates make the affordability of new technology such as electric vehicles very difficult if not impossible. The Africa Growth Initiative (2017) indicates that motorisation increases as per capita income increases; however, there are few people in Africa whose per capita incomes equals or exceeds the global standard. In view of this, the affordability of EVs in Sub-Sahara Africa and for that matter for ordinary South African is a great challenge. Hence, the developed world sells its second-hand vehicles to developing countries to pollute the environment. But unfortunately, the effect of pollution (climate change) does not depend on who pollutes the environment.

2.8 Total cost of ownership (TCO)

The total cost of ownership (TCO) of a vehicle is the purchase price plus the costs of operation. The chapter indicates that in purchase decision-making especially when choosing among alternatives such as EVs and conventional vehicles, buyers should be aware of the vehicle's short-term cost, which is its purchase price, as well as its long-term cost, which is its total cost of ownership. The lower total cost of ownership is the better value in the end. Generally, TCO is an analysis that places a single value on the lifecycle of the vehicle. This value includes purchase cost, operating cost, and any other cost in the acquisition process (Al-Alawi & Bradley, 2013).

Dumortier, Siddiki, Carley, Cisney, Krause, Lane, Rupp and Graham (2015) studied the effects of providing information on the total cost of ownership on consumers' decision to purchase electric vehicles in the US. The study provided information on five-year fuel cost savings, the total cost of ownership and the effects of this information on consumers' purchase decision. Through an online survey with an embedded experimental design using different labels, the study found that respondents' preference for certain vehicles was not affected by information on five-year fuel cost savings. However, the information on the total cost of ownership increased consumers' preference for car size.

Wu, Inderbitzin and Bening (2015) compared the total cost of ownership of electric vehicles to conventional vehicles in Zurich, Switzerland using probabilistic analysis and projection across different market sectors for 2014, 2020, and 2025. The results indicated that the relative cost-efficiency of electric vehicles increases with the consumer's driving distance, especially for smaller vehicles. However, the total cost of ownership is subject to the specifications of the vehicle and operating costs. The study further indicates that the total cost of ownership of electric vehicles may become close to or even lower than that of conventional vehicles by 2025. Moreover, the total cost of ownership does not affect consumers' purchase decision making.

However, the study by Letmathe and Suares (2017) theorized that the total cost of ownership method can be used in two different ways, through a consumer-based method or a society-based method. Their study explains that a consumer-based total cost of ownership method includes the purchasing price as well as all costs related to actually receiving and using the item, which is borne by the consumer, while the society-based total cost of ownership considers environmental costs such as carbon dioxide (CO2) emission costs in addition to the capital and operating cost of the vehicle.

Gilmore and Lave (2013) compared resale prices and total cost of ownership for fossil fuel, hybrid and diesel passenger cars and trucks in the US. The study confirmed that higher fuel economy vehicles retain a higher proportion of their initial price than conventional options and that the ratio of the resale value to the initial purchase price increases at higher fuel prices. The study used estimations for resale ratios to compare the difference in resale prices between the electric and conventional vehicles to the discounted expected fuel savings during the periods of 2008 and 2009.

Al-Alawi and Bradley (2013) developed a comprehensive ownership cost model in the US to analyse different plug-in hybrid vehicle designs within four vehicle classes in order to understand the costs and benefits of plug-in hybrid vehicles purchase and use. The study concluded that the total cost of ownership and payback period are sensitive to resale value, maintenance costs, and fuel economy of the vehicles.

2.9 Conceptual framework

Figure 2.15 conceptualizes the researcher's synthesis of the literature on how to realise the research objectives. It maps out the actions required in the course of the study given the previous researchers' points of view and observations on the subject of research. The conceptual model starts with the main aim of the study, which is to unpack the technical and perceived barriers to electric vehicle uptake in South Africa. It goes on to look at the evolution and development of electric vehicles globally. This development comes with both opportunities and challenges that need to be known and addressed to promote the mass adoption of electric mobility. Some of the electric mobility benefits are related to health, environment and the economy. Some related challenges include social, technical, infrastructure and economic challenges.

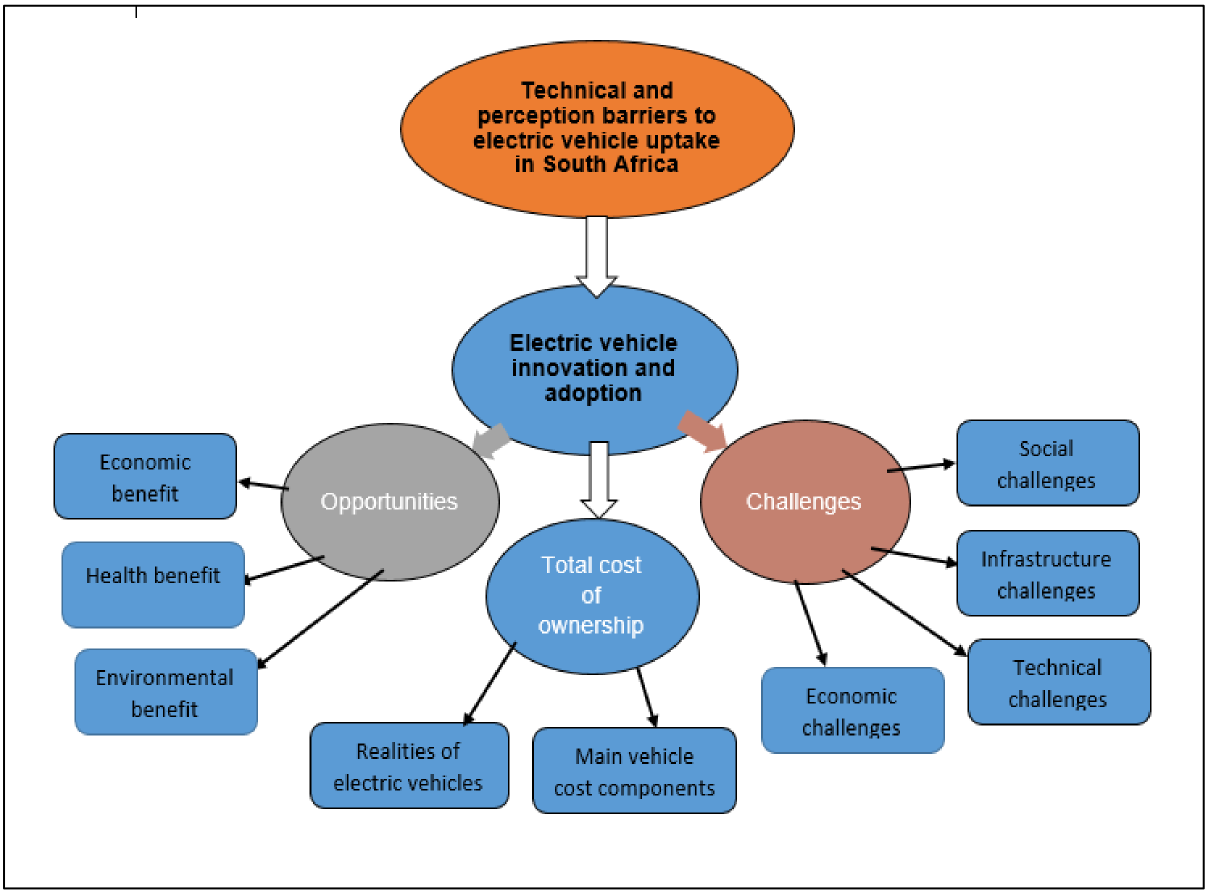

Figure 2.15: Conceptual model of the research

2.10 Conclusion

EV innovation has been in existence for over 100 years and the market is still seeing a rise in popularity for the same reasons such as the impact on climate change. To support the global commitment in rolling out EV technology, almost all the big global brands in the automobile industry have also outlined their commitments and plans to produce and deliver electric vehicles in the years ahead.

Although South Africa's electric vehicle fleet market is disappointing when compared to the rest of the world, there are more opportunities for entrepreneurs to realize their dreams and help stimulate industrial development while reducing oil imports, saving foreign exchange and improving urban air quality. Many organizations and entrepreneurs as stated earlier, are pushing ahead with electric mobility opportunities enabled by current transport innovations and may need supporting policies in place to boost the uptake.

The literature reviewed shows that many challenges are associated with the mass adoption of EVs globally. These challenges differ from country to country based on a number of factors. A mixture of two or more of those factors affects consumers' perceptions of the uptake of EVs in South Africa. These factors can be social, infrastructural, technological, economic and political challenges. The total cost of ownership (TCO) of a vehicle is the purchase price plus the costs of operation. The chapter indicates that in their purchase decisionmaking, especially when choosing among alternatives such as EVs and conventional vehicles, buyers should be aware of the vehicle's short-term cost, which is its purchase price, as well as its long-term cost, which is its total cost of ownership. The lower total cost of ownership is the better value in the end. Generally, TCO is an analysis that places a single value on the complete lifecycle of the vehicle. This value includes purchase cost, operating cost, and any other cost in the acquisition process (Al-Alawi & Bradley, 2013).

Chapter 3: Research design and methodology

3.1 Introduction

Having established in the preceding chapters evidence of the development, potential barriers to the uptake of and opportunities with regard to electric vehicles, this chapter presents the methodology of the study. This study seeks to unpack the technical and perception barriers to the uptake of electric vehicles in the context of South Africa. This chapter presents information on the data used, methods of data acquisition and a description of the techniques used to analyse the data.

3.2 Research methodology

In order to define the kind of problems worth investigating, the researcher used both quantitative and qualitative data to address the research objectives by using both primary and secondary research data. Quantitative research is a systematic empirical investigation of a research problem through statistical and mathematical techniques such as tables and graphs while qualitative research is the collection, analysis, and interpretation of data that cannot be meaningfully quantified (Wiid & Diggines, 2012). The quantitative data method was mostly used for this study because it is highly structured compared to qualitative research, which makes it very easy to measure and analyse the responses. Secondly, respondents are not required to identify themselves in the data collection process. This anonymity reduces the risk of false results because some research participants may be ashamed or disturbed about the subject. In addition, quantitative research does not require the researcher to report to a specific location to collect the data. Data collection can be done on the phone, or the researcher can conduct surveys online, or use other remote methods that allow information to move from one party to the other. Notwithstanding, qualitative research was useful in examining the attitudes and perceptions of the respondents.

Since very little information is available on electric vehicle innovation in South Africa and Sub-Saharan region as a whole, primary data is useful in identifying and assessing the local and international developmental trends, possible barriers and opportunities of the electric vehicle technology. The study used primary data sourced from experts in the automobile industry and the general population. Primary data is information collected directly from subjects for a particular purpose tailored to a specific need. Primary data provides the exact information that the researcher wants to know and it is reported in a way that benefits a specific situation. Moreover, the information collected becomes the researchers own and can remain hidden from others.

Secondary data is second-hand information that is useful for a particular research problem. This type of data is relatively easy to access and time-saving. It can bring unexpected new understandings and save the researcher money and effort (Jan wiid & Colin diggines, 2012). Secondary data for this study was obtained from the World Bank and the various automobile agencies websites. This included vehicle sales data and infrastructure development information.

3.3 Research design

The research design is a descriptive study approach, which is cross-sectional in nature. Using such an approach for the study was deemed appropriate to achieve the research objective and address the research problem specified in the first chapter. A descriptive study is an in-depth analysis of a specific research problem when the knowledge of that particular market or problem among people or community is vague (Jan Wiid & Colin Diggines, 2012). In this case, the study is focused on a specific problem, which is the barriers of electric vehicle uptake in South Africa. The descriptive approach also involves collecting information from a given sample of the population just once based on a previous understanding of the nature of the research problem. A cross-sectional approach involves the collection of data from multiple cases related to different variables. In order words, the data on the variables of interest to the researcher are collected in the same period. The researcher collected primary data for this study over two months, across two different surveys, which are expert and general population surveys.

3.4 Research population

The target population included experts in the automobile industry and ordinary South Africans older than eighteen years (18 years). The experts' survey included people working in the automotive industry in either the public or private sector. Various research methods such as snowball and authoritative methods were used to recruit the participants. The second survey included ordinary South Africans residing in and around Cape Town, Durban, Johannesburg, Pretoria, Nelspruit and Port Elizabeth. The participants from these six cities in South Africa were chosen using convenient sampling method. Convenient sampling is also known as availability sampling. It is a non-probability sampling method that relies on data collection from population members who are conveniently available to participate in the study. Moreover, electric vehicles are known to be popular among city dwellers due to accessibility of charging infrastructure in the city centres. The second survey was to try to use social media such as Facebook to get more general views and perception of electric vehicles. The sample collected was not necessarily the representative of the general population; however, it provides helpful marketing information about electric vehicles uptake in South Africa.

3.5 Sampling methods

In order for the study to be conducted as efficiently as possible, the researcher used the sample that is most relevant to the population of interest. The study used a non-probability sampling method to select the participants for the research. Non-probability sampling is a selection method where the samples for a study are gathered in a process that does not give all of the individuals in the population equal chances of being selected. Selection of the sample was purely based on the researchers own discretion or gut. Non-probability sampling methods considered appropriate for this study included authoritative sampling, snowball sampling and convenient sampling. Authoritative and snowball sampling methods were used to select participants for the expert survey while convenient sampling was used for the public survey. Authoritative sampling is a non-probability sampling method where the researcher samples respondents based on his or her own existing knowledge. This method of sampling takes comparatively much less time than collecting data from a high volume of population. Secondly, authoritative sampling allows the researcher to go directly to the target population of interest as well as increases the relevance of the sample to the population of interest.

The second method used to sample experts was the snowball method. The snowball method is a process of gathering information from a small-specialized target population where each respondent is requested to provide the name of another respondent (s) who will qualify for the sample (Jan wiid & Colin diggines, 2012). It was a useful method employed for the study because potential participants who are experts in the automobile industry are small and hard to find. Secondly, the snowball technique provides information that seems impossible to come by and helped discover the characteristics of electric vehicles that is not known by the public.

Convenient sampling was also used to select participants for the general population survey. Convenient sampling is a process where respondents' are chosen because they are accessible to voluntary participate in a survey. This was a useful method believed to be the best sampling method because the selection probability of the population elements was unknown and uncertain.

3.6 Data collection method and tools

The best method to collect information that answers the research questions is the survey method. The survey is a research data collection method used for gathering information from a pre-defined group of respondents to gain information and insights on specific topics of interest. The required data can be collected by using a self-administered questionnaire which consists of dichotomous, multiple-choice and Likert scale questions.

An online survey was used to obtain the primary data from the respondents using questionnaires as the data collection tool through Facebook and LinkedIn (see Appendices 11 & 12). An online survey is a set of structured questions, that the respondents complete over the internet. Comparatively, an online survey is the easiest way to reach out to respondents. It is also cheaper and less time consuming than other methods. The surveys included an opening letter from the university requesting public voluntary participation. It was posted as a link on facebook so that people within the selected geographical areas can access and take part in the survey (see Appendices 14). This method is relatively the easiest and fastest way of eliciting responses from the general population. The questionnaires were based on the research objectives and questions and the relevant literature reviewed. Two surveys were administered that is the experts' and the public survey. Each survey had its own category of questions taken into consideration the objectives and the research questions.

3.6.1 Expert survey

Since very little information is available on electric vehicle innovation in South Africa, involving experts in the study was a useful method to identify and assess the local and international developments, possible barriers and opportunities for the electric vehicle technology in the country. Experts were recruited based on their perceived knowledge and experience in automobility and general sustainable transportation. These individuals were from public, private, and non-governmental organisations and transport research institutions.

Authoritative and snowball or chain-referral sampling technique was used to recruit the experts. Authoritative or judgment sampling is a non-probability sampling technique deemed appropriate for this research due to the technical nature of electric vehicles. The respondents were sampled based on their existing transport knowledge or professional background. By using snowball sampling, which involves a primary data source nominating another potential primary data source to be used in the research survey, twenty-nine (29) respondents were reached. Five experts were initially recruited through LinkedIn based on their profile information and activities in the transportation domain. An official invitation letter together with the link to the experts' survey was sent to the base participants through emails requesting their voluntary participation in the survey (see Appendix 11). The respondents were requested at the end of the survey to willingly identify and provide the contact details of another expert (s) in the industry to take part in the survey. Each new referral was also requested to identify (an) another expert (s). This pattern was continued until twenty-nine (29) expert opinions were collected.

The sample of 29 experts has a significantly higher representation of males (93%) compared to females (7%). A greater percentage of the respondents (72%) were between the ages of 36 and 56. From the working sector standpoint, less than half (45%) of the sample predominantly worked as consultants, in NGOs and as researchers in the automobile industry.

The experts' questionnaires covered aspects such as vehicle ownership and vehicle use costs in South Africa, cost components of electric vehicles, and public and government involvement in electric vehicle uptake in South Africa. Other sections included the trend in local electric vehicle sales compared to the global trend, potential challenges and opportunities as well as the impact of electric vehicles on the fuel levy in South Africa. The questions were created on the SUNsurvey platform, which is the University of Stellenbosch survey platform with a link to the survey. An official invitation letter with the link to the survey was sent to the respondents through their LinkedIn accounts or to their email addresses, and they could log in to take part anonymously after accepting to participate in the survey. Twenty-nine (29) experts completed the survey within a period of one month, from 20 January 2019 up until 20 February 2019.

3.6.2 Public survey

To complement the opinion of the experts, a second data collection effort was undertaken among the public. The general population survey targeted current car owners of both conventional and electric vehicles, and aspiring car owners aged above 18 years currently residing in South Africa. The targeted population were individuals located within a 50 km radius of selected major cities in South Africa. This was due to financial constraints and the popularity of electric vehicles among city dwellers due to their travel range and the availability of charging infrastructure. These cities included Cape Town, Pretoria, Nelspruit, Johannesburg, Port Elizabeth and Durban. The motive for the survey was to extract some general information about the public's opinion, awareness and attitude towards electric mobility technology in South Africa. The online social media platform Facebook was used to collect data from the sample population.

The social media survey is a data collection method where the survey is posted as a link and people that are on Facebook and reside in the chosen geographical area can have access to and participate in the survey. A Facebook survey is a relatively cheaper and easy way to reach the public for market information. However, Facebook surveys may not be representative studies or quite as valuable as some of the alternatives, but they can be used to gain information from the general population. This method was useful because there was no limit on the number of responses and it was the easiest and fastest way of obtaining responses from the public. Secondly, the social media platform is typically where the young and the technologically inclined consumers will have a presence. These individuals can be considered supporters of technology and sustainability, and are better connected with global innovation and development through social media. These are also deemed possible early adopters or prospective users of electric vehicles if they perceive the innovation to be cost-effective, environmentally friendly and superior in performance compared to its rival, namely conventional vehicles. The sample had a significantly higher representation of males (85%) compared to females (15%). The largest proportion of the respondents (76%) were white, with a greater percentage (81%) aged above 36 years. More than half (81%) of the respondents had some form of tertiary education.

The questionnaires were divided into two different categories (see Appendix 12). The first section comprised respondents' basic information and household characteristics such as age, gender, place of work and education level. The second section dealt with the participants' knowledge of, interest in and motivation for electric vehicle adoption and use. Other questions covered information on electric vehicle infrastructure and charging patterns such as driving distance per day and the infrastructure required. Finally, the survey contained some questions with free text and multiple-choice answers. The questionnaires were pre-tested on five respondents to analyse their validity, reliability, user-friendliness and clarity.

A Facebook page called "Sustainable Transportation Africa" was created for the survey, where an official invitation letter was posted together with the link to the survey, requesting participants to take part in the survey voluntarily. After accepting the invite, the participants could access the survey and take part in anonymously. The link to the survey was shared and advertised on the Facebook page for two weeks at a cost of R345 from 13 to 27 February 2019. About twelve thousand (12 000) Facebook users within the specified geographical areas were reached, with one thousand three hundred and thirty-one (1 231) engagements and eighty-three (83) responses (see Appendix 14).

3.7 Data analysis methods

This section outlines the methods used to analyse the experiential findings gathered from expert and public surveys. The already coded data from the survey platform was captured and analysed in Excel. The analysis of both categories of responses was presented separately using descriptive statistical tables and graphs. Descriptive analysis is the simplest analytical technique that may be utilized in research to help transform information in a way that best describes the responses. Descriptive data analysis was focused on identifying the technical barriers to electric vehicle ownership in South Africa. Graphical descriptions were predominantly used in the analysis. A graphical description is an illustration of information in the form of graphs, tables and figures The analysis was divided into two sections; the first section used the cost model, the second section dealt with the responses gathered from the respondents in the expert and public surveys.

The cost model is a model developed by the University of Stellenbosch Transport Economics unit. It is used to assess daily, weekly and monthly transport operating costs based on the annual cost of vehicle operation. The model is created on an Excel sheet with pre-programmed formulae that aid in calculating the various cost elements associated with the vehicle based on the vehicle's annual cost. The cost model was populated with secondary data obtained from the various automakers, the South African Petroleum Industry Association and the South Africa energy supplier Eskom. This was used in the study to assess and analyse the total cost of vehicle ownership. Four different vehicle types, a conventional vehicle (vehicle D), plug-in hybrid (vehicle C), and two battery-electric vehicles (vehicles A and B) were taken into consideration. The selection of the comparison vehicles was based on the similarity of their size, specifications and vehicle engine displacement. The cost model calculation was only based on private vehicle ownership cost and not a company or public vehicle ownership cost. The cost comparison between electric vehicles and conventional vehicles was done to compare the unit costs (per kilometre, per day, and per week) of the different vehicle types.

A sensitivity analysis was done to compare the effect of variables such as a reduction in import tariffs, insurance cost and fuel price increases on the total cost of ownership of both electric and conventional vehicles under various assumptions. This could help to understand the impact of introducing such market incentives on electric vehicle ownership in South Africa and assessing the impact of various policies.

3.8 Delimitations of the study

Despite the efforts to prevent bias when using the quantitative method, the characteristics of the participants may not apply to the general population. As such, the results may not lead to fully representative findings. The only certainty offered using quantitative method is that the data applies to those who choose to participate.

Quantitative data can be analysed very quickly compared to other methods but there are no face-to-face contact moments with the respondents. This means the researcher cannot determine the truthfulness or authenticity of the responses but can only operate on the assumption that all the answers provided through the surveys were based on a foundation of truth. Facebook surveys may not be representative studies or quite as valuable as some of the alternative methods, but can only give some market information to the researcher.

3.9 Conclusion

This chapter presented information on the research design, methodology and the techniques employed in pursuing the research objectives. The appropriate research data for the study, data sources, and methods of data collection as well as data analysis techniques applicable to the study were outlined.

The research used quantitative data to address the research objectives by using both primary and secondary research data sources. The data collection method that was seen as the most ideal for the study was a survey method using the questionnaire as an instrument. The data collection was administered in two different sections, the experts' survey and the public survey.

The choice of sampling techniques such as authoritative, convenient, snowball and social media, which included Facebook, that was used in the study, was justified by the fact that little is known of electric vehicles and getting hold of respondents was difficult. The responses gained by means of the surveys were presented using statistical methods such as descriptive analysis coupled with modal cost analysis and sensitivity analysis.

Chapter 4: Realities of EVs and charging infrastructure

4.1 Introduction

After a detailed discussion in Chapter 3 of methods, techniques and instruments to use to achieve the set aims and objectives of the study, this chapter outlines the realities of electric vehicle technology and ownership. Similar to buying a fossil fuel vehicle, choosing an electric vehicle (EV) that is best for you depends on things such as type of electric vehicle, travel range and availability of charging infrastructure. In order to illustrate the detailed cost of ownership of electric vehicles, this chapter discusses the realities of electric vehicles, which include electric vehicle types, charging infrastructure types and the charging point options available.

4.2 Types of electric vehicles

Affordable, reliable and sustainable energy is key to electric vehicle innovation and economic growth. Currently, there are three different types of electric vehicles in the automobile market globally. These are the battery electric vehicle, plug-in hybrid electric vehicle and hybrid electric vehicle as discussed in the following sections. Currently, there are few of each type of vehicle in South Africa.

4.2.1. All Electric Vehicles or Battery Electric vehicles (BEVs)

These types of electric vehicles are powered solely by electric energy stored in a battery. Examples include the Nissan Leaf, Mitsubishi i-MiEV, Tesla Model S, Ford Focus Electric, BMW i3 and i8. However, there are only three common types – Nissan Leaf, BMW i3 and i8 – available in the South African automobile market. Battery electric vehicles derive all their power from battery packs and therefore have no internal combustion engine (ICE). Electric vehicles often provide good acceleration and have generally acceptable top speeds. They produce no Green House Gases (GHG), unlike their ICE counterparts, so they are considered green. However, battery electric vehicles can be considered zero-emission only if their source of energy produces no emission of pollutants (Schmalfuß *et al.*, 2017). The innovation cannot be emission-free if there is a production of GHG in the power plants where electricity is generated to charge them; hence, the rapid growth of renewable energy sources in the world today.

The range of electric vehicles remains a major impediment to a larger and faster uptake of BEVs in the automobile market. However, significant improvements in range with the introduction of newer models are beginning to alleviate those concerns. For instance, the new Nissan Leaf can travel 300 km on a single charge, BMW i3 travels 315 km and the latest Tesla Model S has a range of 500 km. This has made electric vehicles a good option for both short and long-distance motorists (Schmalfuß *et al.*, 2017). For instance, if an average motorist lives 20 km from the workplace, he or she can make seven round trips per charge if he or she is driving a Nissan Leaf (300 km/charge divided by 40 km per return trip). This means the owner would have to recharge his or her electric vehicle once a week, all things being equal.

A number of factors can decrease the distance an electric vehicle can travel before needing a recharge. These include driver behaviour, long mountain climbs, non-stop high speeds, strong headwinds, extra weight, loss in battery capacity and high or low temperatures which result in high air conditioner use. To extend the electric vehicle's range, the driver needs to consider the above factors. Fortunately, technology is developing faster to address a number of challenges. For instance, some EVs such as BMW's i3 now come with range extenders (a small motor that charges the battery while in use) (Kihm & Trommer, 2014).

4.2.2. Plug-In Hybrid Electric Vehicles (PHEVs) or (PEV)

The Plug-in Hybrid Electric Vehicle (PHEV) or Plug-in Electric Vehicle (PEV) is a subcategory of electric vehicles that are powered by a combination of battery power and fossil fuel engine. PEV is a type of electric vehicle that is recharged from an external supply of electricity, similar to wall sockets, and the electricity kept within the battery packs drives or contributes to the propulsion of the wheels (Palmer *et al.*, 2018).

Some examples of PHEVs are the Chevrolet Volt, Ford Fusion, and Toyota Prius. Generally, PHEVs do not travel as far as all-electric vehicles on battery power alone. When the battery runs low, the fuel engine turns on to extend the range – hence a good option for longer commutes, road trips and people who need more range flexibility. It is also fuel-efficient when driving around in town at a slower speed because it uses the battery instead of the fuel, but they are not a hundred per cent green as compared to battery electric vehicles.

4.2.3. Hybrid Electric Vehicles (HEV)

A hybrid electric vehicle (HEV) is not a pure electric or all-electric vehicle because it cannot be externally charged or operate in charge-sustaining mode. Instead, it is continually recharged with power from the internal combustion engine and regenerative braking. A hybrid electric vehicle combines a conventional internal combustion engine (ICE) system with an electric propulsion system. HEVs do not travel as far as all-electric vehicles on battery power and are therefore very good for short distances and city commuting. Examples include the Toyota Prius and Honda Insight. There are quite a number of HEVs in South Africa, more than PHEVs. The presence of the electric powertrain is to achieve either better fuel economy or better performance than with a conventional vehicle. Many HEVs have a start-stop system that reduces idle emissions by shutting down the internal combustion engine at idle, and restarting it when needed. A hybrid electric vehicle produces less emission than a complete fossil fuel vehicle (Seixas, J.Simões, S.Dias, L.Kanudia, A.Fortes, P.Gargiulo, M., 2015).

4.3 Electric vehicle charging infrastructure

Charging infrastructure for electric mobility can be categorized into Alternating Current (AC) (standard) charging, Direct Current (DC) fast charging, wireless charging and battery swapping. Some of these infrastructures such as AC and DC charging can be installed at home, in a public place or at the workplace. AC charging provides power to the vehicle's battery charge system from the external charge point within 6 to 12 hours for a full battery charge, while DC fast charging can take less than thirty minutes to fully charge the electric vehicle's battery (Madina *et al.,* 2016).

4.4 Types of charging systems

The three basic standard charging types or levels at which an electric vehicle is charged are level one (120 volts), level two (240 volts) and level three (480 volts DC). The wall charger or charging station is just an electric device that communicates with the electric system of the vehicle to allow electricity to safely flow through to the electric vehicle. These chargers and the procedures established to create them are known as Electric Vehicle Supply Equipment (EVSE). The EVSE enhances safety by enabling two-way communication between the charging unit and the electric vehicle, as shown in Figure 4.1. This two-way communication is to confirm that the electric power passing to the vehicle is below the capacity of the wall charger itself and that of the vehicle (Northeast Utilities, 2018).

Therefore, electric vehicle chargers have a lockout safety feature that does not allow current to flow from the wall charger until the plug is properly inserted into the vehicle. This new standard of safety does result in an additional cost to the consumer in terms of home installation. Secondly, the EVSE systems can also detect hardware faults and disconnect the power to prevent battery damage, electrical shocks, and worse, such as fire outbreaks. Introduction of EVSE is a procedure to simplify the charging process, help keep the user and the electric vehicle safe while charging and help facilitate the adoption of electric vehicles (World Economic Forum, 2018).

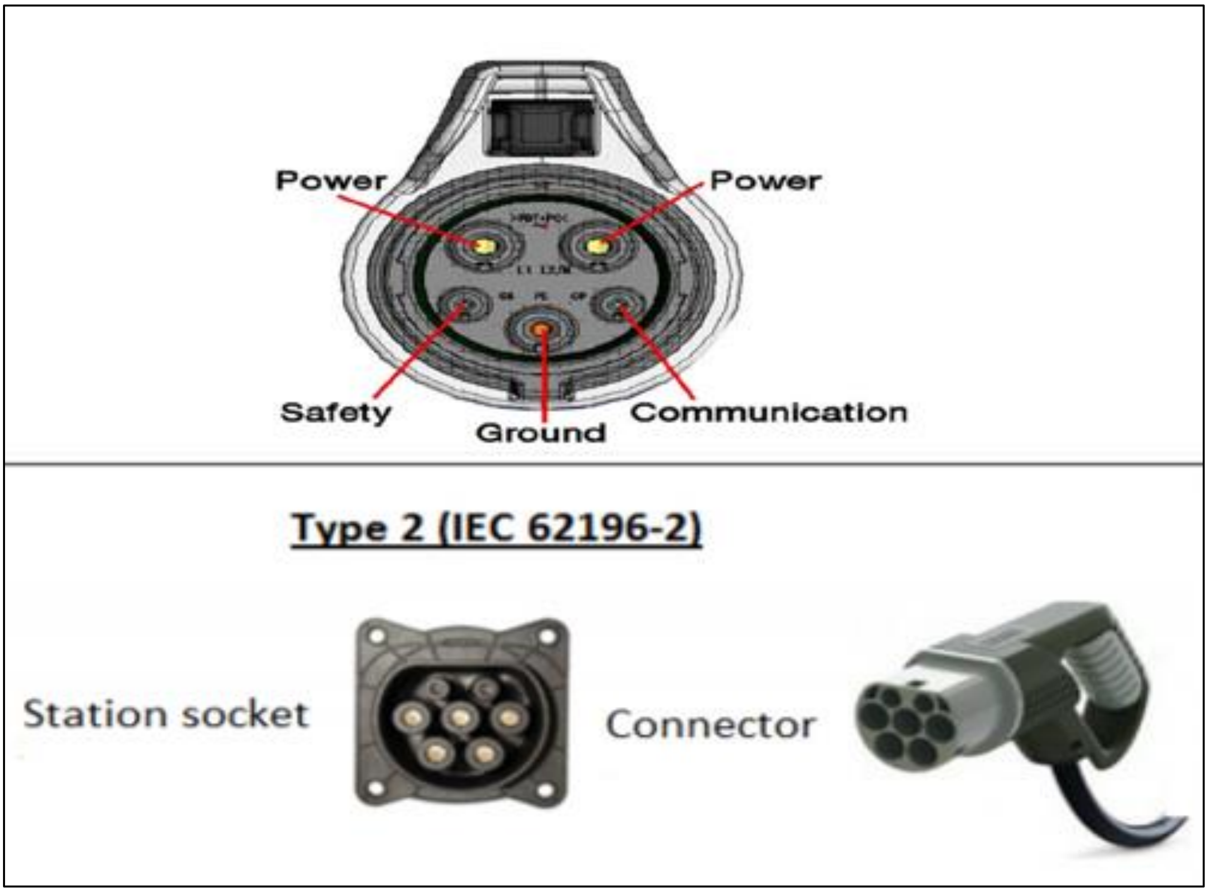

Figure 4.1: AC charge point socket and connector
Source: EVIA, 2017

4.4.1 Level 1 charging (120 volts, 16 amps)

A Level 1 charging system uses an ordinary domestic socket (120-volt current) found in any standard household outlet and can be performed using the power cord or cable that any electric vehicle normally comes with. Making this type of charging available at your home, property or any residential unit is as simple as installing 120-volt outlets. Public charging stations also use the domestic sockets because the Level 1 charging method is a standard charging system available for all types of electric vehicles. The main advantages of the first level charging facility are that every house with electricity is already a charging station and secondly, using Level 1 charging has a very low impact on power utility, especially when charging during off-peak hours. Depending on the electric vehicle's battery condition, Level 1 charging can take six to twelve hours. Hence, electric vehicles can be left on the charger overnight. This slow charging of 5 to 8 kilometres of range per hour is the main disadvantage of Level 1 charging.

4.4.2 Level 2 charging (240 volts, 32 amps)

Level 2 charging uses 240-volts power, which enables faster regeneration of an electric vehicle's battery system than in the Level 1 charging mode. Providing this type of charging requires installation of an electric vehicle supply equipment (EVSE) unit, and electrical wiring capable of handling higher voltage power. A Level 2 charging system has a faster charge time than the Level 1 system. Electric vehicles with a good battery condition get between 16 to 32 kilometres of range per hour of charge. The type two sockets are most common in public charging stations and all level three charging cables can be used with levels one and two. All types of electric vehicles can charge on Level 1 and Level 2 stations but not all can make use of the Level 3 charging system. Level 2 is more energy-efficient than Level 1 but more expensive and potentially has a higher impact on the power utility than Level 1 (International Energy Agency, 2017). Many public charging stations in South Africa are Level 1 and Level 2, and because of the low uptake of electric vehicles in the country, the cost of installing Level 2 charging systems at home could not be determined.

4.4.3 Level 3 DC Fast Charging (DCFC) (480 volts)

All public charging stations using DC fast charging are required to be dual CHAdeMO and Combined Charging System 2 (CCS2), equipped as indicated in Table 4.1. CHAdeMO is an acronym for "Charge de Move" or "charge for moving". This type of charger can be used for both battery electric vehicles and plug-in electric vehicles from all vehicle manufacturers with DC fast-charging capabilities. Currently, there are three common DC fast-charging plugs or cables in the market, the CHAdeMO, SAE Combined Charging System (CCS2), and Tesla Supercharger standards.

However, some vehicles cannot charge at Level 3 due to their battery size and capacity. This is because direct current fast charging (DCFC) converts high voltage alternating current to direct current for storage in an electric vehicle battery within the shortest possible time; it requires an electric vehicle with bigger battery size and capacity. It provides electric vehicles with approximately 80% charge within 20 to 30 minutes. For a DCFC station to charge effectively, the electric vehicle battery power should be less than 80%. Otherwise, charging will be significantly slow (Bonges & Lusk, 2016). There are a few Level 3 fast-charging stations in South Africa, including BMW and Jaguar fast-charging systems predominantly located at their retail outlets.

The EVIA Report (EVIA, 2017) indicates that knowing your vehicle's capabilities is very important when it comes to charging with DC fast charging because not all types of electric vehicles are compatible with the DCFC type. The only standard unit or facility is either the Level 1 or Level 2 types of charging stations. The only way to know or remember your electric vehicle's compatibilities is to look at its make and specifications. The report (EVIA, 2017) further recommends that, before driving to a charging station, you should know if your vehicle is compatible with the connectors available at that particular charging station. Some stations may have just a CHAdeMO connector, others just an SAE Combo CCS2 connector, and others will have both. However, there are operators, general service signs, regulatory signs, parking and special signage at the charging stations to direct the public. Nevertheless, one could say that knowing your vehicle's capabilities before planning a trip is very important for an electric vehicle user.

Table 4.1: EV charging cables

Type of plug	Picture	Amount ex-vat		Uses
		UK (overseas)	RSA (Africa)	
16A Charging Cable / Plugs		£109.99	R1962.56	EV cable for charging your electric vehicle from public charging stations or a dedicated charge point.
CHAdeMO 32A Charging Plugs / Cable		£121.00	R2158.82	Charge your electric vehicle from public charging stations or a dedicated charge point you have installed at home or commercial premises.
SAE (CCS2) Male to Female 32A Charging Plugs / Cable		£135.50	R2408,60	EV charger cable to connect your electric vehicle to public charging stations or a charging point installed at home or the office
Supercharger Male to Female 32A Charging Plugs 3 PHASE		£170.50	R3033 .05	EV charging cable using 3 Phase Power

Source: International Energy Agency, 2017

Nissan and Mitsubishi use CHAdeMO, while many other upcoming electric vehicles use SAE CCS2 ports. Holley (2017) indicates that many EVSE companies are making DCFC facilities to increase accessibility, compatibility and to minimize charge time as compared to Level 1 and Level 2 charging. The disadvantage of this type of charging is the high pressure on utility power and high electricity cost as compared to Level 1 and Level 2, especially when charging during peak hours. Installation of three-phase power connection increases the cost and potentially increases peak demand charges for commercial locations (Bonges & Lusk, 2016).

4.5 Charging points

There are three basic flexible options for charging an electric vehicle based on a consumer's needs and routine. These include home, workplace and public charging stations.

4.5.1 Home charging

Home charging can be either first level or second level charging that takes place at home or place of residence, as shown in Figure 4.2. First level charging happens when one charges the electric vehicle using the charger included with the electric vehicle. This charger can be used in any standard outlet of 120 volts to charge the vehicle. Second level chargers are sold separately from the car, although they are often purchased at the same time. These chargers are used in a 240 volts outlet and therefore need to be set up by a qualified electrician (Madina *et al.*, 2016).

While many electric vehicle models support traditional or normal wall charging, it is also possible to install stations such as the BMW Wall Box, which allows for the charging of a BMW i3 at home. Compared to the normal charging, the BMW Wall Box reduces the charging time by 30%, though it comes at an extra cost. The purchase and installation of the wall box add an additional cost of about R25 000 to the purchase price of BMW i3 in South Africa. This is subject to the compliance of the house electrification system as indicated earlier (Madina *et al*, 2016).

Figure 4.2: Home-charging facility
Source: EVIA, 2018

4.5.1.1 Setting up your home charging outlet.

To set up your home charging outlet you need a licensed electrician or an expert to evaluate your home's wiring system, the electrical outlets and other units that can support the charging of an electric vehicle. It is advisable to know your needs and the possible extra costs such as home assessment cost and installation cost before buying an electric vehicle. The cost depends on factors such as your current home electrical design, the electricity tariff and the charging option you opt for. If you choose a faster charging option, you may need to upgrade your home electrical wiring system and include EVSE with an additional cost.

4.5.2 Public charging

Public charging is charging an electric vehicle at any public place such as charging stations similar to a fuel station or public parking lot such as shopping malls as shown in Figure 4.3. All public charging stations with AC charge points are equipped with Type 2 sockets. The Type 2 sockets allow both battery and plug-in hybrid electric vehicles from all vehicle manufacturers with AC charging compatibilities to charge (Vassileva & Campillo, 2017). Some common charging cables and their estimated cost used globally are indicated in Table 4.1. To be able to charge at the public charging stations, the electric vehicle owner is sometimes required to carry a specific charging cable matching the vehicle connector to the Level 2 socket.

Figure 4.3: Public charging facilities in the Western Cape
Source: EVIA, 2019

Charging service operators (CSO) are found at the public charging station to manage and assist as fuel stations attendants do. They manage by giving charging authorization, charge cards, billing for the charge sessions as well as charging details, which include the speed of the charger, energy used and other services just as the fuel attendants do at the normal fuel stations. There are no fully functioning public charging stations with charging service operators in South Africa yet. In many advanced economies, an Open Charge Point Protocol (OCPP) is used to communicate between public charging stations (Madina *et al.*, 2016). Figure 4.4 shows various examples of electric vehicle signage that helps to provide general guidance in terms of location of the charging station as well as indicating which vehicles are supposed to park in some specific parking bays. Signage can be for general service or be regulatory, special signs and parking bay identification.

Figure 4.4: General Service signs
Source: EVIA, 2017

4.5.3 Workplace charging

Workplace charging works in a similar way to home charging points. In this case, employers offer the charging opportunity to their employees at the workplace. The employees have access to parking spaces with charging facilities purposely for charging their electric vehicles during the day or while at work, as indicated in Figure 4.5. These charging points are usually Level 2 charging stations. Many countries such as Norway and Japan have these incentive packages in place to encourage mass adoption (Bjerkan, Nørbech & Nordtømme, 2016). The advantages of workplace charging include a longer electric vehicle driving range, which results in fuel savings. When combined with home charging, workplace charging can double the daily electric vehicle driving range, especially with pure electric vehicles and plug-in hybrids. This implies that the electric vehicle charges while the owner is busy at work, shopping or at home. This makes electric vehicle charging more convenient and flexible than refuelling a conventional vehicle, as well as increases the driving range while saving more on fuel (Bonilla *et al.*, 2014).

The electricity cost of workplace charging is often an agreement between the employer and the employee. In some instances, employees can freely charge at work, while in other cases the employer charges a token fee that is usually lower than that of a public charging station (Vassileva & Campillo, 2017).

Figure 4.5: Workplace CHAdeMO Charging facility
Source: Photo taken by Author

4.6 Electric vehicle battery life expectancy

An electric vehicle's battery is an important and the main component that decides its economic viability, but many factors such as temperature, rate of charge and discharge affect the life of the battery and the vehicle may need a replacement battery with time. Five years ago, the cost of an electric vehicle battery constituted about 57% of the vehicle cost. However, due to the fast development in battery technology, this has dropped to 33% and will further decline to about 25% by 2025 according to BloombergNEF, (2019.). Most electric vehicle manufacturers such as BMW and Nissan guarantee their batteries for 8 years. The guarantee includes defects for 8 years or 160 000 km, and capacity loss for 5 years or 96 500 km whichever comes first, according to the automobile manufacturer's website (Nissan Motor Corporation, 2017). Most electric vehicle batteries last for 8 to 10 years before the battery capacity declines to below 80% of the initial rated capacity before they are replaced. Declining performance for an electric vehicle battery is evidenced by fewer miles of driving per charge.

An electric vehicle's battery can be replaced and recycled just like laptop and cell phone batteries as indicated in Figures 4.6 and 4.7. When an electric vehicle battery weakens, its travel range decreases and its charging frequency increases. A typical battery component for a family electric vehicle can be used for more than ten years before the battery weakens, and about four years for public use vehicles such as buses and taxis. A typical electric vehicle battery retains about 50% to 70% of its power capacity when it is deemed worn out for driving (Shah, 2019). While the replaced batteries cannot run an electric vehicle again, they are ideal for storing electricity from solar panels and wind turbines to support the grid.at home, and work especially alongside solar, or wind power. The re-use technology can cut household electricity cost by storing power to supplement the flow of electricity until the batteries are completely worn out for recycling. Unfortunately, this technology will not yet be available in South Africa until the complete uptake of electric vehicles is realised.

Figure 4.6: A used lithium-ion battery taken out of a Nissan Leaf electric vehicle
Source: BloombergNEF, 2019

Figure 4.7: Used lithium-ion battery from an electric vehicle
Source: BloombergNEF, 2019

4.7 Conclusion

Electric vehicle technology comes with many lessons and realities that potential adopters need to know before opting for the innovation. Some of these realities identified include the various types of electric vehicles, namely battery, plug-in hybrid and hybrid electric vehicles. Battery electric vehicles are a hundred per cent green or emission-free, followed by plug-in hybrids and the pure hybrid. There are three types of charging levels available for charging electric vehicles. Levels 1 and 2 (AC) are standard charging systems for all types of electric vehicles, while the Level 3 (DC) charging system depends on the size and capacity of the electric vehicle battery. Electric vehicle charging is more flexible because charging points are situated to suit the daily routine of electric vehicle users. These include home, public and workplace charging. With electric vehicle technology, every home, workplace and shopping centre with electricity is a potential charging station. Before driving an electric vehicle to a charging station it is important to know if the vehicle is compatible with the connectors available at that particular charging station.

Chapter 5: Modal cost analysis

5.1 Introduction

The previous chapter gave a detailed description of the realities associated with owning an electric vehicle and the infrastructure needed. The following sections in this chapter further analyse the total cost of ownership of electric vehicles and conventional vehicles by looking at the main consumer-oriented total cost of ownership components such as purchase cost, insurance cost and depreciation among other things. A key factor considered by vehicle owners and road users in their purchase decisions is the cost of fuel. This factor is often seen by vehicle owners and road users as a principal factor influencing vehicle ownership decisions. Before the main cost components are discussed, the fuel and electricity costs in South Africa are analysed and compared. The chapter further discusses the impact of import tariffs as well as insurance and maintenance costs on electric vehicle ownership in South Africa. The current transition in the transportation industry towards green mobility needs a comprehensive total cost analysis to help consumers make proper mobility choices. Generally, EV uptake in South Africa can be facilitated if consumers can place a single value on the complete ownership of a vehicle type, and not consider only the purchase price or the operating cost.

5.2 Cost of charging versus the cost of fuelling

While few countries have technology such as battery-swapping stations and wireless charging available to increase efficiency and reduce cost, many developing countries such as South Africa still rely on the traditional electric source plug-in charging methods. This has generated an interest in the author of this study to compare the cost of charging an electric vehicle with the fuelling of a conventional vehicle in South Africa. Based on current fuel and electricity costs indicated in Tables 5.1 and 5.2, an energy consumption cost comparison between conventional, hybrid and pure electric vehicles has been done to ascertain which vehicle type has a lower energy cost. To be able to compare the exact amount of energy consumed by either conventional or electric vehicle, the fuel and electricity costs in South Africa have to be known first. Table 5.1 illustrates the cost per litre for petrol and diesel in South Africa as of November 2018.

Table 5.1: November 2018 Fuel price

Fuel Type	Cost/litre Inland	Cost/litre Coastal
Petrol (93 LRP)	R16.85	R16.49
Petrol (95 ULP)	R17.08	R16.49
Diesel (0.05%)	R15.65	R15.16
Diesel (0.005%)	R15.69	R15.20

Source: South African Petroleum Industry Association, 2018

In the same way that conventional vehicles depend on fossil fuel for their propulsion, electric vehicles obtain power for their propulsion from electricity and therefore depend on the electricity tariff charged by the service providers such as Eskom and municipalities. Home power standard tariff in South Africa is a group of electricity tariffs for residential customers of both Eskom and municipalities, as illustrated in Table 5.2. These tariffs are applicable to consumers such as churches, schools, hospitals, clinics, and old-age homes. All energy consumed is divided into home power 1 to home power 4 according to levels of consumption (Eskom, 2018). Standard domestic tariffs are generally prepayment or credit meters purposely for low, middle, and high income or usage customers living in detached and semi-detached houses in towns and cities. Monthly electricity usage depends on factors such as family size and service provider. In this study, only single-phase tariffs are considered because the majority of domestic customers in South Africa commonly use single-phase electricity. The prices considered are also based on Eskom's current published tariffs applicable in South Africa's biggest cities for the year 2018.

Table 5.2: Domestic cost of electricity in South Africa's biggest cities

Cities in South Africa (single phase)	**(< 450 kWh/m)**	**(> 450 kWh/m)**
1. Cape Town	R0.9612/kWh	R1.5363/kWh
2. Tshwane	R1.2658/kWh	R1.2908/kWh
3. eThekwini	R0.9414/kWh	R1.3146/kWh
4. Ekurhuleni	R0.9561/kWh	R1.4478/kWh
5. Nelson Mandela Bay	R1.4270/kWh	R1.5790/kWh
6. City Power(Johannesburg)	R1.2208/kWh	R1.1857/kWh
7.Eskom	R0.9722/kWh	R1.1389/kWh

Source: Eskom, 2018

The main question is "how much is the cost of recharging an electric vehicle in South Africa?" The cost of recharging an electric vehicle depends on many factors such as the cost of electricity, the capacity of the electric vehicle's battery, charging time and type of charging station. While it is sometimes impossible to know exactly how much fuel a vehicle will consume due to various factors such as traffic congestion and road quality, it is possible to estimate the cost based on fuel prices, geographical region (inland or coastal) and efficiency (manufacturers' specified vehicle consumption estimates). This is applicable to both electric and conventional vehicles.

Charging technology and charging infrastructure development are key factors in the perceived running cost and the adoption of global electric mobility innovation. Studies show that the availability of fast charging infrastructure has a major impact on the rate of global electric vehicle uptake (Madina *et al.*, 2016). Currently, Japan, Norway and Sweden are among the countries with cheaper electric vehicle charging stations compared to fuel filling stations. This is mainly because of the cheaper cost of electricity and the integration of renewable energy generation in their charging infrastructure development. In the same vein, California and the United Kingdom (UK) are expecting the same trend of solar charging stations by 2020.

More charging techniques such as wireless technology are being developed to improve charging time and cost. Wireless technology uses an electromagnetic field generated in the surface beneath the vehicle to charge the battery. The vehicle charges while in motion by drawing current from technology embedded in the lanes of roads, usually highways. United Kingdom (UK) Highways are undergoing trials on this wireless power transfer technology (UK

Department of Transport, 2017). This will allow EV drivers to travel long distances without stopping to charge their vehicle's battery.

The vehicles used in the cost comparison include a 2017 Toyota Corolla (Vehicle D - conventional), Toyota Prius (Vehicle C - hybrid), BMW i3 and Nissan leaf (Vehicle B and A - battery electric vehicles). All things being equal, for an average South African living in Stellenbosch, who owns and uses a 2017 Toyota Corolla 1.6, works five days in a week and drives a hundred kilometres per return trip, it will cost R109.31 (R17.08 x 6.4L) in fuel cost per day and R546.55 (109.31 x 5 days) weekly. This is approximately R1.09 per kilometre. The same distance would have cost him or her R63.37 a day and R316.85 a week using Vehicle C (hybrid). Moreover, commuting in Vehicles A & B (pure electric vehicles) would lower the cost to only R46.089 per return trip and R230.45 a week, which is R0.46 per kilometre. This means using an electric vehicle would have been 58% cheaper than using the conventional vehicle, and 27% cheaper than a hybrid electric vehicle. This is a notable saving compared to using a conventional vehicle, especially considering the ever-increasing price of fuel in South Africa. However, the hidden cost factors such as charging facilities and charging time need to be taken into consideration when considering owning an electric vehicle in South Africa. It is very clear from the information provided in Table 5.3 that electric vehicles have a cheaper energy cost of about R46 for a 100 km journey, compared to R109 for a conventional vehicle. This does not, however, reflect the total cost of vehicle ownership.

Table 2.3: Energy consumption comparison

Hypothetical 100-km journey	**Conventional vehicle**	**Hybrid vehicle**	**Pure electric vehicles**	
Type of car	**Vehicle D**	**Vehicle C**	**Vehicle B**	**Vehicle A**
Price/litre/unit	R17.08 (95 LRP)	R17.08	R1.5kwh (normal)	R1.5/kwh (normal)
Consumption/l/ kwh)	6.4l	3.7l	33.2kwh	30kwh
Cost (R/100km)	R109.31 (R17.08 x 6.4L)	R63.20 (R17.08 x 3.7)	R49.75 (R1.5kwh x33.2kwh)	R46.089 (R1.5kwh x 30kwh)

Source: Author, based on Eskom"s utility schedule, 2018

5.3 The consumer-oriented total cost of ownership components

The total cost of ownership can be divided into two main cost elements, namely fixed cost and variable cost as illustrated in Figure 5.1. Fixed cost elements include all expenditures that do not change based on how much the vehicle is being used. Examples include capital cost, depreciation, insurance and licence cost. Variable costs are expenses that change in direct proportion to how much the vehicle is being used. These include fuel or electricity cost, lubrication cost, tyre cost and some elements of maintenance. Letmathe and Suares (2017) confirm that factors such as the initial price, depreciation rate, fuel price, maintenance cost and insurance cost are among the cost items that need to be taken into account when calculating the vehicle ownership cost of any type of vehicle.

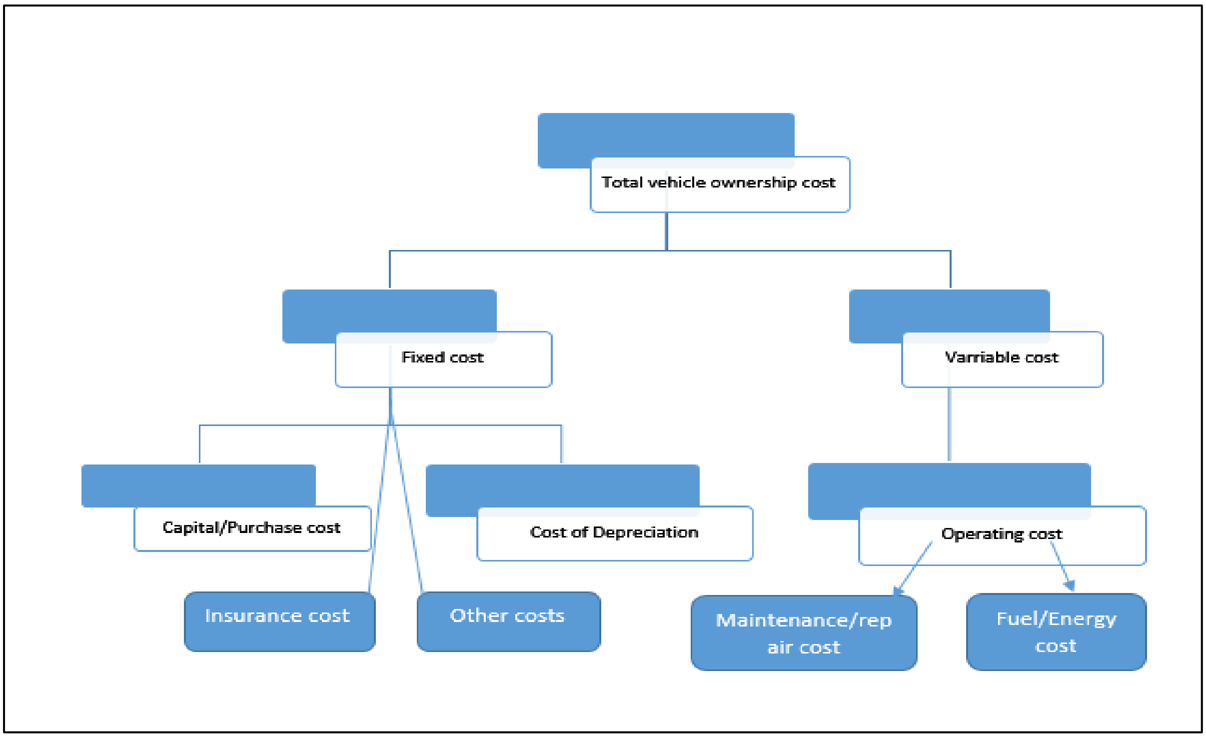

Figure 5.1: Consumer-oriented cost components

Source: Al-Alawi & Bradley, 2013

5.3.1 Initial cost

The initial cost is the retail price or purchase price of the vehicle, which depreciates with time. This includes the carbon tax and the value-added tax. Some cost elements such as insurance, depreciation and capital cost depend on the initial cost of the vehicle. The vehicles' initial purchase prices for this study are taken from the price lists of the official manufacturers and are represented as the replacement cost in the cost model calculation.

5.3.2 Depreciation

Depreciation is the reduction of the initial cost or the capital cost of the vehicle in a systematic manner until the end of its useful life or when the value becomes negligible. Vehicle depreciation is the initial cost of the vehicle less the tyre cost less resale value divided by the anticipated life of the vehicle (Lowe, 1989). Electric vehicles and batteries lose their value in the course of time and therefore have a greater influence on ownership cost. However, since electric vehicles are rare in South Africa, the resale value of the vehicle and the battery after their useful life cannot be determined at this early stage of adoption. The residual value and depreciation rate of electric vehicles are assumed to equal those of a conventional vehicle for the purpose of this calculation. The generally accepted economic life of vehicles in South Africa is 5 years, which figure is used for the calculation. Though useable life can be more than that, it is difficult to forecast vehicle life for longer than five years (Automobile Association of South Africa, 2013).

5.3.3 Fuel and electricity costs

The basic fuel price in South Africa is made up of a domestic transport cost known as the fuel levy, which is the main source of income for funding transport operations and infrastructure development in South Africa (Van Rensburg & Krygsman, 2015). The cost of the fuel levy and the global ever-increasing oil prices makes the cost of fuel one of the highest cost elements in conventional vehicle ownership. In South Africa, either Eskom or the municipalities supply electricity to the public, so the home power tariffs depend on the service provider as discussed earlier (see Section 5.2). Fuel and electricity costs are taken directly from the service providers, and vehicle efficiencies are obtained from the automaker's car specifications. Fuel cost and electricity cost are calculated as usage in litres or kWh per hundred kilometres, multiplied by the cost per litre or kWh of power multiplied by annual kilometres travelled, divided by hundred.

5.3.4 Maintenance costs

The maintenance cost includes the average variable maintenance cost of each type of vehicle. It is assumed that the cost of maintaining electric vehicles will be cheaper due to less wear and tear on parts such as brakes and fewer moving parts, but lack of expertise in South Africa offsets the lower cost of maintenance (Automobile Association of South Africa, 2013). Since EV technology is new in South Africa the maintenance cost, frequency and types of activities are not known. For this study, maintenance cost is assumed to be the percentage (19.55%) of the variable cost. This is obtained by dividing cents per kilometre travelled by hundred and multiplied by the annual kilometre distance travelled.

5.3.5 Insurance costs

Many factors such as cheaper electricity costs and zero-emission may make electric vehicles look attractive and cheaper than conventional vehicles. However, there are other fixed cost elements such as insurance cost that may increase the cost of private ownership. Insurance cost is the protection against risks such as hijacking, theft and accidents, and depends on factors such as the type of car, driver's age and driving history as well as the type of cover selected. To compare the insurance cost of an electric vehicle and conventional vehicles in South Africa, three insurance quotes for each vehicle type are compared to help estimate average insurance premiums for potential electric vehicle owners in South Africa (see appendices 1 to 4). The selected cars are conventional, electric and hybrid and with a purchasing price of between R320 000 and R530 000. The cars are all 2017 models assumed to be driven by a 45-year-old male with five years of uninterrupted driving experience. Table 5.4 shows how insurance rates differ for the electric versions of the vehicles based on the quotes received from some registered insurance companies in South Africa. The average insurance cost as indicated in table 5.4 is about R4 187.61 per month (R1 566 + R5 347.62 + R5 649.21 ÷ 3 = R4 187.61), while the average monthly insurance premium for a conventional vehicle stands at R1 291.89. This indicates how high the insurance cost of electric vehicles is compared to conventional vehicles in South Africa. This is because of a lack of auto parts and technicians in the country. Due to this, many popular insurance companies do not insure electric vehicles at all. The few that do cover electric vehicles do so at a very high cost as can be seen in Table 5.4.

Table 5.4: Insurance cost analysis

Vehicle type	**Vehicle Classification**	**Purchase price (R)**	**Insurance quote (R)**	**Insurance company**
Toyota Prestige	Conventional	328000	1919.55	Discovery Insurance
Nissan Leaf	Electric	457000	1566	Prime Meridian
BMW i3	Electric	527000	5347.62	Out Surance
Toyota Prius	Hybrid	471800	5649..21	King Price
Kia Soul	Conventional	403495	995.70	Budget Insurance
Ford Focus	Conventional	457700	960.42	Budget Insurance

Source: Hippo insurance quote, 2018

The insurance cost obtained for this study does not include passengers of the vehicles but only the comprehensive vehicle cover. It is calculated by multiplying the vehicle replacement value by the insurance rate of 7.5%. This is to ensure that the vehicle owner can replace his/her vehicle with a similar new or used vehicle in the case of a complete write-off (Automobile Association of South Africa, 2013).

5.3.6 Overhead costs

The overhead cost is the cost incurred by the vehicle owner, which is not directly attributed to the vehicle itself. Such costs include professional services, cost of parking and toll fees. It is calculated as a percentage of the annual total fixed cost of the vehicle.

5.3.7 Cost of capital

Cost of capital is a fixed cost element in vehicle ownership that deals with the interest of the capital used in buying the vehicle. It can be capital borrowed from the bank, hire purchase or owner’s savings. Even if the capital is the owner own savings, there is still a capital cost on the amount of money the owner is losing from not investing it. It is calculated as the product of the current prime interest rate (9.5%) and the replacement value divided by two (2).

5.3.8 Residual value

The residual value of a vehicle can be a full commercial second-hand market value or a nominal scrap value at the end of the economic life of the vehicle. It is very difficult to anticipate a specific vehicle's residual value for five years into the future, and therefore it is generally accepted according to industry norms that the residual value should be 25% of the replacement cost at a worst-case scenario (Automobile Association of South Africa, 2013). Gilmore and Lave (2013) argue that higher fuel-efficient vehicles such as electric vehicles retain a high proportion of their initial cost than conventional vehicles, and the ratio of their resale value to the initial cost increases at a higher fuel cost.

5.3.9 Vehicle licences and registration costs

Vehicle licence systems differ from country to country and change over time. In South Africa, the Tara mass of the vehicle determines the registration fees payable by the owner. The Western Cape Motor Licence Fees of R800 for a Tara mass between 1000 and 1260 is used for the calculation (Western Cape Department of Transport. 2018).

5.3.10 Tyre and lubrication costs

Tyre prices were obtained directly from retailers. An average cost of a tyre is assumed to be R800 for all the vehicles. The lubrication cost such as the cost of engine oil is calculated as 2.6% of the fuel cost of the conventional vehicle.

5.3.11 Total cost of ownership

The total cost of ownership (TCO) is an analysis that places a single value on the complete ownership of a vehicle. This value includes the fixed cost and the variable cost or the running cost of the vehicle. In vehicle purchase decision making, especially when choosing among alternatives such as to purchase an electric vehicle versus a conventional vehicle, buyers should be aware of the cost elements that make up the complete cost of ownership. This is necessary because it informs the vehicle owner of the full cost of ownership, not just the purchase price but also the running cost and other expenses such as repairs, insurance and depreciation. The total cost of ownership analysis is very important when comparing an electric vehicle to a conventional vehicle, or a used car to a new car because it highlights the difference between the running costs and the total costs that should influence the ownership decision. A conventional vehicle may have a lower purchasing cost (short term cost) but a higher operating cost (total cost of ownership) than that of an electric vehicle due to the ever-increasing fossil fuel price, while the electric vehicle can use electricity from readily available renewable sources such as solar, wind and water. Nevertheless, the modal cost calculation identified the main cost components for both electric and conventional vehicles ownership to include depreciation, insurance cost and cost of capital, as indicated in the pie charts in Appendices 5.1 to 8.1.

The ownership cost calculations done for each of the four vehicles as indicated in Appendices 5 to 8 are summarised in Table 5.5. The ownership cost includes both fixed and variable cost components such as purchasing cost, fuel cost, insurance, maintenance and depreciation. Detailed cost analyses such as the daily, weekly and monthly costs of the vehicles are obtained using the annual vehicle cost elements in the model calculations. The cost model identifies a single value on the complete ownership of each vehicle type for daily, weekly, monthly and annual commuting based on the assumptions in Table 5.6.

Table 5.5: Modal Cost Calculation Summary

TYPE OF CAR (2017 MODELS)	PURCHASE PRICE (R)	FIXED COST		VARIABLE COST		TOTAL COSTS (R)			
		R/YEAR	**C/KM**	**R/YEAR**	**C/KM**	**Year**	**Month**	**Week**	**Day**
Vehicle A (electric)	527000	174422	1163	10889	72	**185291**	14214	3554	502
Vehicle B (electric)	457000	151277	1009	10823	72	**162099**	12435	3109	444
Vehicle C (hybrid 1.8)	471 800	171861	1148	12995	87	**184855**	14181	3545	506
Vehicle D (conventional 1.8)	328000	99487	663	19637	131	**119125**	9138	2286	326

Source: Author, based on modal cost calculation

The total annual cost of ownership in Table 5.5 is further shown in the form of a column bar graph in Figure 5.2. The vehicles with the highest purchase price, in this case, vehicles A and C, have the highest fixed cost and ownership costs followed by vehicle B and vehicle D (conventional vehicles) respectively. However, all-electric vehicles have a relatively lower variable cost than hybrid and conventional vehicles. While the conventional vehicle has the lowest ownership cost compared to all the electric vehicles, the variable cost exceeds that of the electric vehicles. The main contributing factor to vehicle ownership cost is the vehicle's purchase price. If the initial cost of the vehicle is high, its fixed cost as well as ownership cost increases. Though the variable cost of conventional vehicles is high, and the energy consumption cost of electric vehicles as discussed in Section 5.4 is lower than that of conventional vehicles, these could not offset the high initial purchase cost of electric vehicles. As the cost remains a burden on the shoulders of consumers in South Africa, electric vehicles will continue to have a higher cost of ownership than conventional vehicles, unless the government significantly incentivizes the market.

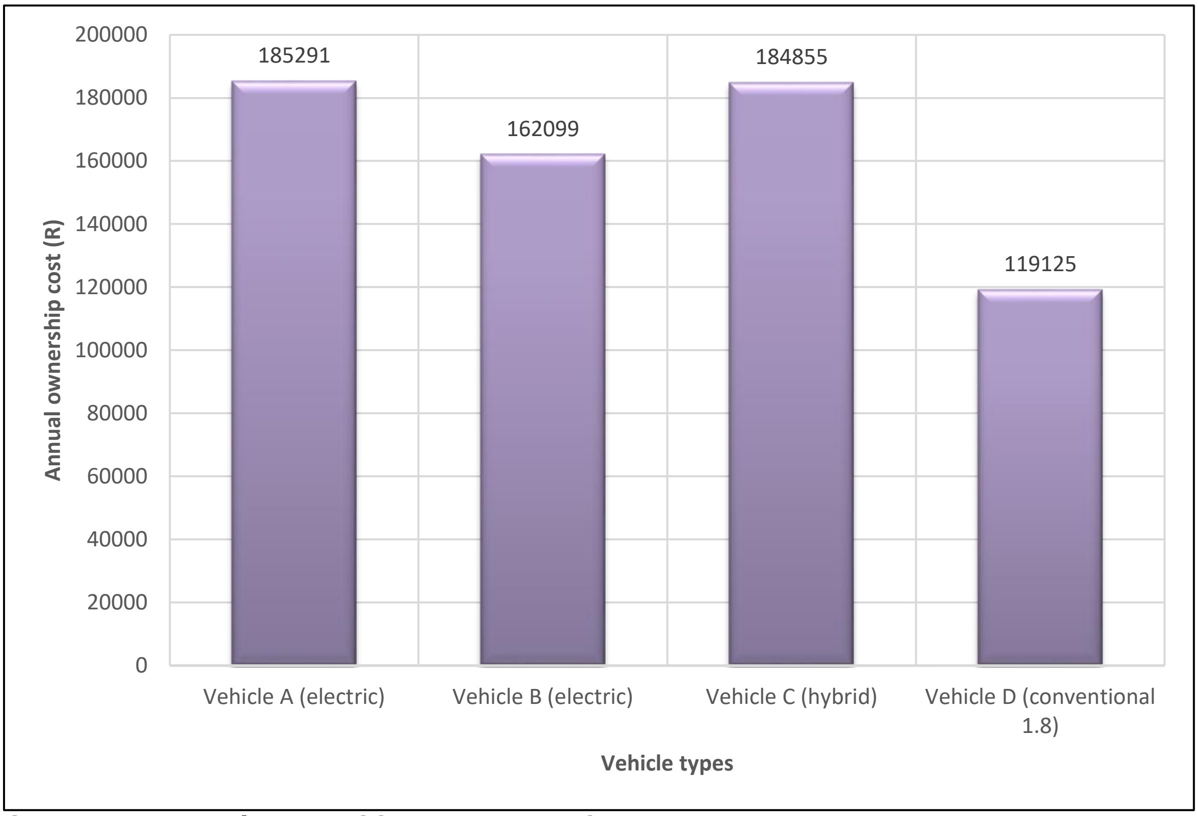

Figure 3.2: Annual ownership cost comparison

Source: Author, based on modal cost calculation

5.4 Cost model analysis assumptions

Due to the low level of electric vehicles uptake in South Africa, its technology remains a topic of debate for many while much still needs to be learnt for mass adoption. For this reason, many cost elements related to electric vehicles are not yet known and are therefore assumed to be the same as those of a conventional vehicle until such time as electric vehicles become popular in the country (see Table 5.6). Additional accessories for comfort and safety as well as charging infrastructure are not included in the calculation. No separate costs for the battery and charging cables are catered for, and it is assumed that the charging facility includes the main cable for the domestic outlet that is already included in the vehicle's purchasing cost. All cost items that differ, such as replacement cost, fuel cost, and lubrication cost are indicated.

Table 5.6: Cost model analysis assumptions

Replacement cost (excl. vat) (R)	*******
Cost of capital/ Finance cost (%)	*******
Depreciation (Yrs.)	5
Residual value (%)	25.00%
Insurance (% of the cost)	7.50%
Licence (1000-1250kg - Tarra) (R)	800
Number of tyres (No)	4
Price per tyre: New (R)	800
Number of tyres (front) (No)	2
Number of tyres (rear) (No)	2
Tyre life (front) (Km)	50000
Tyre life: Rear (Km)	50000
Number of steering axles (No)	1
Number of other axles (No)	1
Overhead cost per year (% of the fixed cost)	10.00%
Variable maintenance cost (c/km)	19.55
Fuel/Electricity Usage (l/100km) (u/100km)	*******
Cost per litre (Petrol) (c)	*******
Lubrication (% of fuel cost)	*******
Average distance per return trip (km)	80
Average distance per single trip (km)	40
Return trips per day (No)	1
Working days per week (No)	5
Return trips per week (No)	5
Weeks per year (No)	45
Return trips per year (No)	225
Yearly kilometres (Km)	15000
Working days per year (days)	200

Source: Automobile Association of South Africa, 2018

5.5 Sensitivity analysis

Some input variables such as import tariffs, insurance and maintenance costs and the fuel price are altered to assess their sensitivity to the total cost of ownership

5.5.1 Effect of import tariffs on vehicle ownership

Currently, the import tariff on electric vehicles is 25% compared to that of normal vehicles at 18%. This has contributed to the high cost and less competitiveness of electric vehicles in South Africa. For instance, the grouped bar graph in Figure 5.3 shows that a reduction in import tariffs has a significant effect on ownership cost for an electric vehicle. In a normal situation where electric vehicles have 25% and internal combustion engine vehicles 18% tariffs respectively, the electric vehicles have a much higher ownership cost compared to conventional vehicles. When the tariffs are equal for both vehicles (18%), the conventional vehicle remains cheaper but the electric vehicles get competitive. In the third scenario where there is no tariff on electric vehicles, the conventional vehicle remains cheaper but the electric version becomes more competitive, especially the pure battery electric vehicle (BEV).

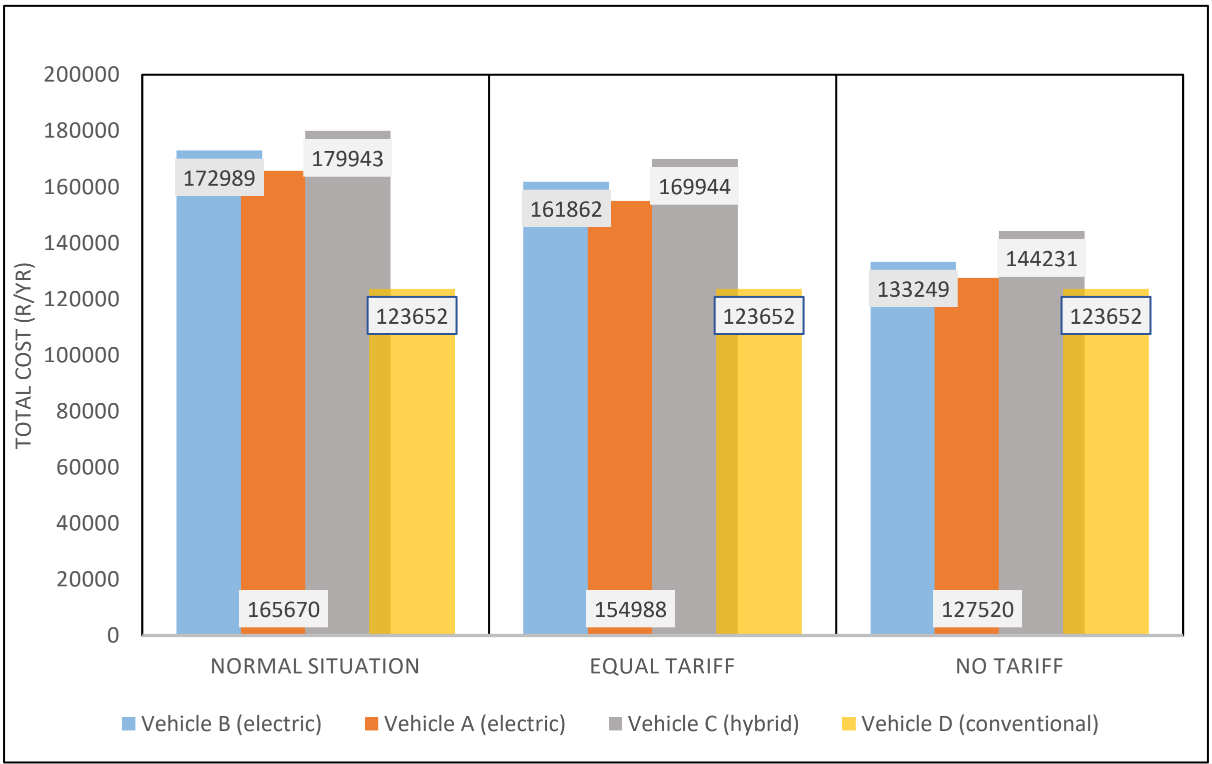

Figure 5.3: Effect of import tariffs changes on ownership cost
Source: Author, based on sensitivity analysis

5.5.2 The effect of insurance and maintenance costs on vehicle ownership

As the South African automobile market prepares to embrace the electric vehicle innovation, adopters need to be aware of all the various aspects that could affect their expenses, thereby enabling them to make a cost-effect decision when it comes to buying an electric vehicle. Plötz *et al.*, (2014) confirms that, as global and domestic fuel prices continue to increase, consumers are always looking for ways to save money – and apart from being environmentally friendly, a reasonable and user-friendly car that has lower operating costs than the combustion car will be an attractive option to the local market.

While the energy cost of electric vehicles may be less than for internal combustion vehicles, their maintenance and repairs can be more expensive, and as a result may increase the insurance premium for electric vehicles (Palmer *et al.*, 2018). Secondly, internal combustion engine vehicles have more moving parts such as the alternator, clutch and radiator that need regular servicing, while electric vehicles have few parts and require less attention. However, the cost involved is directly the opposite due to more expensive parts, advanced technology, a specialist battery system and the need to use specially trained mechanics to service the technology of the electric vehicle. Components that need to be replaced in electric vehicles are not readily available in South Africa and need to be imported from overseas. This can be costly and take up a great deal of the insurer's time as well as inconvenience the consumer.

Furthermore, many mechanics in South Africa are trained in repairing internal combustion engine cars; few of them know much about the advanced technology of an electric vehicle. Therefore, it is not only about parts but also that the right experts are currently not available in the country. This is likely to increase the cost of labour involved with the maintenance of an electric vehicle.

Lower energy costs compared to the price of fossil fuels in South Africa can make electric vehicles seem more cost-effective than a conventional vehicle; however, once you factor in car insurance and maintenance cost, cost of capital, and cost of depreciation, you might not be saving that much on electric vehicles. How insurance will affect electric vehicles in South Africa is not yet very clear, but will surely become cheaper over time as the initial cost keeps on dropping, parts are becoming locally accessible due to mass adoption and fossil fuel prices keep on increasing. Local insurance companies will adjust to the innovation as the battery technology improves and the market share increases.

5.5.3 Effect of fuel price increases on vehicle ownership cost

The recent series of fuel price increases in South Africa has negatively affected the country's economy and consumers in general. Vehicle ownership cost has been hard hit, especially for conventional vehicle owners. Nevertheless, on the positive side, it has created an opportunity for consumers, researchers and engineers to search for alternative energy sources in the transportation sector, such as electric and biofuel technology to offset the uncertainty in the fossil fuel market. For every cent that the fuel price increases in the country, vehicle owners' annual running cost increases by R9.85 and the annual total cost by R9.83 (see Appendix 12).

For example, when the petrol price increased by 72 cents per litre in April 2018, the total annual ownership cost of a Toyota Corolla owner with an average travel distance of 80 km per return trip increased by R708 (R136 966 – R137 674), R54 monthly, R13 weekly and R2 daily. The impact of a fuel price increase has little effect on the cost per kilometre travelled but has a significant effect on the annual variable cost of a conventional vehicle. However, it cannot offset the high purchase cost of EVs. Figure 5.4 compares the trend in fuel and electricity cost increases in South Africa for the past ten years. Based on the cost increase from 2008 through to 2022, it can be deduced that there are much bigger increases in the cost of fuel than that of electricity. This implies that the running cost of electric vehicles will continue to be lower, while the conventional vehicle's running cost will continue to increase. With such high fuel costs coupled with tighter global climate change policies, electric vehicle technology stands a chance of gaining popularity in the South African automobile market if educating the public in this regard can be intensified.

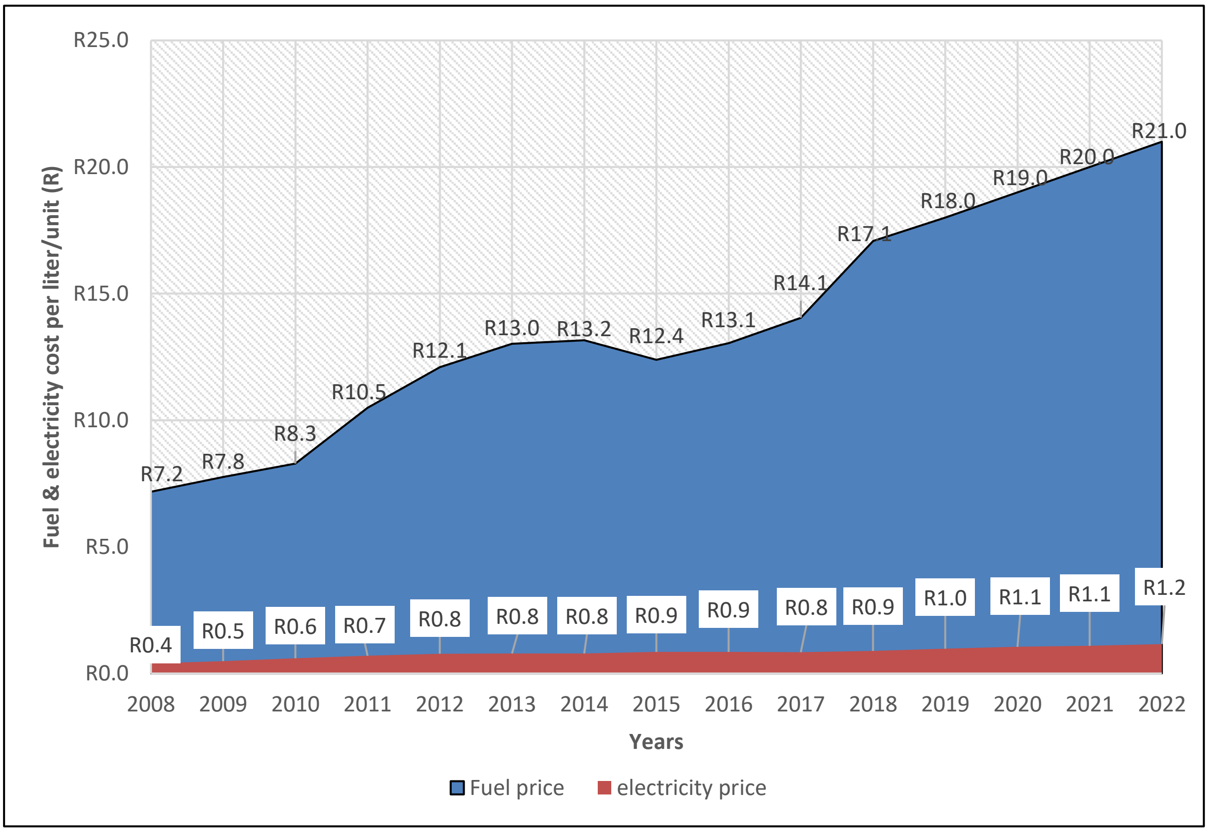

Figure 5.4: Trend of fuel price increases in South Africa

Source: South African Petroleum Industry Association, 2018

5.6 Conclusion

The analysis in this chapter focused on assessing the cost relationship between the conventional vehicle and an EV in South Africa. Depreciation, insurance cost and capital cost are the greatest cost components of vehicle ownership. It is evident that vehicle TCO is highly sensitive to changing the rates of any cost component. These components vary across vehicle type and purchase price. The higher total cost of ownership is the greatest cost to the South African consumer and it is most distinct for electric vehicles due to their higher initial purchase cost. Therefore, the lower running cost of electric vehicles does not make them cheaper than normal vehicles. Reductions in capital cost and import tariffs can lead to a significant reduction in the high-cost factor of electric vehicles. Annual fuel cost increases contribute to the vehicle ownership cost of a conventional vehicle. For every cent that the fuel price increases, the total annual variable cost increases by R709 and the total annual ownership cost increases by R708. Insurance cost and cost of capital featured as the second and third highest cost for both electric and normal vehicles respectively. Generally, the greater the discount rates on these variables the greater the variation in cost.

Chapter 6: Data analysis – expert survey

6.1 Introduction

After identifying the consumer-oriented total cost of ownership factors and their implication in vehicle ownership cost in South Africa in the preceding chapter, this chapter analyses the experiential findings gathered from the expert survey. The data analysis is presented in the form of statistical descriptions such as tables and graphs. Detail analysis is done on the cost factors associated with electric vehicle ownership, possible cost reduction strategies and ownership cost of electric vehicles versus conventional vehicles in South Africa. Secondly, concerns about electric vehicle technology as well as the trend in electric vehicle sales and adoption over the past five years are analysed. Some challenges and opportunities for electric vehicle innovation and its possible impact on government revenue and employment are presented.

6.2 Sample description

The sample size of 29 experts as indicated in Table 6.1 has a significantly higher representation of males (93%) compared to females (7%). One should note that the sample collected might not be statistically significant; however, it provides helpful information about EV technology and its enthusiasts' views in South Africa.

A greater percentage of the respondents (72%) are between the ages of 36 and 56. The age of the respondents can be attributed to the fact that the targeted population are experts who are working or have worked in the automobile industry. From the working sector standpoint, less than half (45%) of the sample predominantly work as consultants, NGOs and as researchers in the automobile industry. About 17% work in the public sector and in the infrastructure provision sector respectively.

Table 6.1: Characteristics of the sample (N=29)

Sample attributes	Characteristic	Count	%
Gender	Male	27	93.10
	Female	2	6.90
Age	18 – 25	2	6.90
	26 – 35	6	20.69
	36 – 45	8	27.59
	46 – 55	8	27.59
	56 or older	5	17.24
Occupation	Vehicle sales	1	3.45
	Transport infrastructure provision	5	17.24
	Consultancy, NGO or research	13	44.83
	Government	5	17.24
	Transport operator	1	3.45
	Other	4	13.79

Source: Author, based on the expert survey, 2019

6.3 Electric vehicle ownership cost factors

The respondents were asked to rate and rank on a 5-point scale from 1 (unimportant) to 5 (very important) some of the related cost factors as seen in the preceding chapters. Such factors include capital cost, maintenance cost, charging cost and overhead cost (see Appendix 10 question 4). The result presented in the column bar chart in Figure 6.1 shows the capital cost (53%) as the most important cost factor, followed by the overhead cost (43%). Maintenance cost (40%) as well as charging cost (33%) featured third and fourth respectively, while vehicle depreciation (27%) represents the least important cost factor in electric vehicle ownership in South Africa. Other costs that are seen to be of concern to some of the experts include the insurance cost, batteries replacement cost and high import tariffs on electric vehicles.

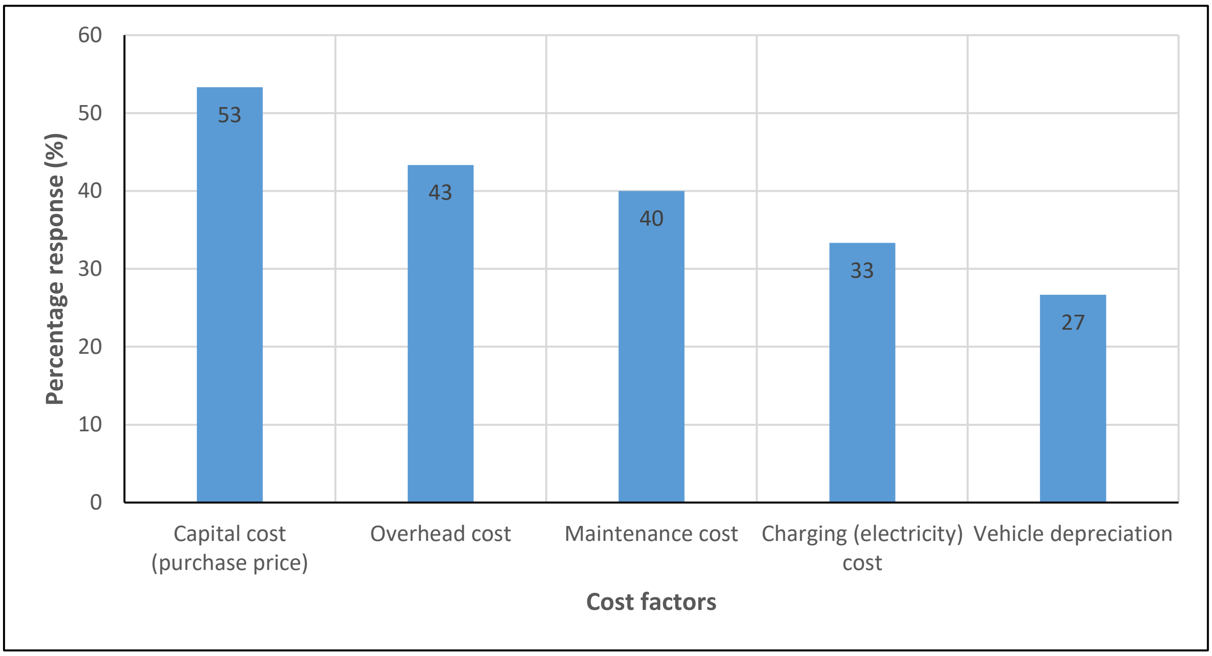

Figure 6.1: Main cost factors of EV ownership
Source: Author, based on the expert survey, 2019

6.4 Possible cost reduction strategies

Many developed countries, for instance, Norway and the US have different strategies such as subsidies and tax exemptions to lower electric vehicle ownership cost and to stimulate their uptake. In the case of South Africa, the bar chart shown in Figure 6.2 indicates some possible cost reduction strategies that the experts deem applicable. A greater percentage (70%) of the respondents suggest a reduction in import duties as the best strategy government can implement to lower electric vehicle ownership cost, followed by the provision of a capital subsidy on retail prices (52%) and subsidization of electricity cost (30%).

These answers reaffirm the high purchase cost identified initially in Chapter 5 Section 5.5.11 and Section 6.3. Other strategies indicated by the respondents include lowering annual licence and registration cost and providing free parking in city centres for electric vehicle owners. Implementing such strategies could help lower the fixed cost of electric vehicles and induce mass uptake. South Africa has no specific strategy in place to either induce electric vehicle uptake or reduce the cost. When asked for further comments, the respondents alluded that increases in the fossil fuel tax to subsidize electric vehicle cost could be a way to stimulate uptake. Also, the government can support the growth of local lithium-ion battery manufacturers and subsidize renewable energy systems at home to charge vehicles and power homes. This can incentivize the electric vehicle market and promote national adoption.

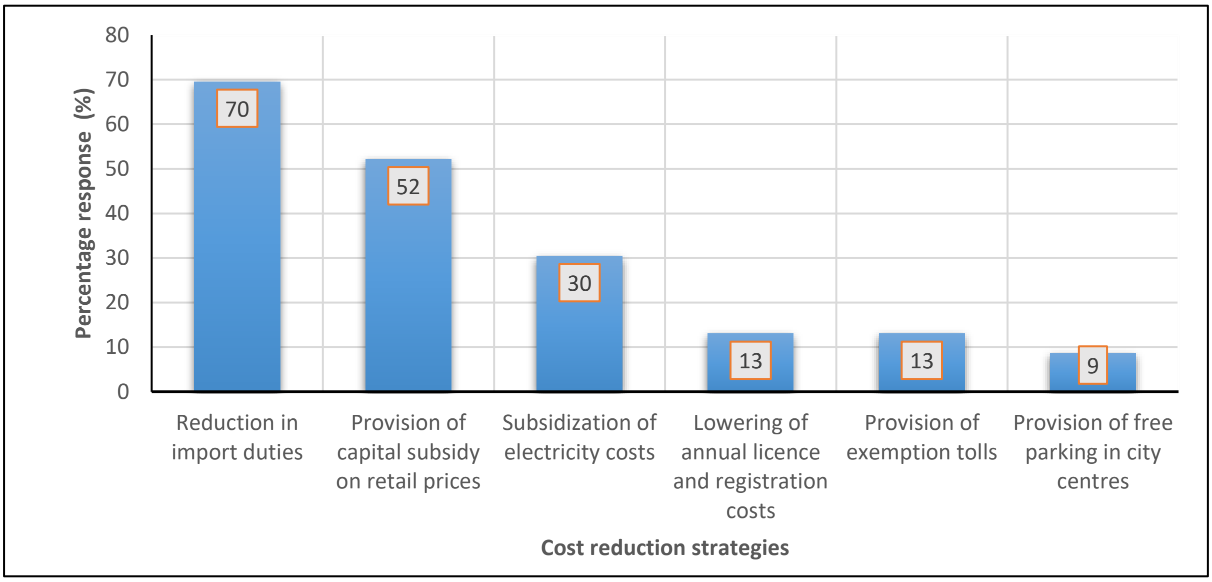

Figure 6.2: EV cost reduction strategies
Source: Author, based on the expert survey, 2019

6.5 Ownership cost comparison in South Africa

Comparing the cost of ownership between electric vehicles and conventional vehicles, 83% of the respondents strongly agree or agree that electric vehicles have a very high ownership cost compared to conventional vehicles in South Africa. Only a few (17%) of the respondents disagree with the high ownership cost of electric vehicles. The pie chart in Figure 6.3 graphically shows the respondents' views when asked to indicate whether they strongly agree, agree, disagree or strongly disagree with the current electric vehicle ownership cost compared to that of a conventional vehicle.

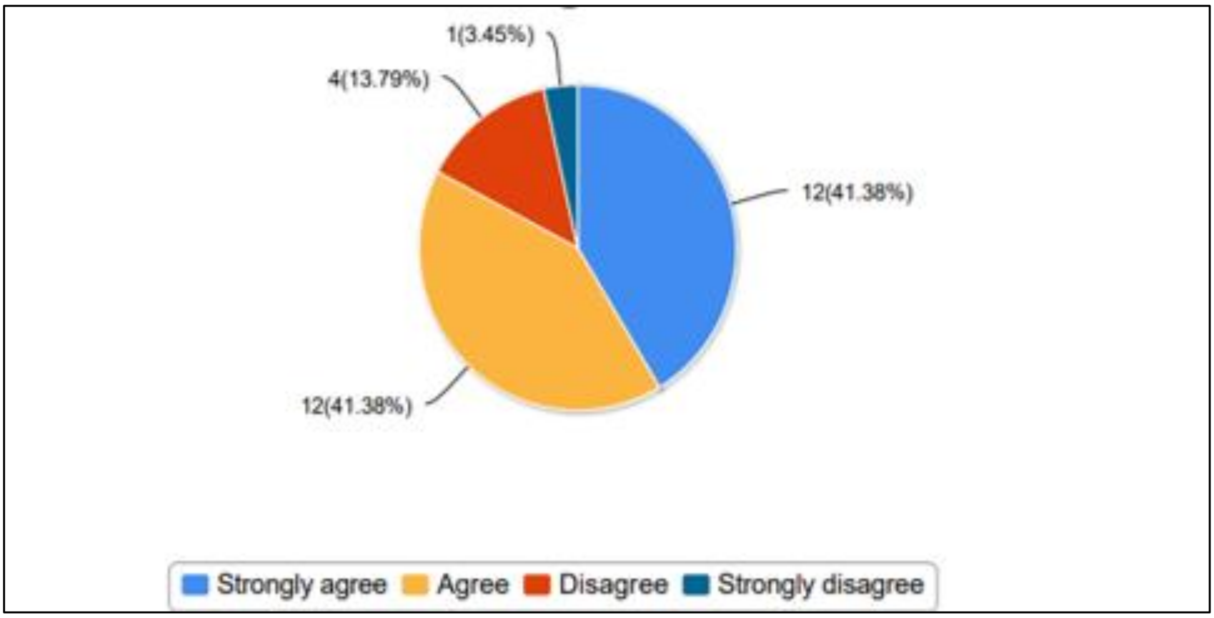

Figure 6.3: Cost comparison
Source: Author, based on the expert survey, 2019

To find out more about the future of EVs in South Africa, respondents were asked to compare some cost factors between EVs and conventional vehicles now (2018) and what they expected to happen in the next five years, as shown in Appendix 10 question 9. The clustered column chart in Figure 6.4 shows that more than half (87%) of the respondents are of the view that the current purchase price and overhead cost (57%) of electric vehicles are much higher than those of conventional vehicles due to the low market share of electric vehicles in South Africa. However, these costs may be equal to or much lower than conventional vehicles in five years' time. The maintenance cost (61%) and charging cost (65%) of electric vehicles is much lower now and will still be lower than those of conventional vehicles in the next five years, all things being equal. This seems possible because electric vehicles are gradually becoming common on South African roads, which is making the necessary auto spare parts available in the market, and local technicians are becoming conversant with EV technology.

Responses to the same question further show that the depreciation, insurance, licence, and vehicle registration costs of both electric and conventional vehicles are currently equal and will remain equal in the next five years' time. This response confirms the modal cost calculation in the preceding chapter but only differs with regard to the depreciation cost. LeBeau (2017) also argues that BEVs, PHEVs and HEVs depreciate quicker than conventional vehicles because of their high initial cost premium. Concerning the overhead cost, more than half (57%) of the respondents are of the view that the overhead cost of electric vehicles is much higher now, but stands to be much lower than or equal to that of conventional vehicles in the next five years. This may be because of lack of infrastructure and special professional services related to electric vehicle technology.

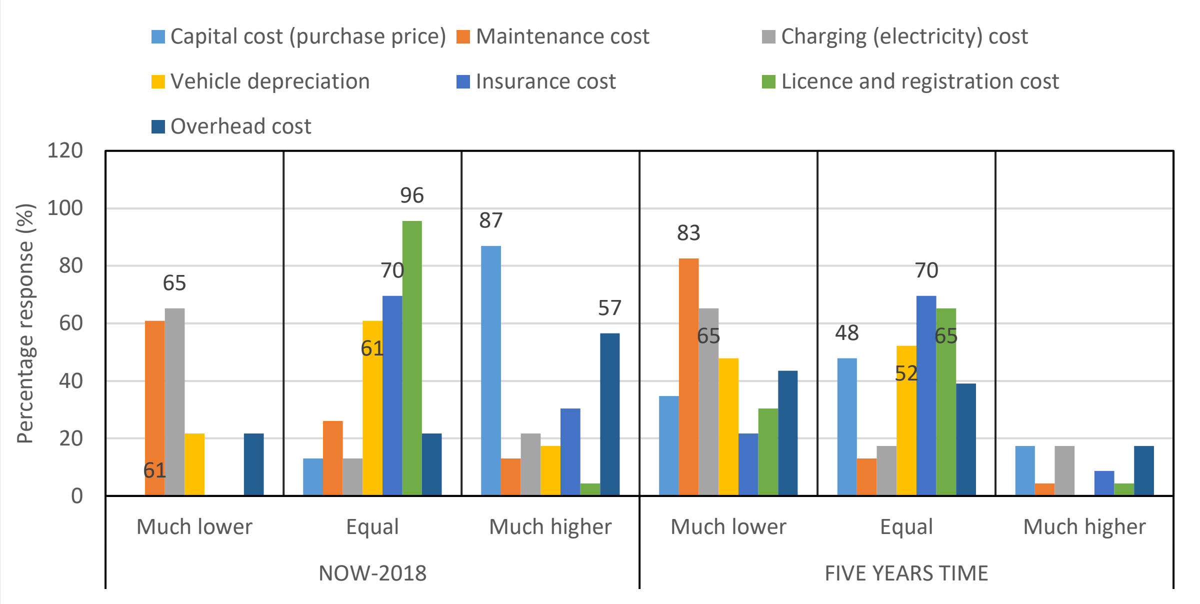

Figure 6.4: Comparing EV cost now with 5 years to come
Source: Author, based on the expert survey, 2019

6.6 Electric vehicle adoption concerns in South Africa.

On the aspect of public awareness of electric vehicle innovation and acceptance in South Africa, the respondents were requested to indicate the level of their agreement with statements regarding some adoption concerns, using a 5-point scale. Table 6.2 provides detailed responses for each of the items. The table shows that more than half of the respondents agreed with any of the statements describing the adoption of electric vehicles in South Africa with item one ".Most people in South Africa have little or no information on electric vehicles" attracting the greatest percentage of 66% and a mean score of 4.7. Only items 8 and 9 had a percentage score lower than 50% and a mean score less than 4.0 on the 5-point scale, showing that respondents were mostly positive about electric vehicle technology in South Africa. The lower percentages and average mean of items 8 and 9 indicate that demand for electric vehicles in South Africa may not necessarily depend on incentives and the current electricity problem in the country is not a serious barrier to the uptake of electric vehicles, according to the respondents.

Table 6.2: Adoption concerns

Adoption concerns	Response (n=29)	(%) Count	Std. Dev	Average rating
1. Most people in South Africa have little or no information on electric vehicles	19	66	0.48	4,7
2. The government and automobile industries in South Africa are not doing enough to create public awareness of electric mobility and its benefits	14	48	0.91	4,3
3. Electric vehicles are more environmentally sustainable than internal combustion engine vehicles	17	59	0.81	4.4
4. At a national level, electric vehicles can help to reduce the country's dependence on crude oil as the main source of energy for the transport sector	18	62	0.68	4.5
5. The government should invest in renewable energy sources like solar and wind to support the mass uptake of electric vehicles	18	62	0.89	4.4
6. Electric vehicle technology can stimulate innovation and create new job opportunities	18	62	1.02	4.3
7. Tax breaks, capital subsidies and free charging facilities can support electric vehicle uptake	18	62	0.56	4.6
8. Electric vehicles are not demand-driven but incentive-driven, which explains the low uptake in South Africa	16	55	0.9	3.9
9. Electric vehicles may worsen South Africa's electricity problem	8	28	1.25	2.6

Source: Author, based on the expert survey, 2019

Concerning some opportunities for electric vehicle technology, more than half (59%) of the respondents are of the opinion that electric vehicles are a more sustainable form of transportation than conventional vehicles. Secondly, electric vehicles can help the country's transport sector to be independent of foreign crude oil (62%). Moreover, electric vehicle technology can stimulate innovation and create new job opportunities (62%), especially in the manufacturing industries.

6.7 The trend in electric vehicle adoption in South Africa

With regard to the electric vehicle developmental trend in South Africa as indicated in part 4 of Appendix 10 question 10, respondents were asked to rate on a scale of 1 to 5 (1 = Lower than expected, 3 = Average 5 = Higher than expected) some attributes of electric vehicle development and adoption in South Africa compared to the rest of the world.

It is interesting to find from the results that the lack of knowledge of electric vehicle benefits (69%), coupled with limited government support systems (52%) contributes greatly to the slow pace of electric vehicle development and adoption in the country (69%), as indicated in Figure 6.5. Both electric vehicle infrastructure development and the availability of models in South

Africa are also significantly lower than expected when compared to the rest of the world, as per the respondents' argument.

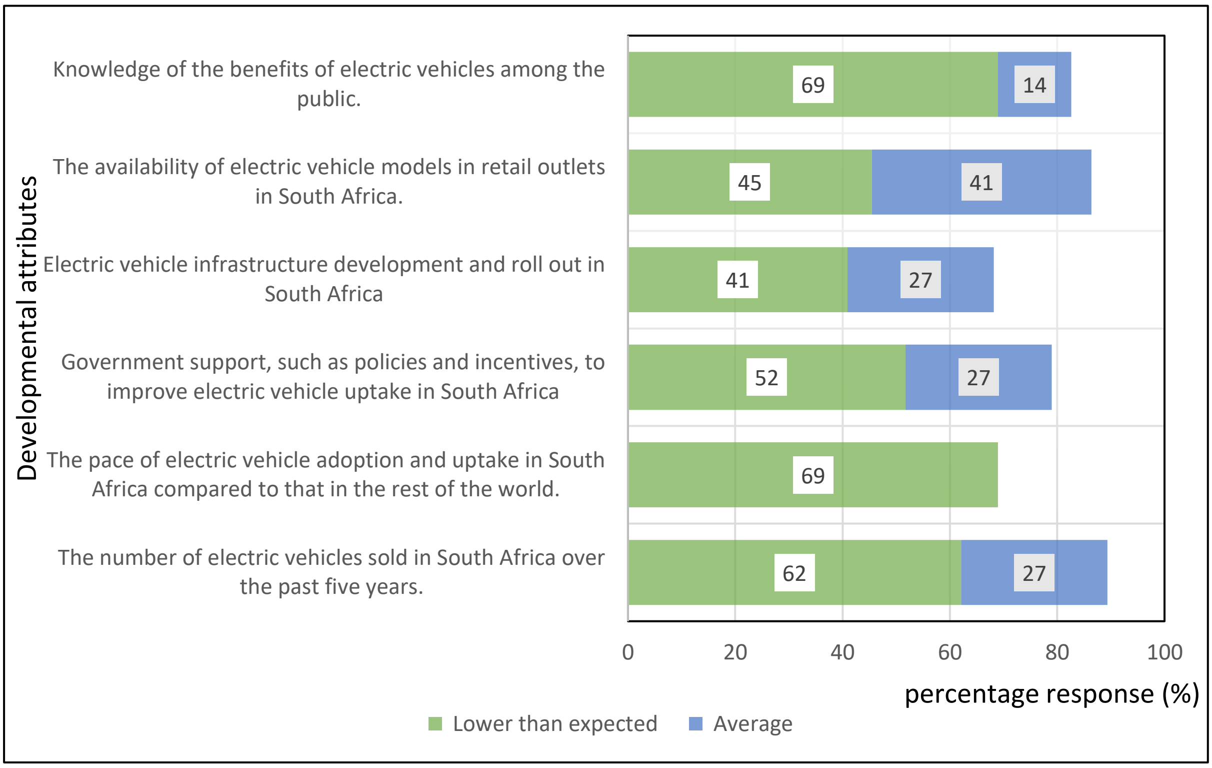

Figure 6.5: The trend in EV development in South Africa
Source: Author, based on the expert survey, 2019

6.8 Challenges of electric vehicle adoption in South Africa

As indicated in the questionnaire (see Appendix 10 question 12), respondents were asked to rank in order of importance five challenges that potential electric vehicle owners could face in South Africa. In Figure 6.6 it can be seen that more than half (57%) of the respondents ranked high purchase cost as the most important challenge, followed by the uncertain retail value (23%) of electric vehicles as the second most important challenge. The others include a lack of charging infrastructure (20%) and maintenance technicians (20%). High maintenance and insurance cost and limited electric vehicle models (17%) were ranked fourth and fifth respectively.

Figure 6.6: Major EV challenges in South Africa
Source: Author, based on the expert survey, 2019

6.9 Opportunities for electric vehicles in South Africa

Electric vehicles are known to have many benefits over their rivals, conventional vehicles. To assess opportunities for electric vehicle adoption and innovation, the respondents were asked to rank in order of importance some benefits of electric vehicle innovation. The column bar graph in Figure 6.7 indicates that a greater proportion of the respondents (23%) believe that the adoption of electric vehicles can decrease the country's dependence on fossil fuel. The reduced dependence on foreign fuel can benefit the country's economy, as increases in the fossil fuel prices will not affect the country and the ordinary South African so much. Secondly, 17% of the respondents indicate that EV adoption can foster economic development by lowering transport costs in South Africa. In response to the same question, (13% suggest that electric vehicle adoption can stimulate innovation in entrepreneurs, and 10% suggest it can lower the rate of carbon emissions in the country. Cheaper operating cost and an improvement in air quality are ranked below all the others. This might be due to the fact that electric vehicles are charged from a source (coal), which many of the respondents think is a pollutant on its own. Secondly, electric vehicle technology is new in South Africa and the country has not yet experienced its real benefits yet.

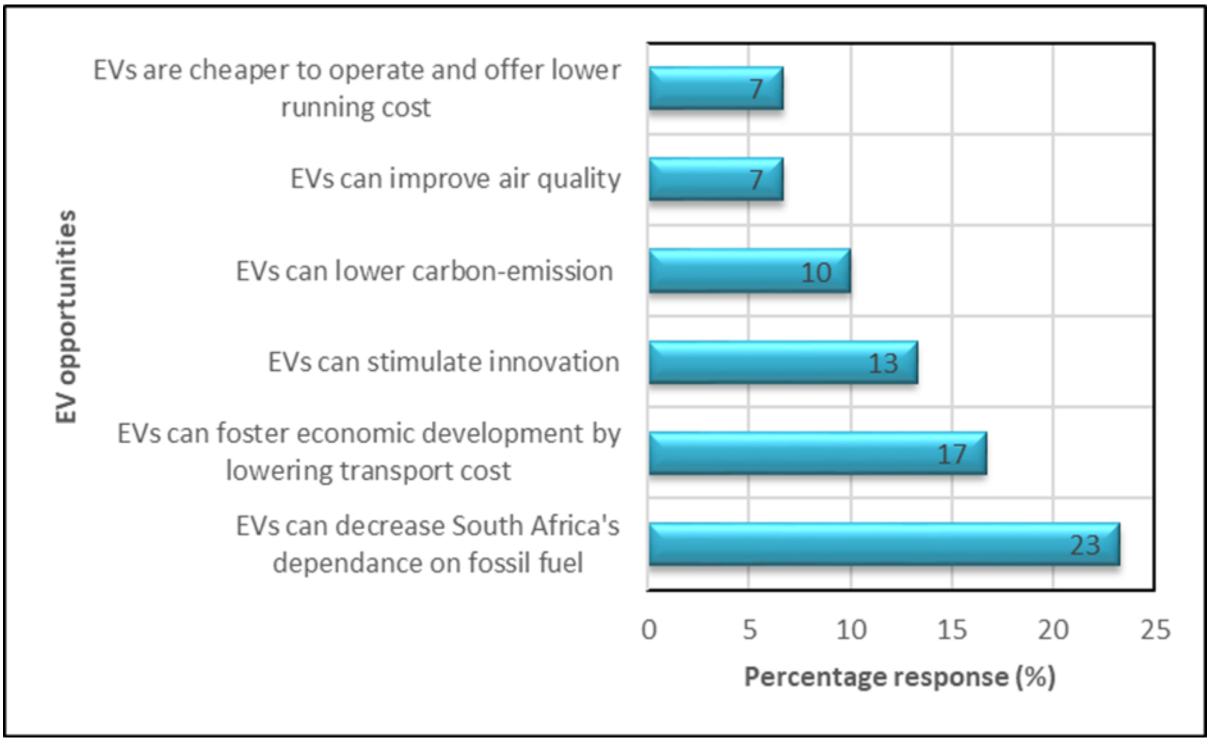

Figure 6.7: Some major EV opportunities
Source: Author, based on the expert survey, 2019

6.10 The impact of EV uptake on government revenue

The fuel levy is seen as a main source of revenue for many developing countries including South Africa. In view of this, respondents were asked for their opinion concerning government revenue from the fuel levy and the impact that electric vehicle adoption will have on road infrastructure development and employment. The clustered column chart in Figure 6.8 shows that only a few (24%) of the respondents agree that electric vehicle adoption will negatively affect road funding, which is partly sourced from the fuel levy. On the other hand, only 17% of them agree that adoption is seen as a strategy to mitigate the impact of increasing fuel prices on individuals and countries. When asked in the same question for an alternative source of funding in the form of unit cost per electricity used, 41% strongly disagree that electric vehicles should be taxed based on every unit of electricity used or on the distance per kilometre of road used. On the contrary, 38% suggest that electric vehicles should be taxed less than conventional vehicles because they do not pollute the environment. Less than quarter (24%) of the respondents agree strongly that electric vehicle innovation can lead to job losses for fuel attendants, fuel tanker drivers and refinery jobs, but the majority (27%) disagree that electric adoption will negatively impact South Africa's automotive manufacturing industry. Generally, the respondents have no concrete or overwhelming opinion as to what exactly the impact of electric vehicle innovation will be on government revenue and employment in South

Africa, confirming the lack of knowledge of electric vehicle benefits identified earlier in Section 6.6.

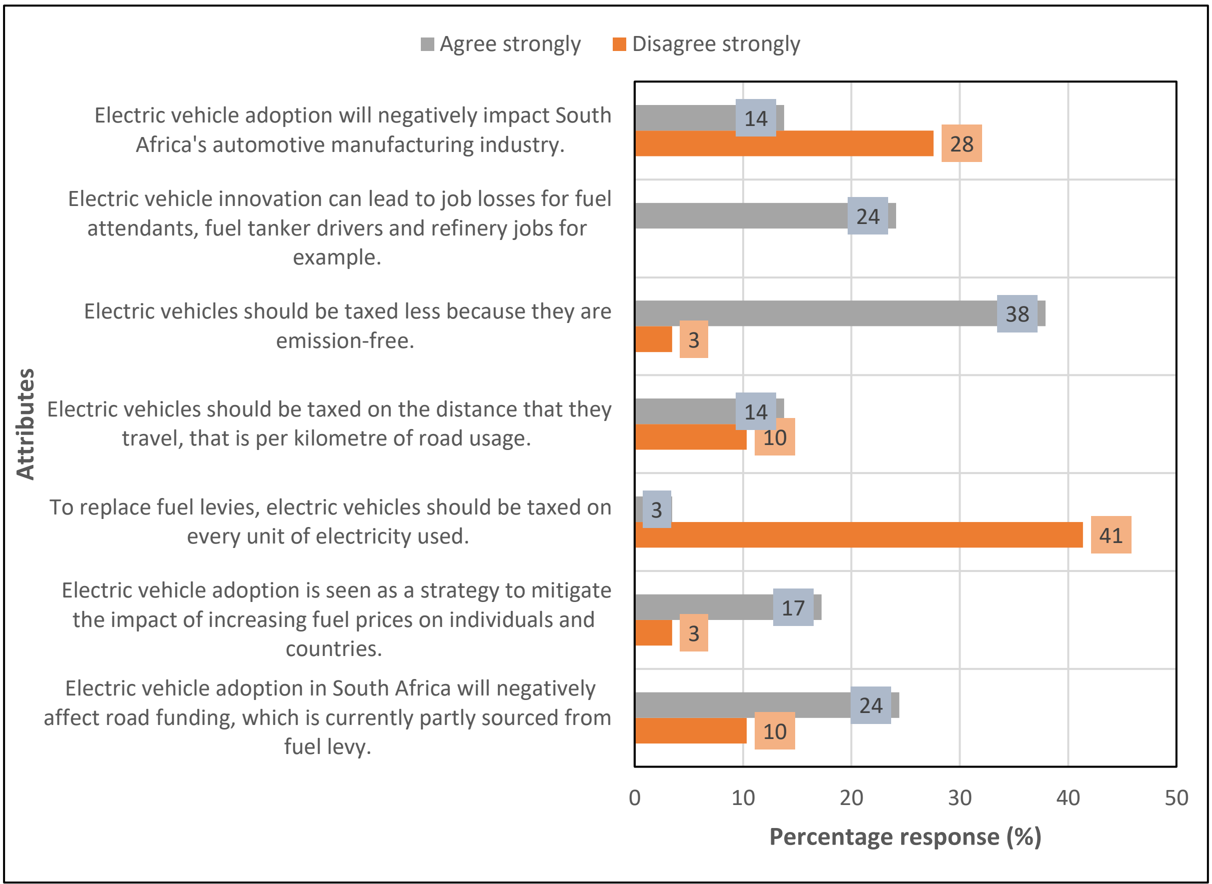

Figure 6.8: Some attributes of electric vehicle uptake in South Africa
Source: Author, based on the expert survey, 2019

6.11 Conclusion

Based on the above data analysis it is clear that several cost factors serve as a hurdle to the uptake of electric vehicles in South Africa. The most significant ones are purchase cost, depreciation cost, maintenance cost, charging cost and overhead cost. These uptake barriers can be addressed through various policies, including the provision of capital subsidies on electric vehicle retail prices, a reduction in import tariffs and subsidization of electricity cost to help reduce the cost burden on potential electric vehicle users.

The expert survey reveals that electric vehicles have a higher ownership cost now than conventional vehicles, but as the electric vehicle technology keeps on improving the total cost of ownership will soon be equal and even lower. The trend in electric vehicle adoption in South Africa compared to the rest of the world is much slower than expected, due to factors such as poor publicity for electric vehicle technology on the part of the automobile industries and lack of enabling governmental policies.

Respondents are of the view that electric vehicle innovation and adoption come with enormous opportunities such as a decrease in the national dependency on fossil fuel, plus economic growth and the stimulation of technological innovation. Hence, electric vehicle technology is not seen as a threat to road infrastructure development and employment in South Africa, especially when there is no more a fuel levy to generate income to fund transport developments.

Chapter 7: Data analysis – public survey

7.1 Introduction

The previous chapter analysed the opinions of experts in the automobile industry concerning the uptake of electric vehicles in South Africa. The following chapter complements the findings in the preceding chapter with the findings from a general population survey. This chapter analyses in detail the responses gathered from the public in the survey conducted. The analysis of the respondents' views is presented in the form of statistical tables and graphs such as bar graphs and pie charts.

7.2 Sample description

The respondents were sampled from different geographical areas in South Africa as can be seen from the map in Figure 7.1. Six profile variables have been investigated, namely: gender, ethnicity, age, occupation, level of education and income. The sample has a significantly higher representation of males (85%) compared to females (15%). The largest proportion of the respondents (76%) were white, with a greater percentage (81%) aged above 36 years. Respondents were requested to indicate their employment status. The results shown in Table 7.1 indicate an even distribution among the business, education and transport sector, and other white-collar jobs within the business sector (29%) having the greatest proportion. From the education perspective, more than half (81%) of the respondents have some form of tertiary education, with only 15% of the respondents having just a secondary qualification. About 51% of the respondents reside in the Western Cape province, and 29% and 13% live in Gauteng and KwaZulu-Natal respectively. More than half (60%) of the respondents have an annual income that exceeds R200 000, and 40% are below R200 000.

About 82% of the respondents predominantly use their own cars for their daily commute, while only 18% use any other form of transportation for their daily commute, as is clear from their answers to question 7 in Appendix 12. Though young people are known to be more technologically inclined and enthusiastic about innovation than the older generation, relatively few young respondents completed the survey. Statistically, the sample collected might not necessarily be representative of the general population; however, it provides helpful information about electric vehicle innovation and the views of its enthusiasts in South Africa.

Table 7.1: Characteristics of the sample (N=82)

Sample attributes		**%**
Gender	Male	85%
	Female	15%
Ethnicity	White	76%
	Black African	13%
	Indian	2%
	Asian	1%
	Other	5%
Age	18-25	12%
	26-35	7%
	36-45	15%
	46-55	26%
	55 or older	40%
Occupation	Education sector	12%
	White-collar job	11%
	Business sector	29%
	Agric. Sector	6%
	Transport sector	11%
	Other	31%
Education	Secondary education	15%
	Diploma/post-diploma	27%
	Graduate degree	16%
	Postgraduate degree	39%
	Other	4%
The income per month	Under R100000	6%
	R100000-R200000	20%
	R200000-R300000	11%
	R300000-R400000	11%
	R400000-R500000	5%
	R500000 and above	15%

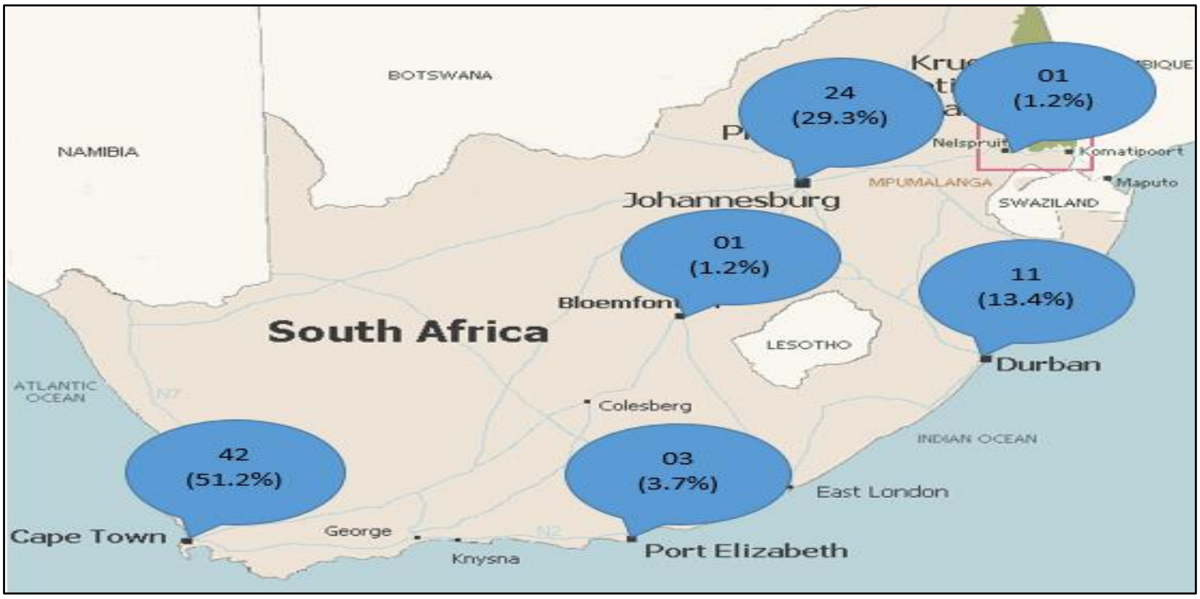

Figure 7.1: Geographical representation of the population
Source: Google maps, based on the public survey, 2019

7.3 Public awareness of EVs in South Africa

In Appendix 11 question 9, respondents were asked to indicate which of the alternative vehicle types they were aware of. Overwhelmingly, 82% of the respondents indicated they had heard of all three electric vehicle types, namely hybrid electric, plug-in-electric and battery electric vehicles (HEV, PHEV, BEV) before. Only 4% of the respondents had never heard of any of the three electric vehicle types.

Respondents were further asked to rate on a 5-point scale from 1 (least appealing) to 5 (most appealing) some characteristics of electric vehicles. The clustered column chart in Figure 7.2 shows that a high proportion of the respondents agreed with all the characteristics describing the electric vehicle as having the most appealing transport technology, with 49% of the respondents indicating the improvement in urban air quality as the most appealing attribute.

Environmental friendliness (46%) and lower ownership cost (31%) were also indicated as appealing factors.

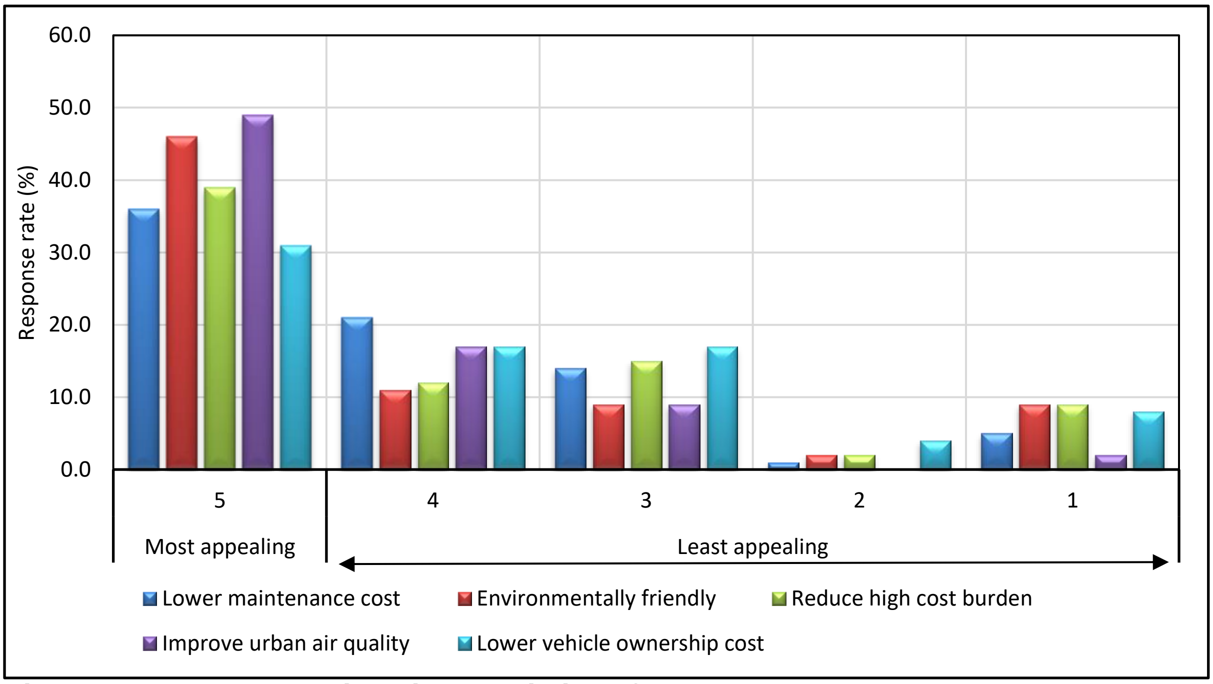

Figure 7.2: Some appealing characteristics of EVs
Source: Author, based on the public survey, 2019

7.4 Challenges of EV technology

Although electric vehicle technology is referred to as the future of transportation due to the numerous environmental benefits as indicated earlier, some challenges still impair its uptake in South Africa. Respondents were asked to rank in order of importance the serious challenges early adopters in South Africa are likely to face. The bar graph in Figure 7.3 shows some of these challenges to include high purchase cost (20%), limited charging infrastructure (17%) and a shorter travel range of EVs (15%) as the most serious challenges. Other challenges include longer charging time (13%), high cost of electricity (13%) and lack of technicians in South Africa (12%). These and other factors discourage consumers from buying EVs in South Africa.

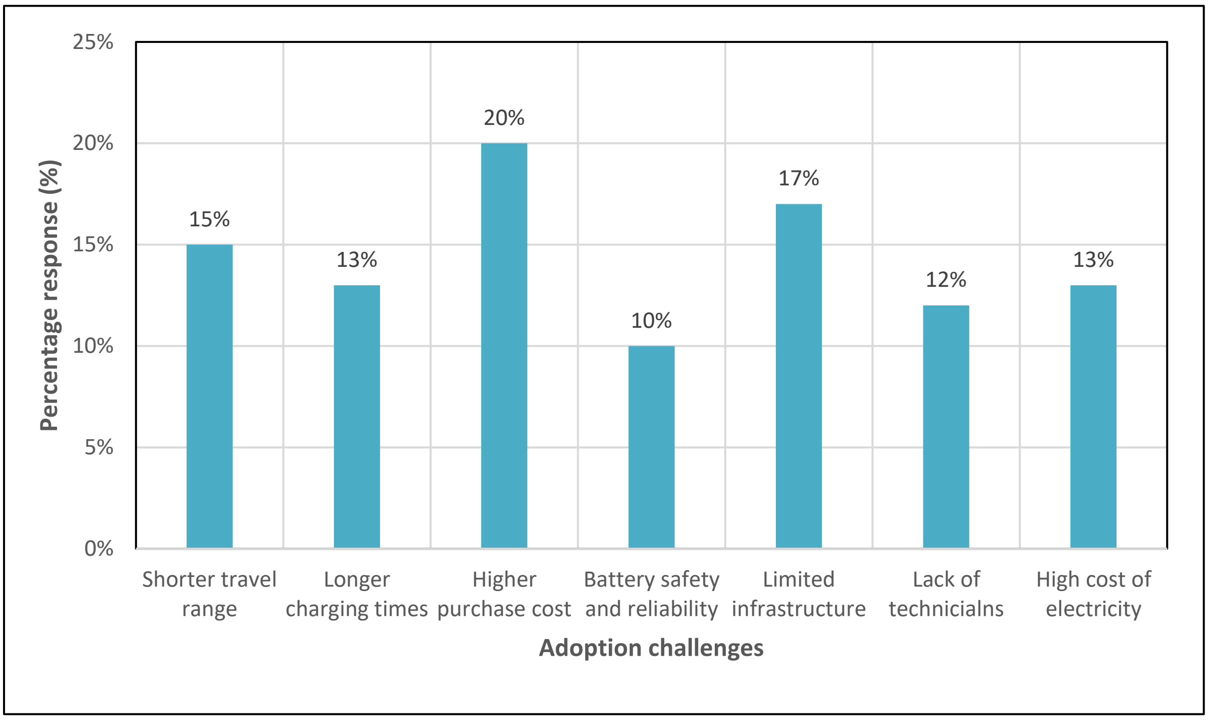

Figure 7.3: Some challenges of EV technology
Source: Author, based on the public survey, 2019

The respondents were further asked how willing they would be to buy an electric vehicle if the ownership cost of the battery and the vehicle were separated to help reduce the high initial cost (see Appendix 12 question 18). The results show an average likelihood of respondents purchasing an electric vehicle, with 43% likely to purchase, 19% unlikely and 37% unsure. A large number of uncertain responses indicates that there is limited knowledge about electric vehicle technology, even among the so-called technology enthusiasts.

7.5 Range anxiety

Concerning the driving range analysis, the study mainly focused on the approximate distance travelled by respondents on a daily or frequent basis, so the respondents were asked to indicate their average travel distance per day. Less than half of the respondents (38%) travel less than 30 km a day, while 16% travel between 30 km and 50 km a day. The results further indicate that 21% travel from 50 km to 70 km a day, while 14% travel from 70 km to 100 km a day. Only 11% of the respondents travel more than a hundred kilometres a day. This shows that a significant proportion (89%) of the respondents travel less than a hundred kilometres (return trip) a day, as depicted in the column chart in Figure 7.4.

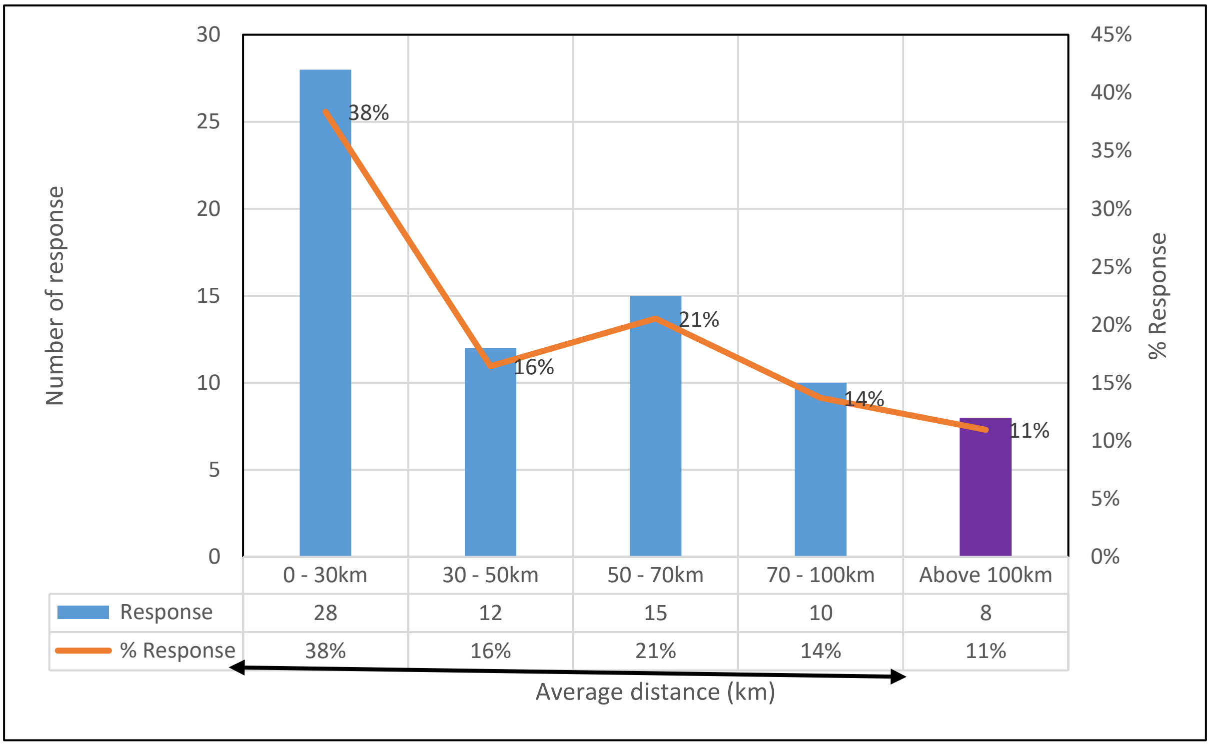

Figure 7.4: The average travel distance of participants
Source: Author, based on the public survey, 2019

This means the current travel range of many common electric vehicles, which is generally within 150 km, could provide in a large percentage of the daily travel needs of South Africans. Even though electric vehicles with a greater range are more desirable, the cost increases significantly as the range increases. Pearre Egbue, OnaLong, Suzanna. (2011) confirmed that battery technology is advancing rapidly and range limitation will be outdated soon.

A follow-up question was asked to find out how long respondents were willing to wait at a public charging station to recharge their electric vehicle battery; the bell shape bar graph in Figure 7.5 displays the average willingness of respondents to wait to recharge their electric vehicles within fifteen minutes. Only 10% said they were willing to wait more than thirty minutes to recharge.

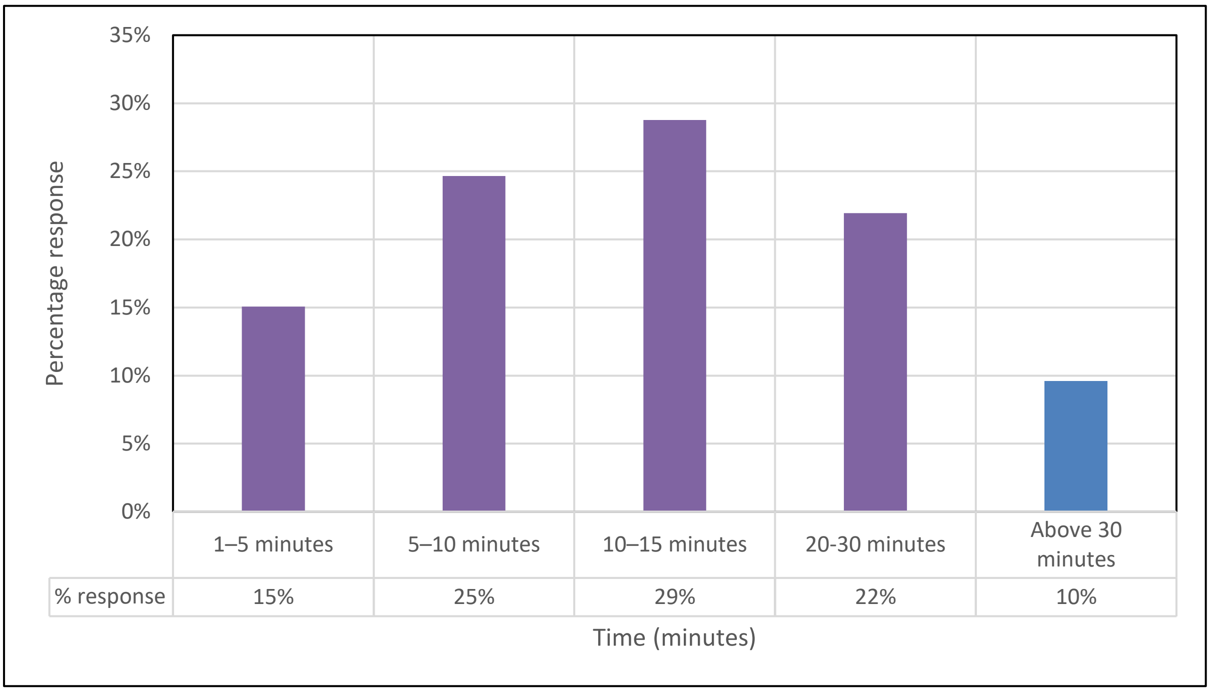

Figure 7.5: Willingness to wait for EV charging
Source: Author, based on the public survey, 2019

To assess the respondents' willingness and attitude towards electric vehicle charging they were asked if they perceived charging an electric vehicle as being convenient or inconvenient (see Appendix 12 question 17). More than half (53%) of the respondents said they perceived charging to be inconvenient, while only 38% saw charging to be as convenient as fuelling a conventional vehicle at a fuelling station, while a few (8%) are not sure. The high inconvenience rate illustrates that charging time is one of the main challenges that could hold back the uptake of electric vehicles in South Africa. However, being able to charge at home and at the workplace as indicated in Sections 4.8.1 and 4.8.3 could mitigate this challenge.

Globally, a number of strategies such as battery renting and battery swapping stations are being developed to solve range anxiety and the high purchase cost challenge. Respondents were asked if they would like the idea of battery renting and battery swapping (see Appendix 12 questions 18 and 19). Less than half (44%) of the respondents show a willingness to accept the battery renting strategy, while a greater percentage (56%) of the respondents were either against it or were unsure of the strategy.

Concerning battery swapping, the results shown in the pie chart in Figure 7.6 indicate that a greater percentage (69%) of the respondents liked the idea of battery swapping stations, while some (33%) do not like it or are not sure of the swapping strategy. The greater number of unsure responses means there is more education work to be done on cost reduction options in the area of electric vehicle ownership in South Africa.

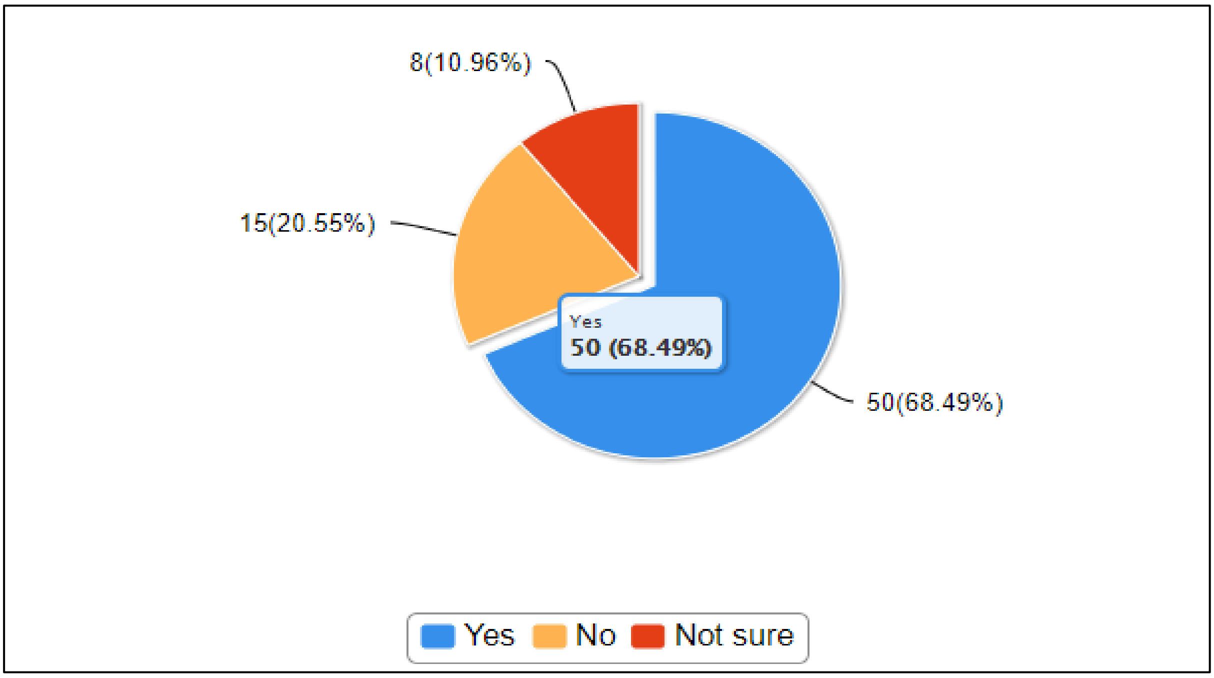

Figure 7.6: EV battery swapping strategy
Source: Author, based on the public survey, 2019

7.6 Cost of fossil fuel and electric vehicle adoption

The cost of fuel has an increased influence on electric vehicle uptake, as the high price of fuel may stimulate consumers to look around for an alternative way of travel. Respondents were asked what petrol or diesel would have to cost to persuade them to buy an electric vehicle (see Appendix 12). More than half of the respondents (75%) indicated that they would only be persuaded when a litre of fossil fuel reached a maximum of R25, while only a quarter (25%) of the respondents indicated that a litre of fuel would have to cost above R25 before they would look around for the alternative way of travel such as an electric vehicle. The results are presented in the pie chart in Figure 7.7 and confirm that electric vehicle adoption will be low as long as the purchase price is high unless fossil fuel price is high. The current fuel price of R16.75 per litre in South Africa is within the scope of the larger proportion (45%) of respondents, indicating that electric vehicle adoption is not far from becoming a reality.

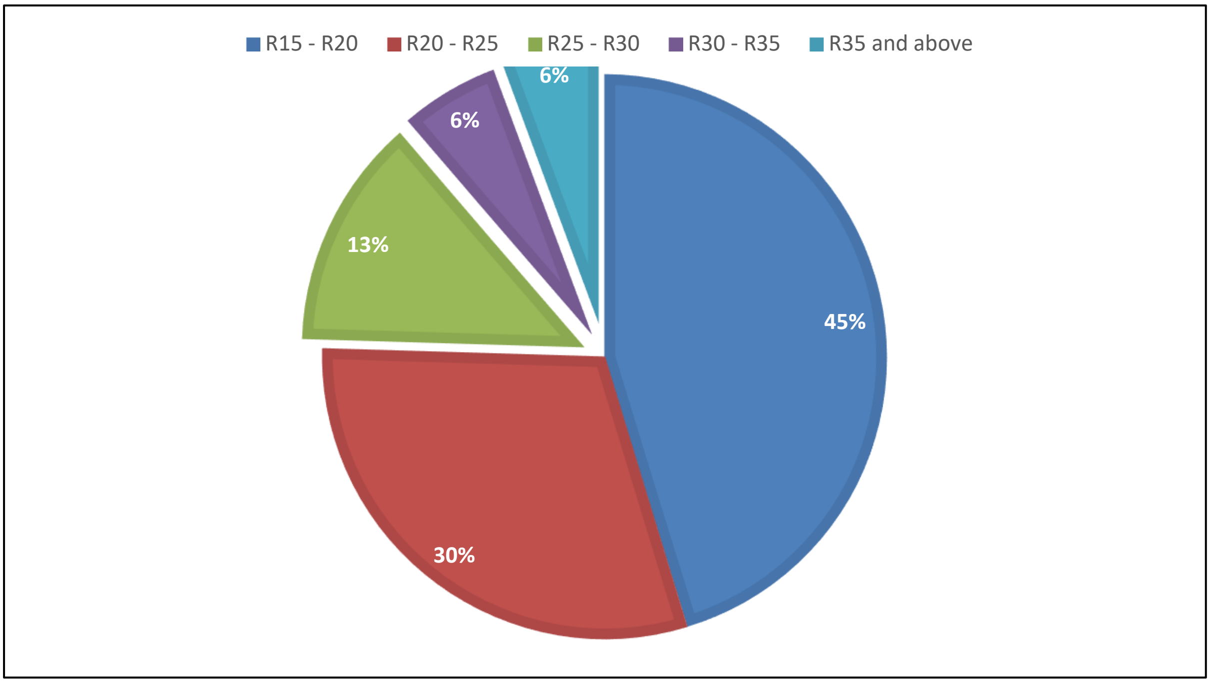

Figure 7.7: Cost of fossil fuel and EV adoption
Source: Author, based on the public survey, 2019

7.7 Advantages of EV technology

Despite the number of challenges identified with EV innovation, the respondents were asked to give four main advantages of electric vehicles over conventional vehicles. The column chart analysis in Figure 7.8 shows the same advantages of EVs as seen in the preceding sections of being emission-free, and the most environmentally friendly technology with cheaper operating costs.

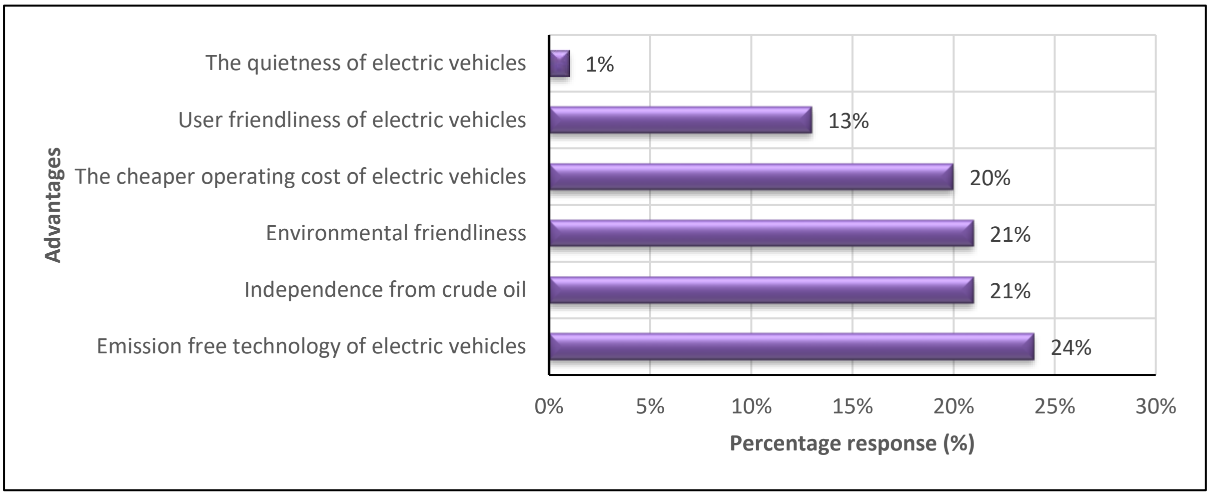

Figure 7.8: Advantages of electric vehicles
Source: Author, based on the public survey, 2019

Considering the potential environmental advantages of electric vehicles over conventional vehicles, respondents were asked if sustainability influence their vehicle purchase decisions (see Appendix 11). The pie chart in Figure 7.9 shows that 66% of the respondents consider sustainability when purchasing a vehicle, while only a few (34%) do not necessarily consider sustainability in their vehicle purchase decision making.

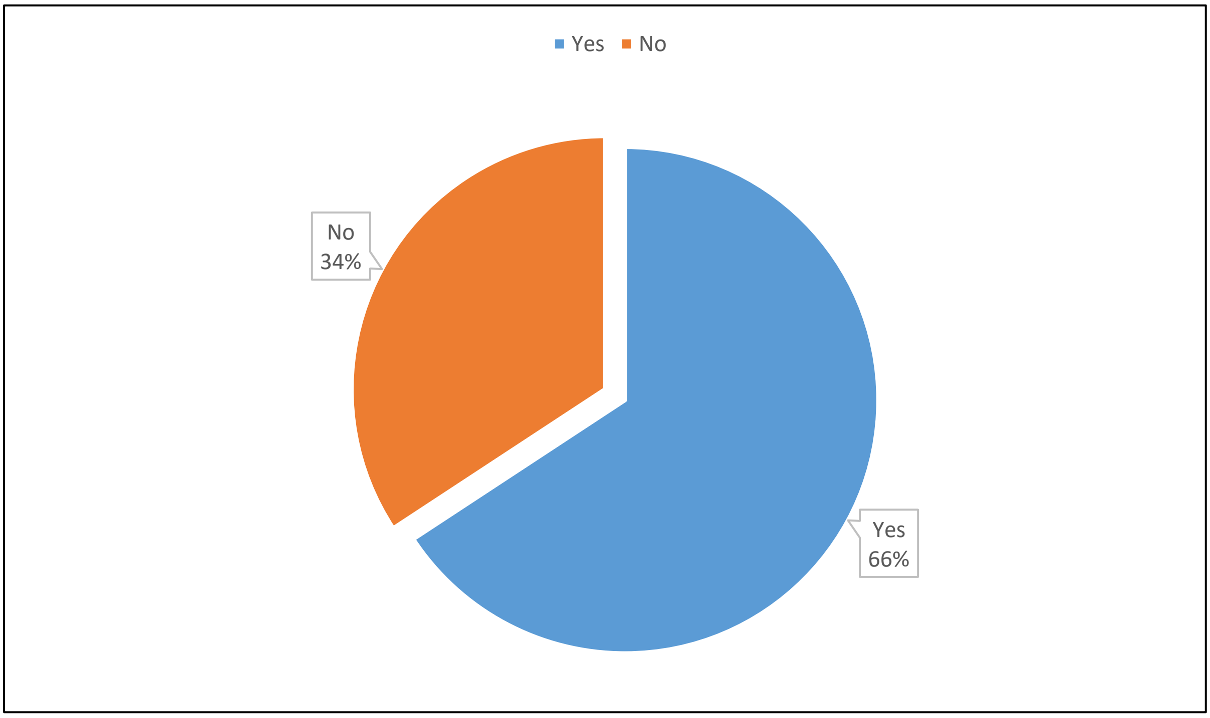

Figure 7.9: Sustainability and vehicle purchase decisions
Source: Author, based on the public survey, 2019

The sustainability factor in vehicle choice affirms the age group of the respondents who participated in the survey. More than half of the respondents (66%) are aged above forty years. Naturally, people in the age category above forty years are more likely to be familiar with sustainability and more conscious of environmental health issues than the younger age group (Plötz *et al.*, 2014). This suggests that the early adopters of electric vehicles would not necessarily be the younger age group due to the high initial cost. Early adopters in South Africa will be individuals who can afford an electric vehicle and who are more conscious of sustainability and climate change.

Concerning respondents' willingness to purchase electric vehicles instead of conventional vehicles, they have some level of willingness depending on the initial cost of electric vehicles and the availability of charging infrastructure. Figure 7.10 shows that less than half of the respondents (42%) are more willing to buy electric vehicles only when the purchase price is equal to the normal vehicle's purchase price and when charging stations become as common as fuel stations. The rest (47%) are more willing when the purchase price is lower than the conventional vehicle with improved travel range and charging time.

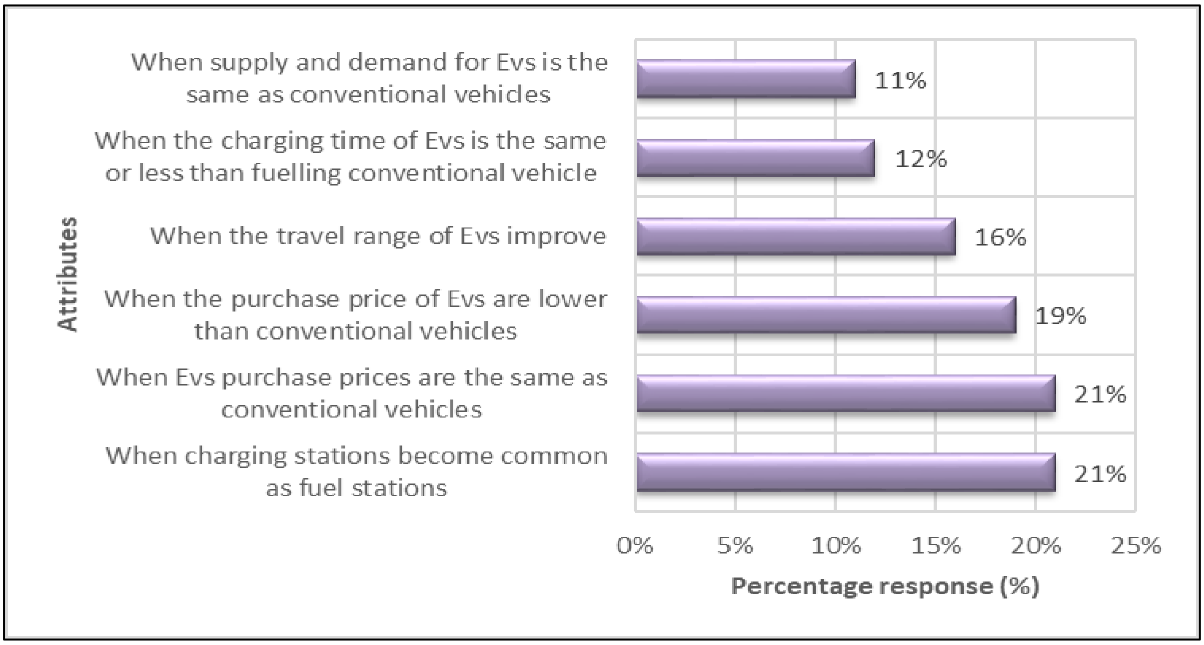

Figure 7.10: The advantages of EV technology
Source: Author, based on the public survey, 2019

7.8 The electric vehicle infrastructure challenge

In spite of the rapid global development and mass uptake of electric vehicles, their infrastructure development remains the most significant challenge in developing countries including South Africa. To understand this challenge, respondents were asked how common electric vehicle charging stations are in their provinces and residential areas where they live. Fifty-two per cent (52%) indicated that electric vehicle charging infrastructure is very rare, while 27% said charging stations are rare and 18% indicated that there is no charging infrastructure at all in their province. Only 3% have access to charging infrastructure in their province. This is illustrated in the form of a pie chart in Figure 7.11 and is confirmed by 85% of respondents indicating the absence of any form of charging facility either at their home or workplace. These results indicate that massive infrastructure development is needed in South Africa to facilitate the mass adoption of electric vehicle technology.

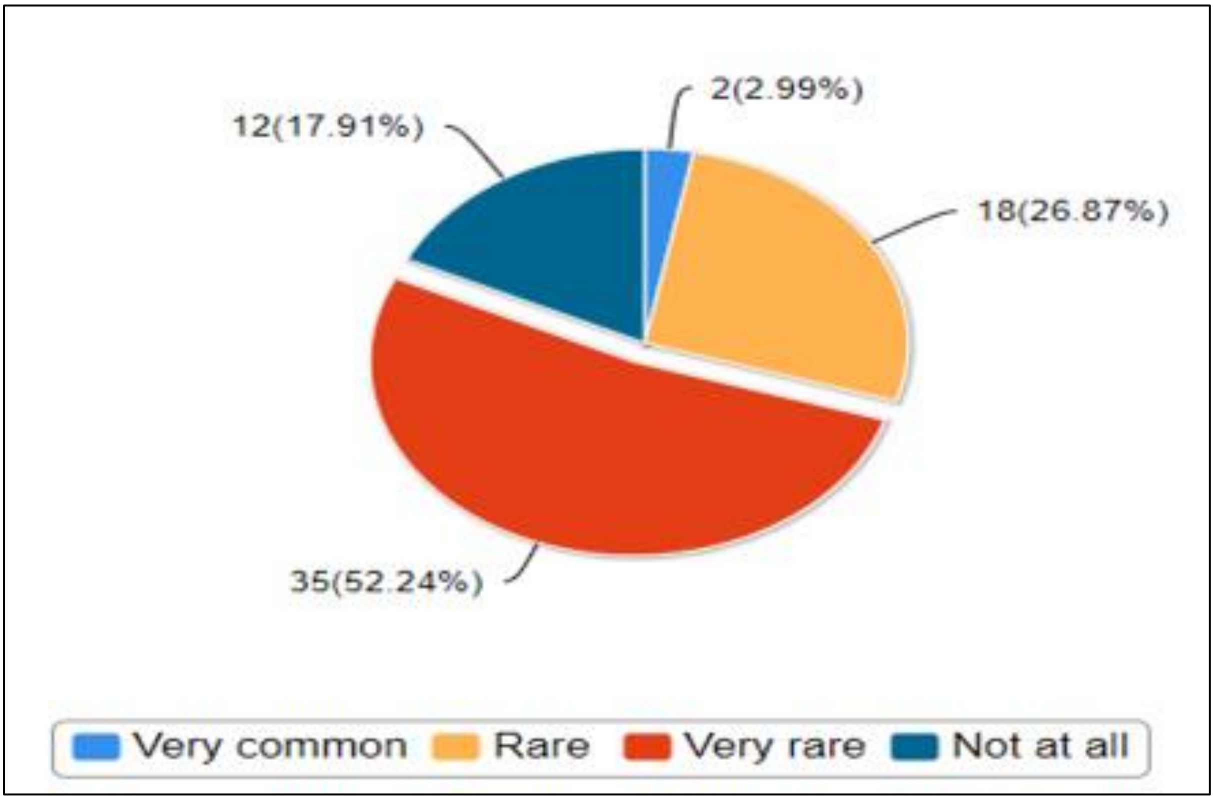

Figure 7.11: EV infrastructure accessibility in South Africa
Source: Author, based on the public survey, 2019

7.9 The future of electric vehicles in South Africa

To assess the future of electric mobility in South Africa, respondents were asked to give their opinion on the future of electric vehicles in the country. With all the hurdles outlined by the respondents in the earlier sections, many (62%) still believe that electric vehicles can be as successful as the normal conventional vehicles. Only 18% of the respondents do not believe electric vehicles can be successful, while 20% are not sure of the future of electric vehicles in South Africa.

7.10 Conclusion

The results of the analysis show an average likelihood that respondents will purchase an electric vehicle, though quite a number of the respondents are not yet sure of the electric vehicle technology. A large number of unsure responses indicate the level of public education needed in the country. The most appealing attributes of electric vehicles over conventional vehicles include their emission-free nature, environmental friendliness and freedom from fossil fuels as a nation and consumers.

The technological advantages of electric vehicles over conventional vehicles as identified come with some challenges, especially to the early adopters in South Africa. Some of these challenges are the high purchase price, limited charging infrastructure, shorter travel range and longer charging times. Others include the lack of local technicians and an unreliable supply of electricity in South Africa. Contrary to the range anxiety, a greater percentage of the respondents are found to travel within the current range of the available electric vehicle models per return trip per day. And range would not be a challenge if charging infrastructure were readily available at homes, shopping malls and workplaces.

Furthermore, supercharger facilities at public charging stations will be more preferable to the respondents since a greater number of the respondents are willing to wait a maximum of thirty minutes to recharge their electric vehicles, which is in line with the current supercharger capacity. The fast-charging strategy that seems more appealing to the respondents is battery swapping, which is currently applicable only to buses. However, the respondents had mixed feelings about the idea of battery rental as a strategy to reduce the initial cost of electric vehicles.

The results show that the highest price of fossil fuel that can possibly persuade respondents to buy an electric vehicle instead of a conventional vehicle is when a litre of fuel reaches a maximum of R25. Other persuasive situations according to the respondents include when the purchase prices of electric vehicles and conventional vehicles are equal and when charging stations become as common as fuel stations. Charging infrastructure is a real challenge in South Africa, and that is contributing to the snail’s pace of electric vehicle uptake. Despite all these challenges, however, the electric vehicle market has a bright future in South Africa because technology has instant benefits for now and the future.

Chapter 8: Analysis of findings

8.1 Introduction

The preceding four chapters analysed in detail the data gathered from the cost model, experts and public surveys in relation to electric vehicle development, challenges and opportunities as well as the ownership cost comparison between electric and conventional vehicles in South Africa. The total sample size of 112 respondents used in this study may not be representative of the entire population of South Africa; however, it provides helpful insights into the perceptions and preferences of electric vehicle technology-minded individuals in the country. This chapter will now discuss the global development of electric vehicles and the driving forces behind their development. Other sections outline the findings from both expert and public surveys and the modal cost calculation, after which the main findings are discussed.

8.2 Global EV development

The relevant literature reviewed and the survey conducted show exponential growth in EV technology globally. Some leading countries in the uptake of EV include Norway, China and the US. Most of these countries have plans to completely ban the use of conventional vehicles or have set strict regulations to discourage their use. Figure 8.1 indicates the global short-term and long-term passenger EV adoption by region. It can be seen that China, Europe and the US are currently the global leaders in the uptake of EV technology. The earlier chapters indicated that the global transition to electromobility is happening rapidly. To avoid the negative impact of the transition, developing countries such as South Africa have to join in the transition process.

Current figures of EVs in South African are far lower than expected compared to what is happening globally. For the country to catch up with the rest of the word as far is EV technology is concerned, it needs to intensify its policies, educate the public and create an enabling environment for mass uptake to meet its sustainability targets while catching up with the global rate of development. The findings show that electric vehicles are well placed to vary the energy mix in the current global transport system, which is predominantly based on fossil fuel, the mass uptake of EVs in South Africa is necessary to meet the country's sustainability targets, improve daily comfort for city dwellers and deliver climate change-related benefits for future generations. This is possible due to the immediate benefits EVs provide to the quality of life, climate and the environment (EVIA, 2017).

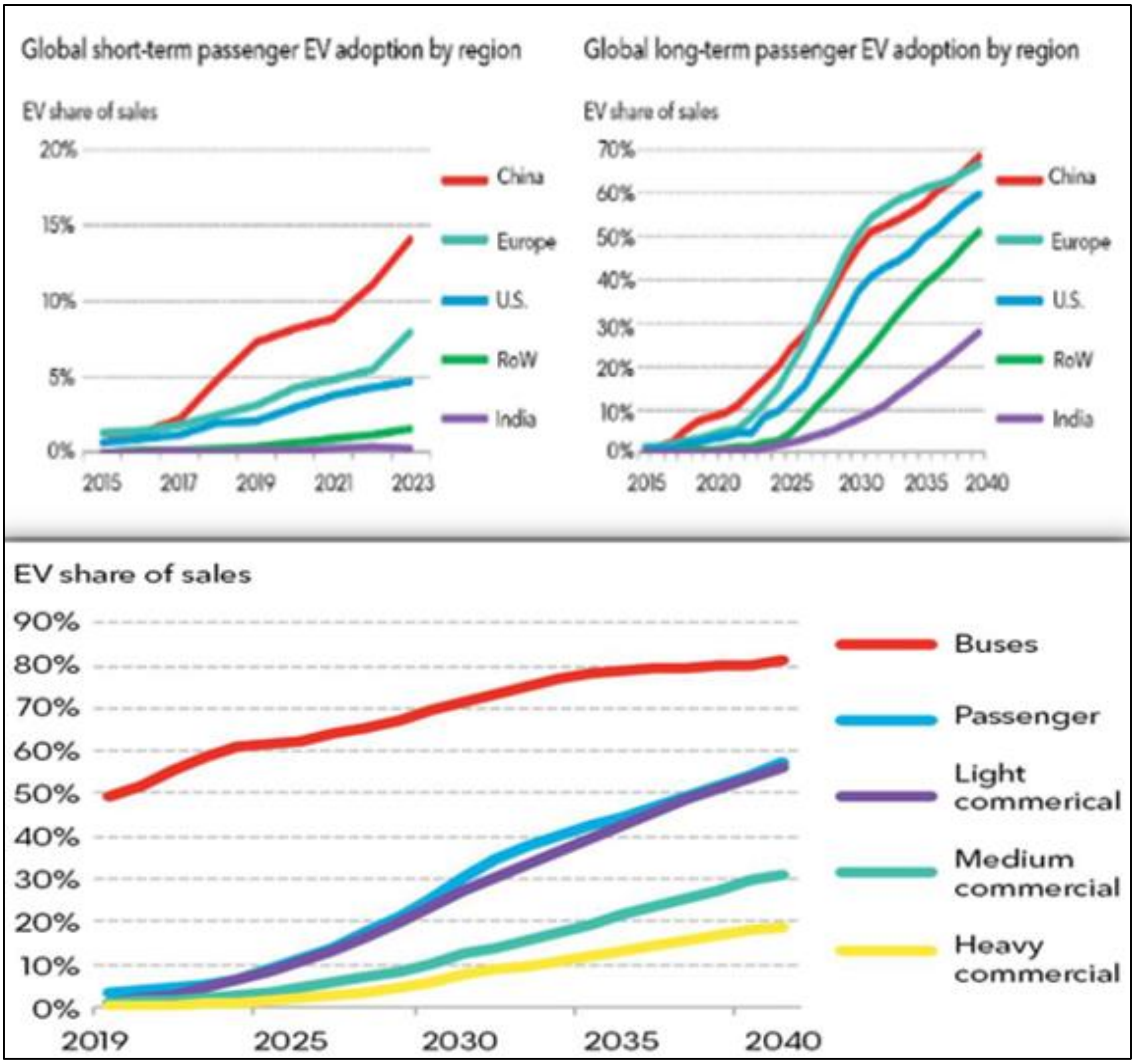

Figure 8.1: Global EV development
Source: Bloomberg NEF 2019

8.2.1 The driving force behind EV development

There are a number of factors behind the global deployment of electric vehicles. The recent soaring oil prices, fuel shortages, greenhouse gas emissions and the impact of climate change are some of the driving forces behind the rapid growth in the EV market. These have resulted in the formulation of tighter limits on carbon emission, and incentive packages for carbon-free vehicles as conceded in the previous chapters of this study. For instance, the findings indicate that several policy changes in many countries such as China, the European Union and India that focus on de-incentivising the use of conventional vehicles, have resulted in the rapid growth of electric vehicles in those countries.

On the other hand, various incentive schemes for electric vehicle users such as tax relief, cash-backs and free-toll initiatives in many countries are supporting the mass adoption of electric vehicles in those countries. unfortunately, South Africa does not have any incentive or supporting policy in place to induce adoption.

8.3 Findings from the expert survey

Based on the analysis of the experts' views, several cost factors are seen as potential challenges to the uptake of electric vehicles in South Africa. The most significant ones include purchase cost, overhead cost, maintenance cost, charging cost and depreciation cost of electric vehicles. Strategies such as the provision of capital subsidies on electric vehicle retail prices, reduction in import tariffs, and subsidization of electricity cost are seen to be some possible ways to relieve the cost burden on electric vehicle early adopters.

Comparatively, many cost components of electric vehicles such as the purchase cost and insurance cost are currently much higher than those of conventional vehicles, but these costs are perceived to have the potential to equalize or become much lower in the next five years due to economies of scale and technological development. Currently, due to the high initial cost factor, unfavourable policies such as high import tariffs and lack of proper electric vehicle information have resulted in low uptake of electric vehicles in the country. The high initial cost factor of the electric vehicle has also led to the high ownership cost compared to conventional vehicles, but as the technology keeps on improving, the ownership cost could become equal or even less.

The study shows that EV innovation and adoption have immense health, environmental and economic benefits. Other opportunities to benefit include a decrease in national dependency on fossil fuel, improvement of urban air quality and stimulation of technological innovation. Electric vehicle technology is not seen as a threat to road infrastructure development and employment, but as an opportunity to improve human health, the quality of life and growth in the economy of South Africa.

8.4 Findings from the public survey

The results from the data analysis of the public survey show an average likelihood of respondents being willing to purchase electric vehicles, though quite a number of the respondents are not yet sure of the technology. A large number of unsure respondents and the limited participation of the generation of so-called technology enthusiasts (youth) indicate the level of public education needed in the country. The study reveals that a greater proportion of consumers have heard of the various types of electric vehicles and the most appealing attributes of electric vehicles over the conventional vehicles, namely their emission-free nature, environmental friendliness and their potential to free the nation from foreign fossil fuels.

The technological advantages of EVs over CVs as identified come with some challenges, especially to the early adopters in South Africa. Some of these challenges are the high purchase price, limited charging infrastructure, shorter travel range and longer charging times. Others include lack of local technicians and unreliability of the national electricity grid. Contrary to the reasons for range anxiety, the findings show that the majority of South Africans travel within the current range of the available EV models, and range would not be a challenge if charging infrastructure were accessible within the communities and the public places. The study confirmed that limited charging infrastructure remains one of the main challenges, as charging facilities are currently very rare in South Africa, which is contributing to the slow pace of electric vehicle adoption and uptake.

When it comes to charging points, supercharger facilities at public charging stations will be more preferable, as shown by the willingness of potential consumers (the respondents) to wait at a charging station. The consumers are willing to wait for a maximum of thirty minutes to recharge their EV, which is within the current super charger's capacity. Another fast charging strategy that seems more appealing is the battery swapping idea, but the idea of battery rental as a strategy is less appealing – perhaps because of consumers' experience with cell phone contracts. Recent fuel price fluctuations could be a factor that could stimulate the public to switch to EV technology, as the findings indicate that R25 per litre of fossil fuel could persuade the majority of consumers to buy EVs instead of conventional vehicles.

Despite the cost challenges associated with EV technology, it is perceived to be the greener form of transportation, environmentally friendly and a possible technology that could free the country from crude oil dependence while improving urban air quality for the present and future generations. The findings also confirm that sustainability influences a number of consumers' vehicle purchase decisions, which can positively impact EV adoption in South Africa. However, a greater number of consumers will be willing to buy electric vehicles instead of conventional vehicles on condition that the purchase price of electric vehicles and conventional vehicles are equal and charging stations become more accessible – just like the fuel stations. The respondents conceded that though the uptake is slow, the electric vehicle market has a bright future in South Africa because of the massive opportunities it provides for both individuals and the nation as a whole.

8.5 Findings from modal cost calculation

This section of the study shows that cost components vary over vehicle type and purchase price; the greatest cost to the South African consumer according to the model cost calculation has been the vehicle depreciation, insurance cost, cost of capital, overhead cost and fuel cost for conventional vehicles. These are most distinct for battery electric and hybrid vehicles due to their higher initial purchase cost, and a lower running cost compared to the conventional vehicles. Depreciation and insurance featured as the most costly components followed by the cost of capital for all the vehicle types, while annual fuel cost contributes a greater percentage of the vehicle ownership cost for conventional vehicles and overhead cost for the electric vehicles respectively. Although the link between ownership cost of electric and conventional vehicles and adoption has been the focus of this section, it is not the only factor in vehicle purchase decision making.

The results further indicate that the insurance cost of electric vehicles is currently higher than that of conventional vehicles, because of a lack of auto parts as well as technicians to work on the vehicles when the need arises. Due to the difficulty in determining exact price structures for electric vehicle insurance due to their high initial cost, scarcity of parts and lack of technicians, many popular insurance companies in South Africa do not insure electric vehicles at all. It was established in the modal cost calculation that the running cost of electric vehicles is cheaper than that of conventional vehicles, but with a higher ownership cost premium. Specifically, the hybrid electric vehicle has a high annual ownership cost, followed by the battery electric vehicles, and with the conventional vehicle being the cheapest. The main contributing factor in this high ownership cost scenario is the high initial cost of the electric vehicles compared to that of conventional vehicles. The findings emphasize that low emission vehicles are associated with a higher price premium, which cannot be offset only by lower running costs but a combination of lower running cost and other incentives such as a reduction in import tariffs and cash incentives for electric vehicle purchasers. This can make EVs more competitive if not cheaper than the conventional vehicles in the automobile market.

8.6 Main findings of the study

The study establishes that EV technology comes with many technical and perception barriers as well as opportunities. The following sections illustrate the main findings of the study in relation to the research aim and objectives.

This study shows the results to support the uptake of electric vehicle technology and the consumers' perception by using basic statistical analysis. More research is needed to evaluate potential electric vehicle users' behaviour for the mass uptake of electric vehicles in South Africa. However, the results indicate that environmental awareness and national fossil fuel security or independence has a significant influence on consumers' preference for electric vehicle technology. This implies that public education on environmental, health and economic benefits of electric vehicles and public policy from the government can improve mass adoption. It is also consistent with previous findings that a country's environmental awareness influences its citizen's adoption behaviour.

The statistical analysis shows that respondents have a strong willingness to adapt to the electric vehicle technology regardless of the challenges early adopters are bound to face in the country. The greatest challenge is around the initial cost and access to charging infrastructure. There are other concerns such as maintenance, insurance and depreciation costs; however, the advantages of electric vehicles accounted for a higher percentage. It can be inferred that if consumers can have sufficient knowledge and opportunity to experience the advantages of electric vehicles, there can be a significant rise in willingness to buy and the mass uptake of electric vehicles in the country. This is consistent with the literature that the initial cost price of electric vehicles is a critical barrier to their adoption.

This implies that cost reduction and incentive policies initiated by governments such as price reduction on electric vehicles can affect consumers' willingness and uptake of electric vehicles. This is confirmed by the sensitivity analysis done in this study that a reduction in cost factors such as import tariffs, insurance cost and increasing fuel cost has a significant impact on the ownership cost and competitiveness of electric vehicles. Furthermore, government support and charging infrastructure development are critical factors to the mass uptake and adoption of electric vehicle innovation.

8.6.1 Adoption barriers

The study ascertains that many challenges are associated with the mass adoption of electric vehicles. These challenges can be a mixture of two or more of the following factors, which include social, infrastructural, technological, economic and political factors.

8.6.1.1 Social barriers

The findings illustrate that consumers perceive charging an electric vehicle to be inconvenient and are only willing to wait less than thirty minutes to recharge at a public charging station, which currently can only be done by supercharger point. This is because conventional vehicle drivers are used to driving long distances or for many days before refuelling their vehicles. However, with electric vehicles, consumers probably have to take a long time to charge their vehicles for a short distance of driving or charge at home every day. Nevertheless, many potential electric vehicle adopters may see home charging as attractive and cheaper, but a lack of charging facilities may make these hopes difficult or impossible to fulfil for early adopters in South Africa.

Secondly, the range limitation of electric vehicles compared to conventional vehicles may force many consumers to adapt to alternative ways of public transportation such as trains, buses, metered taxis and aeroplanes for longer distances, and use electric vehicles for their short distance commutes. Many consumers may find such habits difficult to change and to adapt because of the ill state of the country's public transport system.

8.6.1.2 Infrastructure barriers

As seen in the preceding section, many consumers may find certain habits difficult to change and adapt to and the lack of charging infrastructure both at home and public places remains a hurdle that is difficult to overcome. This confirms the findings of previous studies that the mass uptake of EVs depends on the accessibility of charging infrastructure at home, in the community and at the workplace. This is negatively affecting consumers' willingness to purchase electric vehicles instead of conventional vehicles. The findings show that consumers are more willing to buy electric vehicles on condition that charging stations become as accessible as fuel stations in South Africa. However, the current local developments headed by Jaguar Land Rover South Africa in partnership with electric vehicle charging authority GridCars may eliminate this challenge.

8.6.1.3 Technological barriers

Many consumers still doubt the technology of electric vehicles, especially with regard to travel range and charging time. A large proportion of consumers are not willing to purchase electric vehicles unless the travel range and charging time improve. This further indicates that the long charging time of electric vehicles, particularly pure battery electric vehicles (BEV) makes them less attractive to many consumers. This challenge has resulted in low customer value for the EVs but the ongoing technology improvement will have much impact on consumers' decisions, especially in the areas of battery performance since it is a key component and cost factor in the total cost premium. Moreover, the charging technology with regards to fast chargers is being improved significantly, with the current fast charger being able to charge 80% of the electric vehicle's battery within twenty minutes.

8.6.1.4 Economic barriers

In economic terms, the purchase price of an electric vehicle is the main cost factor identified as being the most discouraging cost component. Other cost components include overhead cost and maintenance cost. The study ranks purchase price and maintenance cost of an electric vehicle as to the highest cost factors, while the cost model calculation in Chapter 5 had vehicle depreciation and insurance as the highest cost factors. It can, therefore, be concluded that the top four cost components in the ownership cost of an electric vehicle are the purchase cost, maintenance, depreciation, insurance and capital costs. However, the study indicates that these high-cost factors of electric vehicles will be equal to or much lower than those of the conventional vehicle in future when local manufacturers start to produce electric vehicles and their accessories in South Africa, and government incentivizes the electric vehicle market. The findings of this study also confirm that electric vehicle adoption will not have any negative impact on government revenue towards the country's roads infrastructure and maintenance, despite the fact that fuel taxes are a source of revenue for running and upgrading transport infrastructure and operations in South Africa.

The previous studies agree that educating consumers on vehicle ownership cost could help increase electric vehicle adoption, because consumers may be able to compare their saving against the costs when making their purchase decisions. Comparing the cost of ownership between the electric and conventional vehicle in South Africa, the results showed that electric vehicles have a very high ownership cost compared to conventional vehicles. The BEV, HEV, PHEV are known to have a high purchase cost, resulting in high ownership cost compared to the conventional vehicles. On the other hand, electric vehicles have a lower running cost than conventional vehicles at the current cost of electricity and fossil fuel in South Africa.

However, the cost of ownership is sensitive to some cost factors such as import tariffs, insurance rates and fuel costs. Generally, the greater the discount rates of these variables the greater the variation in cost between the hybrid, battery and conventional vehicles. The sensitivity analysis suggests that a reduction in import tariffs on an electric vehicle has a significant influence on ownership cost and its competitiveness in the automobile market. For instance, in a situation where there is no import tariff on electric vehicles, the conventional vehicle becomes less competitive, with a very marginal cost difference (R3868=0.0007%) in annual ownership cost between the electric and conventional vehicles. Therefore, any form of cost reduction such as in import tariffs, the carbon tax, finance cost and luxury tax will have a significant effect on electric vehicle costs and can lead to mass adoption in South Africa. This implies that if electric vehicles can be financially incentivized, they can become more competitive and even cheaper than conventional vehicles.

The analysis further showed that the cost of fuel has a greater influence on electric vehicle uptake because the high cost of fossil fuel makes consumers look around for alternatives. Also, as the price of fossil fuel increases, the running cost of conventional vehicle increases and the demand for alternative energy sources also increases. The study further revealed that a greater percentage of consumers would be willing to buy electric vehicles if the cost of fossil fuel per litre reached levels as high as R25 or more. Therefore, anything – be it political or non-political – that keeps the fossil fuel price low or high will have a concomitant negative or positive impact on the electric vehicle adoption rate.

8.6.1.5 Political barriers

The study established that electric vehicle uptake in South Africa is very slow due to a lack of consumer education, an unfavourable electric vehicle market environment and low level of government policy support systems. The support systems identified to have an influence on the adoption process include financial incentives, tax reliefs, reduction in import tariffs on electric vehicles and tight regulations regarding carbon emissions. Such support systems are dependent on government actions that could increase or decrease electric vehicle adoption. The results further outlined that a capital subsidy on retail prices and subsidization of electricity cost are some of the best strategies that could be implemented to help make the electric vehicle market more competitive and attractive in South Africa. To promote the mass uptake of electric vehicles the literature reviewed advocates that government intervention in the promotion process is necessary for many actions, such as the laying down of regulations. The previous studies further indicate that the global electric vehicle deployment targets in countries such as China, US, Germany and Norway have been complemented by restrictions on conventional vehicles. Therefore, the government's involvement in electric vehicle adoption, regulation and provision of market incentives is indispensable.

8.6.1.6 Africa specific issues

In as much as electric vehicles are environmentally friendly and come with many advantages over conventional vehicles, previous studies suggest that governments around the world, especially in Sub-Sahara Africa, probably see them as a threat to their sources of revenue. However, the findings of this study disagree that electric vehicles will have a negative impact on government revenue towards the country's roads infrastructure and maintenance. Regardless of the fact that fuel taxes are the source of revenue for running and upgrading transport infrastructure and operations in South Africa, the results indicated that consumers see the advantages of electric vehicles to far outweigh those of fuel taxes. Nevertheless, the affordability of electric vehicle technology in Sub-Sahara Africa and for that matter ordinary South Africans is the main challenge. Moreover, due to the high-cost premium, many consumers perceive an electric vehicle to be a luxury vehicle designed for a group of people within the high-income bracket.

8.6.2 Opportunities for electric vehicles

As every new technology comes with challenges and opportunities, electric vehicles are known globally to have many more benefits than the rival internal combustion engine vehicles; however, the results of the study identified several reservations towards electric vehicle opportunities in South Africa. The general consumer attitude towards electric vehicle opportunities was neither entirely positive nor entirely negative; there were no completely negative attitudes towards electric vehicle technology. Some positive opportunities that the study identified include a decrease in the country's dependence on fossil fuel, fostering of economic development by lowering transport costs, stimulation of innovation in entrepreneurial skills and lowering carbon emissions into the environment.

Evidence provided in the study points to the need to educate the public on the opportunities and benefits electric vehicle technology can offer. It also confirms that more investment in cheaper and readily available renewable energy sources such as solar and wind is an opportunity to support the mass uptake of electric vehicles. These findings reaffirm those of an earlier study that the country's large share of renewable energy sources and its citizens' environmental awareness make it suitable for the large-scale uptake of electric vehicles.

8.7 Conclusion

Generally, consumers' attitudes toward EV opportunities are neither wholly positive nor wholly negative. The study identified the need for public education on opportunities such as cleaner urban air, crude oil independence, environmental friendliness and the cheaper running cost of electric vehicles as an essential tool for mass adoption. It confirmed that more investment in infrastructure development, especially in the areas of renewable energy sources such as solar and wind, is needed to support an inclusive uptake of electric vehicle technology in South Africa.

The results further showed the main ownership cost components to include depreciation, insurance cost, cost of capital, fuel cost in the case of a conventional vehicle and overhead costs for all vehicle types. The findings indicated that comparatively, electric vehicles have high ownership cost and lower running cost than the conventional vehicles. It needs to be emphasized that the higher price premium associated with electric vehicles cannot be offset by lower running costs only but by a combination of lower running cost and other financial and non-financial incentives such as tax reliefs, cashback, free parking and free tolls.

Chapter 9: Conclusion and recommendations

9.1 Introduction

The former chapter analysed the findings of the study in relation to the research aims and objectives. This chapter draws the conclusion of the whole study and also discusses if the study meets the research objectives and answers the research questions. It further addresses implications for policy recommendation as well as recommendations for further research.

9.2 Conclusion

While there are still uncertainties on how to integrate electric vehicle innovation with the existing conventional vehicle technology and infrastructure development in the most sustainable way, the uptake has experienced steady growth in South Africa. The country has many features such as renewable energy sources and road networks that make it suitable for electric vehicle market uptake. However, the lack of solid government support in the form of incentive programs and other barriers have resulted in the country's lagging behind in the global mass adoption of electric vehicle technology.

In order to tackle the potential perception barriers to electric vehicle uptake, a survey among experts in the transport sector and among the public was used to gather information for the study. The study further compared the cost of electric vehicles with that of conventional vehicles to ascertain the cost-effectiveness of the two types of vehicles. The questionnaires included in the survey were aiming to collect respondents' basic information, cost components of electric vehicles, challenges and opportunities potential electric vehicle owners might face.

The sample population used in this study was limited and may not be fully representative of the entire population; however, the results can be used to understand the electric vehicle market and also provide helpful insights into potential barriers and opportunities of electric vehicle technology in South Africa.

The study showed that the rapid global deployment of electric vehicles is necessary to meet sustainability targets because electric vehicles provide immediate benefits for air quality due to zero-emission and reduced noise levels. For that reason, electric vehicles can be the best way to vary the energy mix in transport, which is currently dependent on only foreign fossil fuel. Furthermore, the findings suggested that although the environmental benefits and sustainability of electric vehicles have a major influence on electric vehicle adoption, they are ranked behind the initial cost of the electric vehicle in this country. This means the general public's interest in electric vehicles is seriously affected by the current purchase price of the vehicle, resulting in several reservations expressed by consumers towards EV adoption.

In general, consumer perception of electric vehicle adoption is neither completely positive nor negative. This is due to their lack of proper information and awareness of EV technology. However, the minimal negativity towards the technology that was detected, cannot be ignored. Evidence revealed in this study accentuates the need to address the perception and technical barriers faced by EV technology in South Africa. As previously alluded to, some major challenges faced by EV adopters in South Africa include high initial cost, limited charging infrastructure, battery technology and lack of a government support system; however, consumers' acceptance of the technology is very important as it is the key to the general success or failure of the EV technology, even if the other concerns are taken care of.

Other potential barriers to the uptake of EVs that were detected include high maintenance cost, cost of capital, overhead cost and insurance cost. While some of these challenges may be attributed to lack of maintenance technicians and long charging times, others may be as a result of unfamiliarity with EV technology and the fact that several individuals and insurance companies in South Africa are not yet convinced that EVs are a better option than the conventional vehicles.

From an environmental point of view, the study showed that EVs that are charged using renewable energy are the greener form of transportation compared to those charged from sources such as coal. The fact that South Africa still relies on coal for power allows some consumers to question the sustainability and environmental friendliness of EVs compared to conventional vehicles. Those with this uncertainty may not consider the purchase of an EV to be as beneficial to the environment as it is supposed to be. The energy sector in South Africa will have to work towards a greener, the cleaner and more sustainable energy source to help promote green transportation in the country.

From a policy perspective, EV uptake will require inclusive policy support systems to accelerate the adoption process in a way that will suit every. race and class of South Africa's consumers through the provision of incentives, tax breaks and a reduction in the high import tariffs on EVs and their accessories. These policy support mechanisms may have little effect on EV uptake with the current nascent nature of the market, and if the low interest in EV technology in South Africa is not addressed. However, consumer education could address this barrier, such that potential vehicle purchasers could assess their savings against the costs. Public education will break down the technological, social, economic, and political resistance forces created by developments in the conventional vehicle market for the past decade. Automobile industries and policymakers can use media and social networks to positively influence the public's appreciation and mass adoption of EV technology. When these barriers are dealt with, the consumer's attitude and willingness will automatically increase.

The study confirmed that capital investment in the development of EV charging infrastructure at homes, workplaces and public places such as malls and parking lots is needed to help eliminate charging time and range anxiety challenges. Accessibility of charging infrastructure at these places can alleviate the current range anxiety and adverse perceptions regarding long charging times because EVs can then be charged while parked at home, the workplace or at shopping centres. In that case, the electric vehicle's recharging may be more flexible than a conventional vehicle's refuelling, because it can be charged while the user is busy elsewhere and the vehicle is standing idle.

From an economic perspective, electric vehicles will have a significant impact on the way people travel which may affect the transport expenses of households such as higher capital outlays but less fuel and maintenance charges. What is less well understood is the impact on the road generated revenue, or the fuel tax and other charges based on fuel use.

The results revealed that the potential electric vehicle adopters in South Africa could be predominantly middle-aged males within the middle-high income group. Not only can these individuals afford electric vehicles, but they also have a general interest in environmental issues and sustainability considerations will affect their vehicle purchase decision making. Although electric vehicles are currently more expensive to buy, they are cheaper to operate than the conventional vehicles hence they can be cost-effective to a consumer with an average daily travel range of 150 km per return trip. The current distance of between 30 km and 150 km per day driven by a potential South African electric vehicle owner, could be used as a valid argument to reduce the range anxiety identified as a barrier to the mass uptake because they can charge their EVs overnight at low cost (off-peak) using the home charging option. Their high annual kilometres make the use of electric vehicles the best option in environmental and economic terms. Moreover, with the introduction of smart grid technology, EV owners can use their vehicles to provide many services to the power utility at home. The vehicle to grid technology can provide uninterrupted power support for home and backup energy storage for home renewable energy sources. It can also be sold back to the energy utility company during peak hours.

The study also revealed that ownership cost components vary over vehicle type and purchase price; however, the greatest cost to the consumer has been the vehicle depreciation factor in all the vehicle types. This is most pronounced for BEVs and HEVs due to their higher initial purchase prices and lower running cost compared to the conventional vehicles. Insurance cost featured as the second-highest cost for all the vehicle types, while annual fuel cost contributed a greater percentage to the conventional vehicle. The other costs include the overhead cost and capital cost respectively.

Electric vehicles offer many environmental, health and economic benefits due to their low carbon emission and low pollution levels compared to conventional vehicles; however, their fleet share in the South African automobile market is too small to make any significant difference. In order to achieve an inclusive and sustainable use of electric vehicles, governments should focus on providing accessible charging infrastructure in public places such as malls and parking bays. Government support for low-emission vehicles needs to address the various technical and perception barriers to help the electric vehicle market break out of the niche automobile market in South Africa. The study showed that government support needs to be tailored towards the high initial vehicle cost, creation of public awareness and the relief of high import tariffs to create an enabling environment for the rollout of electric vehicles. These findings are important for policymakers, automobile industries and consumers in making mobility decisions in the country.

9.3 Did the study meet the research objectives?

The primary objective of the study was to unpack the barriers hindering the mass uptake of electric vehicles in South Africa, assess the opportunities for electric vehicle innovation and determine the ownership cost and the growth thereof.

The study confirmed that China, Europe and the US are currently the global leaders in the uptake of electric vehicle technology. A global transition to electromobility is happening rapidly due to inconsistent crude oil prices and concerns about climate change. To avoid the negative impact of the transition, developing countries such as South Africa need to join the masses in the transition process. Current figures regarding the use of electric vehicles on South African roads show that the country is lagging behind when compared to the rest of the world. The study recommends that for the country to catch up with the rest of the world as far as the use of electric vehicle technology is concerned, it needs to intensify its policies, educate the public and create an enabling environment for mass uptake in order to meet its sustainability targets. This satisfies the first objective and answers the research question of the study.

The second objective was to calculate and compare the ownership cost of electric, hybrid and conventional vehicles in South Africa. The cost model developed by the transport unit of Stellenbosch University's department of logistics was used in the study to calculate and compare the ownership cost of conventional, hybrid and pure electric vehicles. It was evident in the analysis and the discussion that the main ownership cost components include the vehicle depreciation cost, insurance cost, cost of capital, fuel cost for only conventional and overhead costs for both conventional and electric. The BEV, HEV, PHEV are known to have high purchase costs, resulting in a high ownership cost compared to the conventional vehicle. On the contrary, it was established that electric vehicles have a lower running cost than conventional vehicles at the current costs of electricity and fossil fuel in South Africa. The study further established that though the running cost of electric vehicles is much lower than that of conventional vehicles, the high initial cost factor balances that advantage. And as the ownership cost of electric vehicles remains solely on the shoulders of consumers, they will remain to have higher ownership costs than the owners of conventional vehicles have, unless government incentivizes the electric vehicle market. These analyses, therefore, take care of the second objective and answer the fourth research question.

Several barriers hindering the uptake of electric vehicle technology in South Africa were identified and can be categorised as being social, infrastructural and economic barriers, technological and political barriers. The opportunities of electric vehicle innovation identified included a decrease in the country's dependence on fossil fuel, fostering of economic development by lowering transport costs, stimulation of innovation and entrepreneurial skills, and lowering carbon emission into the environment. These findings accommodate the third objective and research questions two and three of the study.

9.4 Recommendations for policy consideration

To overcome the adoption challenges of electric vehicle uptake, governments should provide the policy framework, which includes subsidies and other tools to stimulate electric vehicle adoption. The study found that individual corporate players cannot win the game alone, but the whole ecosystem of partners coming together to define clearly the standards for an inclusive rollout strategy for the electric vehicle innovation, can succeed. These roleplayers include the government, investors, industries and consumers. The study suggests the following concentric model approach to the rolling out of electric vehicle technology in South Africa.

9.4.1 Concentric model approach

Figure 9.1 shows the concentric model approach, which puts the government as the pivot around which everything in the policy framework for electric vehicles adoption revolves. These policies include government regulations and incentives, without which mass adoption cannot happen. Everything that happens between spheres one to three depends on the need of the consumers (sphere 4), who form the majority in the system. This denotes that an inclusive transition in the transport technology cannot be effected without addressing the concerns of each stakeholder. Notably, there is a concentric point for all stakeholders, a point where the needs and decisions of each stakeholder depend on those of the others and none can function in isolation.

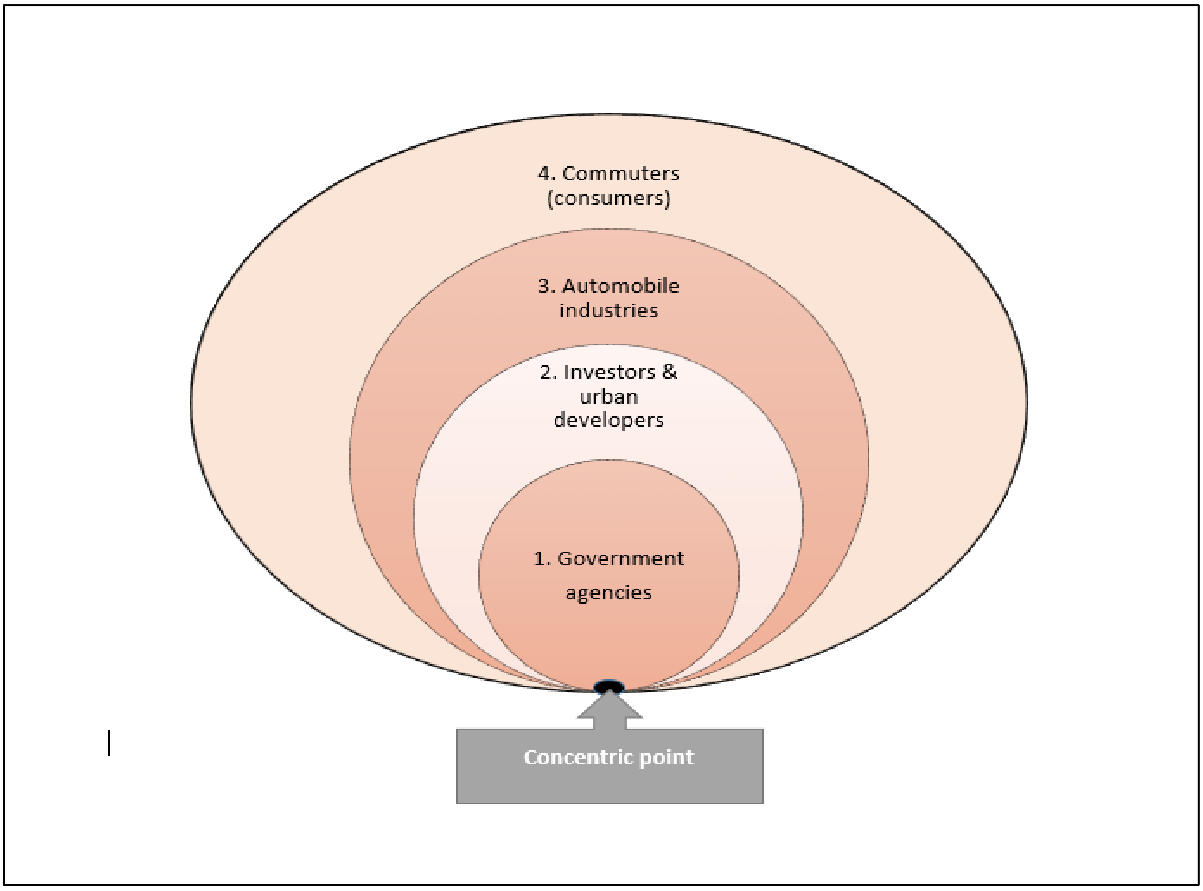

Figure 9.1: Concentric model

Source: Author, based on findings

9.4.2 What is the Concentric Model?

The Concentric Model is a model that explains the inclusive internal structure of electric vehicle adoption policy setting, with an arrangement of role players in a bottom-up series of rings. It is a model that describes the distribution of various role players in the electric vehicle adoption policy framework. The development of the model is based on the idea that electric vehicle technology starts from a central point and grows outwards to include a series of wider rings. Conspicuously, the order of the rings is constant, but their sizes change.

9.4.3 Model description

The sectors of the policy setting, according to the model, include the government at the centre, investors and industries within the inner circles as well as the commuters at the outer circle. The model implies that the extension of the policy structure begins from the central part, which is the government and its agencies such as the department of transport, energy and land. These form the small inner circle that holds all other circles or role players together at the concentric point, as shown in Figure 9.1.

The second inner circle is formed by the investors and urban developers who invest in transport infrastructure development, and town planners who make sure everything is situated at the right place to the convenience of the consumer. Next to that is the fourth circle which encloses the automobile industries, who provide the right quantity and quality of vehicles based on the policies and regulations instituted by the government in an enabling environment to satisfy the needs of the consumer.

The bigger sphere engulfs the general population of a country, who form the potential automobile market. As one moves further up from the concentric point, the size and the density of role players increase and the enabling authority decreases. There is also the tendency of a rise in individual satisfaction based on needs fulfilled and economic status enhanced.

9.4.4 The important features of the model

The key characteristic of the concentric model is that there is a positive relationship between the various role-players directly from the government who is more affluent through to the commuter who is less affluent, everyone has a decision to make in the uptake of the electric vehicle technology. This chain pattern of policymaking can bring about the process of “inclusivity” resulting in successful mass uptake of the innovation.

The development and uptake of the technology entail the transfer of growth pressure outwards to the successive commuters, who have mostly low socioeconomic status. Therefore, as the policies include them and growth expand towards them, their socioeconomic status improves together with that of those with high socioeconomic status.

9.5 Limitations and areas of further research

The sample used in the study may not be representative of the entire population of South Africa. Secondly, the assumptions used in the TCO calculations may have an effect on the results. The consumer-based ownership cost may not include the complete vehicle ownership cost. Many other factors such as brand reliability, doubt in new technology, family size and model colour come into play at the point of purchase. Other costs, such as the social cost of emissions and noise pollution have not been taken into account in this calculation. Although the study addressed a range of topics relating to electric vehicles such as barriers and opportunities, the cost of development and ownership cost, there are still more areas for future research that can be undertaken.

Future studies can be conducted on the safety of EVs and health benefits associated with electric vehicle adoption in South Africa. As mentioned in the introduction to the research, greenhouse gases claim millions of lives globally every year, and therefore knowing how many lives can be saved by opting for an electric vehicle can improve the uptake.

Similar studies could be done on the maintenance cost, frequency and resale value of EVs as well as the number of job losses and job gains in the country. This will help to understand the real costs and benefits of electric vehicles. Information on the spillover effects of electric vehicle adoption on South Africa’s economy is necessary to help policymakers formulate policies that could improve mass adoption. It will be interesting to extend the study to the current challenges in the country, such as load shedding in South Africa. Will the integration of electric vehicle smart grid technology alleviate South Africa’s electricity crisis?

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Appendices

1. Insurance quote Discovery

Discovery Insure

Discovery Insure Quote Schedule

Plan number 4001678906

Plan type: Essential

Quote date: 17/08/2018

Quote effective date: 17/08/2018

This quotation is valid for 60 days from the quote date. Please check all of the information contained in this document and advise us of any changes immediately.

Planholder details

Planholder	Mr Benson Manu	**Planholder type**	Natural Person
Identity/passport number	7306305929188	**Date of birth**	30/06/1973
Gender	Male	**Occupation**	Business Owner
Residential address	F4, ROYAL STREET, PONGOLA A, Pongola, Kwazulu-Natal	**Postal address**	
Previous insurer	Previously uninsured	**Number of years un-interupted comprehensive insurance**	Less than 1 year/Never been insured.
Have special terms and conditions been imposed or has cover ever been refused or cancelled for you or anybody that will have cover on this Plan?		No	

Payment method and banking details for premium collection

Account holder		**Account number**	*******
Financial institution		**Account type**	
Branch name and code		**Monthly debit day**	

Financial adviser on record

Discovery Connect Distribution Services Pty Ltd is an authorised Financial Services Provider.

DISCLOSURE OF ALL RELEVANT FACTS

- I declare that I have accurately disclosed all important information and facts. I agree to disclose any other important information to Discovery for the duration of my insurance contract with Discovery Insure.
- I agree that it is my responsibility to make sure that all information provided by me or on behalf of me, is accurate.

Quote Number: 4958397 Page 3

Rate date: 17/08/2018

Summary of cover

Cover section	Details	Plan details	Sum Insured	Premium
Motor vehicles	**Primary driver:** Benson Manu TOYOTA, COROLLA 1.6 PRESTIGE	**Effective date: 17/08/2018** Comprehensive (Motor)	Market value	R1 917.53
Benefits included at no cost	24-hour emergency roadside services			R0.00
SASRIA				R2.02
Vitalitydrive				Not selected
Total due monthly				**R1 919.55**

Value added tax (VAT)

All premiums and sum insured amounts include VAT at 15%. This document serves as a VAT invoice if all premiums are received.

2. Insurance quote King Price

Waterkloof Glen XII, Pretoria, 0181
PO Box 284, Menlyn, 0063
T +27 12 001 0800

Executive Directors: G Galloway, RJP Finch, JH Huyser
Non-Executive Directors: G Radley, LL van der Nest, NJ Viviers, PH Faure

King Price INSURANCE

Quote summary

13 Aug 2018

Congratulations Benson
It's with great pleasure that the king and I present this quote to you

Name Benson
ID no. 7306305929188
Quote no. 7491220
Phone no. 0719223559
Email obour.manuc@gmail.com

Summary of your insurance cover

Insured items	Premium
Car/s	R 5,647.19
Motorbike/s	R 0.00
Trailer/s	R 0.00
Caravan/s	R 0.00
Home contents	R 0.00
Buildings	R 0.00
Portable possessions	R 0.00
Personal liability	Included
The king's emergency assistance	Included
Sasria	R 2.02
Total monthly premium due	**R 5,649.21**

Please note:

- The premium amount is 15% VAT inclusive.
- The above quote is valid for 30 days only.
- King Price is an authorised financial services provider (FSP no. 43862).
- Only comprehensive car insurance premiums decrease monthly.

Don't forget that we automatically DECREASE your comprehensive car insurance premium every month... Saving you even more! Give us a call to accept your quote and join our royal family now!

0860 50 50 50

3. Insurance quote Outsurance

RISK SUMMARY: PERSONAL

Previous Insurance History	
Currently covered	NO
Cover duration	3-5 YEARS
Previous insurer	DIAL DIRECT
Previously cancelled	NO
Cancellation reason	NONE

Item	**OUTsured Value**	**Excess**	**Premium**
VEHICLE			
2017 BMW I3 (94AH) (INTRO 2017-01) TBA			
Required Cover: COMPREHENSIVE	RETAIL	R4,420.00	R5,326.31
Additional Cover Options			
RADIO	R2,000.00	R750.00	R7.21
CD SHUTTLE			OPTIONAL
MISCELLANEOUS SPECIFIED ACCESSORIES			OPTIONAL
CREDIT SHORTFALL			OPTIONAL
CAR HIRE			OPTIONAL
HELP@OUT MEDICAL & LEGAL			OPTIONAL
OUT-IN-AFRICA COVER			OPTIONAL
EXTENDED LIABILITY			OPTIONAL
HELP@OUT TRAUMA SUPPORT AND HIV CARE			OPTIONAL
EXTENDED TERRITORIES			OPTIONAL
VEHICLE SOLD ON YOUR BEHALF			OPTIONAL
BUSINESS USE OUTSIDE SOUTH AFRICA			OPTIONAL
			R5,333.52

MONTHLY Premium	**R5,333.52**
Administration Fee	**R14.10**
Total MONTHLY Premium	**R5,347.62**

SASRIA cover is automatically included.

An initial take-on fee of R325.00 is not included in the total premium.

Your premium is guaranteed for 12 months. This guarantee applies to all risks added at inception of the facility. Should you, for example, verify your quote/schedule and notice that you forgot to mention a previous claim to us - you have to advise us and the premium will be corrected. Similarly, if you, for example, advise us that your vehicle must be covered for business use but our advisor incorrectly captures private use - the premium will also be corrected when you advise us of the error. It is therefore essential for you to verify that all details noted on your schedule are correct for the 12 month premium guarantee to apply.

4. Insurance quote PMD

FIXED PREMIUMS FOR LIFE

PMD
Prime Meridian Direct

E info@primemeridian.co.za
T 011 745 7800
F 011 367 7288

PREMIUM ESTIMATE — **10 AUGUST 2018**

Dear Mr Manuk,

Thank you for allowing us the opportunity to provide you with a tailor made premium estimate. PMD would like to assist you to make an informed decision. Should you require any further assistance please do not hesitate to contact us and we will be delighted to assist you.

Kindly find your premium estimate as per your request below. Due to the dynamic nature of our pricing this estimate may change at any time.

PLAN	INSURED DETAIL	PREMIUM
Prime MotorTHRIFT	2017 NISSAN LEAF 5DR (47044150)	R 1 466.73
Prime Motor Assist Cross Sale	2017 NISSAN LEAF 5DR (47044150)	R 99.50

OVERALL PREMIUM — **R 1 566.23**

PRIME MOTORTHRIFT — **2017 NISSAN LEAF 5DR (47044150)**

- Write-off*
- Theft
- Hijacking
- Fixed Premiums for life
- No excess payable when you claim
- Third Party Vehicle Liability Protection
- Natural Fire and Natural Disaster
- Towing Extension
- Accident Contribution

*Terms and Conditions please download our policy pack **here**..

PRIME MOTOR ASSIST CROSS SALE — **2017 NISSAN LEAF 5DR (47044150)**

- Roadside assistance
- Autobody care and maintenance

*Terms and Conditions please download our policy pack **here**..

5. Vehicle A (electric)

Private car COST CALCULATION

	H Group NEW			
VEHICLE	**BMW i3 2017 (electric)**			
New				
	ASSUMPTIONS			Notes
	Replacement cost (VAT excl)	(R)	527000	1
4x2	Finance cost	(%)	9.50%	
	Depreciation	(Yrs)	5	
	Residual value	(%)	25.00%	
	Insurance (% of cost) OR	(%)	11.00%	2
	Insurance: Total (Rand/yr)		0	
	Licence (1000-1250kg - Tarra)	(R)	800	3
	Number of tyres	(No)	4	
	Price per tyre: New	(R)	800	4
	Price per tyre: Retread	(R)	0	
	Number of tyres (front)	(No)	2	
	Number of tyres (rear)	(No)	2	
	Tyre life (front)	(Km)	50000	5
	Tyre life: Rear	(Km)	50000	5
	Tyre life: Retread: Front	(Km)	0	
	Tyre life : Retread : Rear	(Km)	0	
	Number of steering axles	(No)	1	
	Number of other axles	(No)	1	
	Number of retreads: Front	(No)	0	
	Number of retreads: Rear	(No)	0	
			10	
Drivers	Number of	(No)	1	
	Monthly salary of driver	(R)	0	
Assistents	Number of	(No)	0	
	Monthly salary of assistant	(R)	0	
		(R)		
Overhead cost	Per year OR	(R)		
	% of fixed cost	(%)	7.00%	
Maintenance	% of Fixed cost	(%)	0.00%	
	% of Running cost OR	(%)	0.00%	
	Variable maintenance cost	(c/km)	19.55	6
Fuel/electricity	Usage (kwh/100km)	kwh/100km	30.2	
	Cost per kwh	(c)	154	7
Other variable operating costs		(R)	0	
Additional provision for tyres per year		(R)	0	
Average distance per return trip		(km)	80	
Average distance per single trip		(km)	40	
Return trips per day		(No)	1	
Working days per week		(No)	5	
Return trips per week		(No)	5	
Weeks per year		(No)	45	
Return trips per year		(No)	225	
Passengers per trip (return)		(No)	1.5	
Passengers transported per year		(No)	337.5	
Yearly kilometres		(Km)	15000	
Working days per year		(Dae)	200	

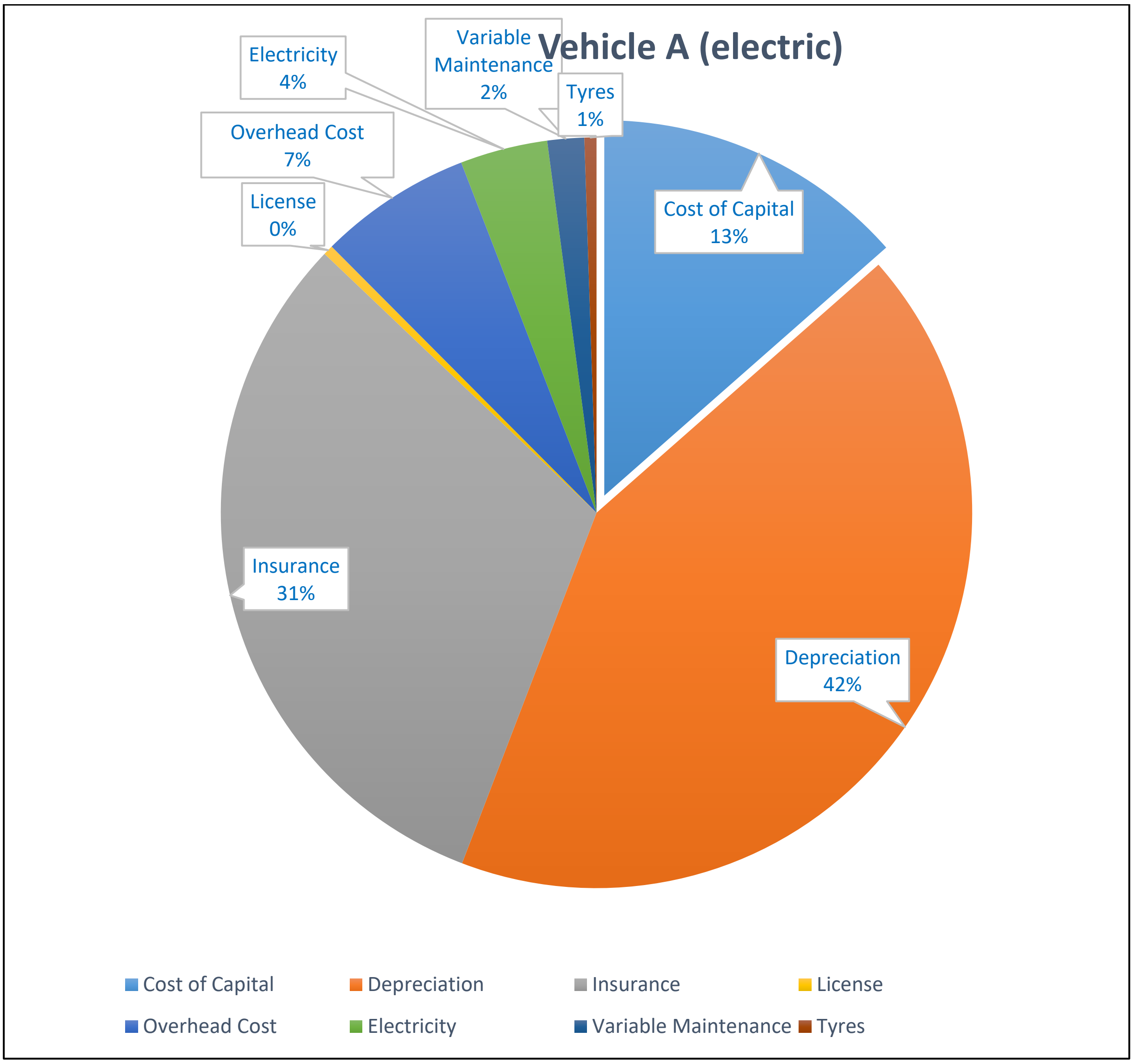
COST CALCULATION: SUMMARY

	(R/yr)	(C/KM)	(%)	(%)
Fixed Cost				
Cost of Capital	25,033	167	14.35%	13.51%
Depreciation	78,410	523	44.95%	42.32%
Insurance	57,970	386	33.24%	31.29%
Vehicle personel	-	-	0.00%	0.00%
License	800	5	0.46%	0.43%
Fixed maintenance	-	-	0.00%	0.00%
Overhead Cost	12,210	81	7.00%	6.59%
Total Fixed Cost R/yr)	174,422	1,163	100.0%	94.1%
Variable cost				
Fuel	6,976	47	64.19%	3.77%
Lubrication	-	-	0.00%	0.00%
Variable Maintenance	2,933	20	26.98%	1.58%
Tyres	960	6	8.83%	0.52%
Other	-	-	0.00%	0.00%
Total Variable Cost (c/km)	10,869	72	100.0%	5.9%
TOTAL COST	185,291	1,235		100%

Single trip distance	40			
Return trip distance	80			
FIXED COST PER DAY	872.11	Total costs		
FIXED COST PER YEAR	174422.04	Day	Week	Month
TOTAL COST PER YEAR	185290.74	R 508	R 3,554	R 14,214
RETURN TRIP LEARNERS P/YR	338			
TOTAL COST: RETURN TRIP	**930.08**			
RATE RETURN TRIP	**1069.59**			

1 Recommended Retail Price for a Standard 1.6 Toyota Corolla Professional (excluding VAT)
2 Source: AA
3 Source: Western Cape Government
4 Unit price for 195/65 R15 tyre (excluding VAT)
5 Typical Tyre Damage Insurance schemes extend cover up to 50000km
6 Maintenance cost for 1600cc vehicle (excluding VAT). Source: AA
7 Source: AA

5.1 Vehicle A (electric)



6. Vehicle B (electric)

Private car COST CALCULATION

				Notes
	H Group NEW			
VEHICLE	**NISSAN LEAF 2017 (electric)**			
New				
	ASSUMPTIONS			Notes
	Replacement cost (VAT excl)	(R)	457000	1
4x2	Finance cost	(%)	9.50%	
	Depreciation	(Yrs)	5	
	Residual value	(%)	25.00%	
	Insurance (% of cost) OR	(%)	11.00%	2
	Insurance: Total (Rand/yr)		0	
	Licence (1000-1250kg - Tarra)	(R)	800	3
	Number of tyres	(No)	4	
	Price per tyre: New	(R)	800	4
	Price per tyre: Retread	(R)	0	
	Number of tyres (front)	(No)	2	
	Number of tyres (rear)	(No)	2	
	Tyre life (front)	(Km)	50000	5
	Tyre life: Rear	(Km)	50000	5
	Tyre life: Retread: Front	(Km)	0	
	Tyre life : Retread : Rear	(Km)	0	
	Number of steering axles	(No)	1	
	Number of other axles	(No)	1	
	Number of retreads: Front	(No)	0	
	Number of retreads: Rear	(No)	0	
			10	
Drivers	Number of	(No)	1	
	Monthly salary of driver	(R)	0	
Assistents	Number of	(No)	0	
	Monthly salary of assistant	(R)	0	
		(R)		
Overhead cost	Per year OR	(R)		
	% of fixed cost	(%)	7.00%	
Maintenance	% of Fixed cost	(%)	0.00%	
	% of Running cost OR	(%)	0.00%	
	Variable maintenance cost	(c/km)	19.55	6
Fuel/electricity	Usage (kwh/100km)	kwh/100km	30	
	Cost per kwh	(c)	154	7
Other variable operating costs		(R)	0	
Additional provision for tyres per year		(R)	0	
Average distance per return trip		(km)	80	
Average distance per single trip		(km)	40	
Return trips per day		(No)	1	
Working days per week		(No)	5	
Return trips per week		(No)	5	
Weeks per year		(No)	45	
Return trips per year		(No)	225	
Passengers per trip (return)		(No)	1.5	
Passengers transported per year		(No)	337.5	
Yearly kilometres		(Km)	15000	
Working days per year		(Dae)	200	

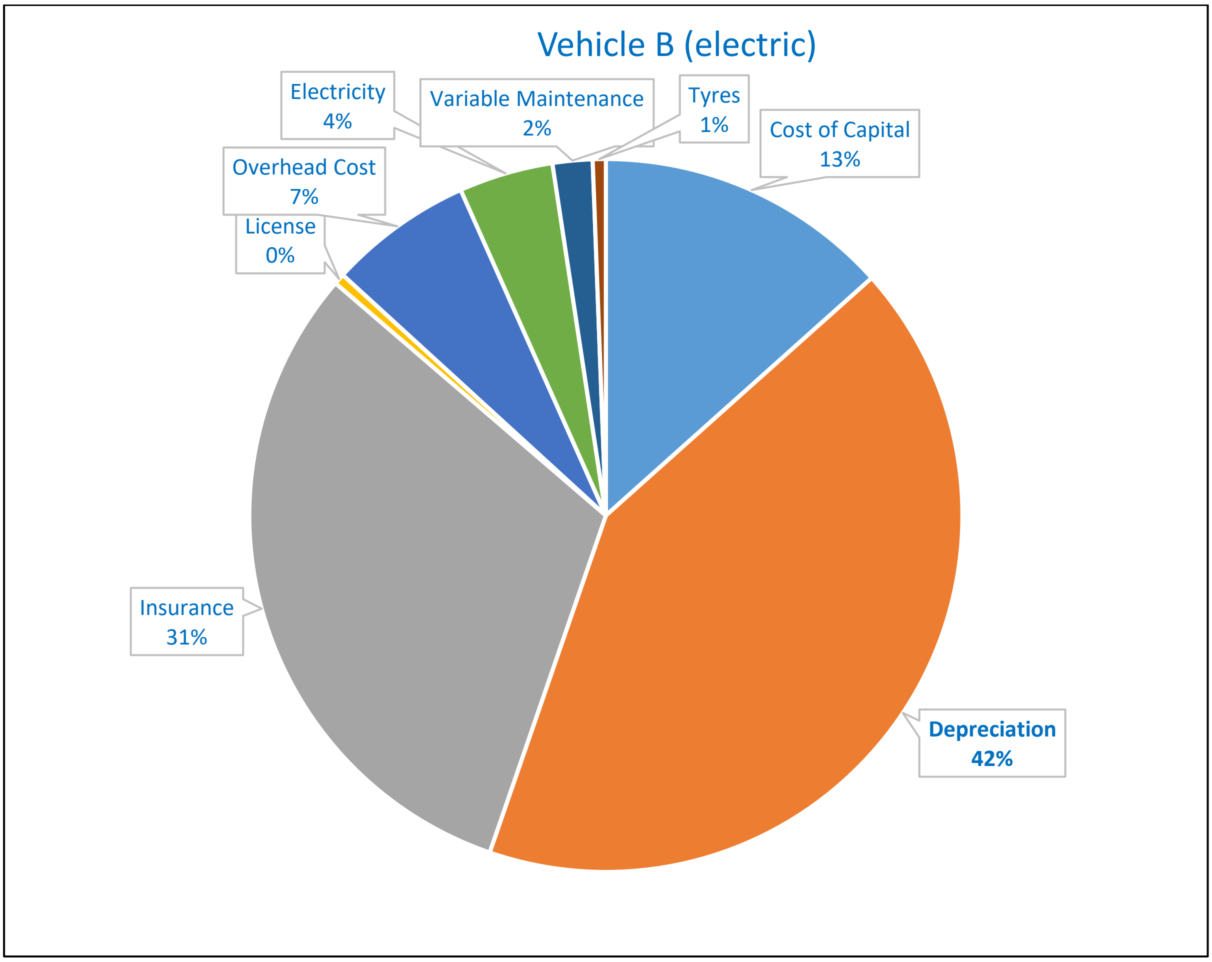
COST CALCULATION: SUMMARY

	(R/yr)	(C/KM)	(%)	(%)
Fixed Cost				
Cost of Capital	21,708	145	14.35%	13.39%
Depreciation	67,910	453	44.89%	41.89%
Insurance	50,270	335	33.23%	31.01%
Vehicle personel	-	-	0.00%	0.00%
License	800	5	0.53%	0.49%
Fixed maintenance	-	-	0.00%	0.00%
Overhead Cost	10,589	71	7.00%	6.53%
Total Fixed Cost R/yr)	151,277	1,009	100.0%	93.3%
Variable cost				
Fuel	6,930	46	64.03%	4.28%
Lubrication	-	-	0.00%	0.00%
Variable Maintenance	2,933	20	27.10%	1.81%
Tyres	960	6	8.87%	0.59%
Other	-	-	0.00%	0.00%
Total Variable Cost (c/km)	10,823	72	100.0%	6.7%
TOTAL COST	162,099	1,081		100%

		Total costs		
Single trip distance	40			
Return trip distance	80			
FIXED COST PER DAY	756.38	Day	Week	Month
FIXED COST PER YEAR	151276.88	R 444	R 3,109	R 12,435
TOTAL COST PER YEAR	162099.38			
RETURN TRIP LEARNERS P/YR	338			
TOTAL COST: RETURN TRIP	**814.10**			
RATE RETURN TRIP	**936.22**			

1 Recommended Retail Price for a Standard 1.6 Toyota Corolla Professional (excluding VAT)
2 Source: AA
3 Source: Western Cape Government
4 Unit price for 195/65 R15 tyre (excluding VAT)
5 Typical Tyre Damage Insurance schemes extend cover up to 50000km.
6 Maintenance cost for 1600cc vehicle (excluding VAT). Source: AA
7 Source: AA

6.1 Vehicle B (electric)



7. Vehicle C (hybrid)

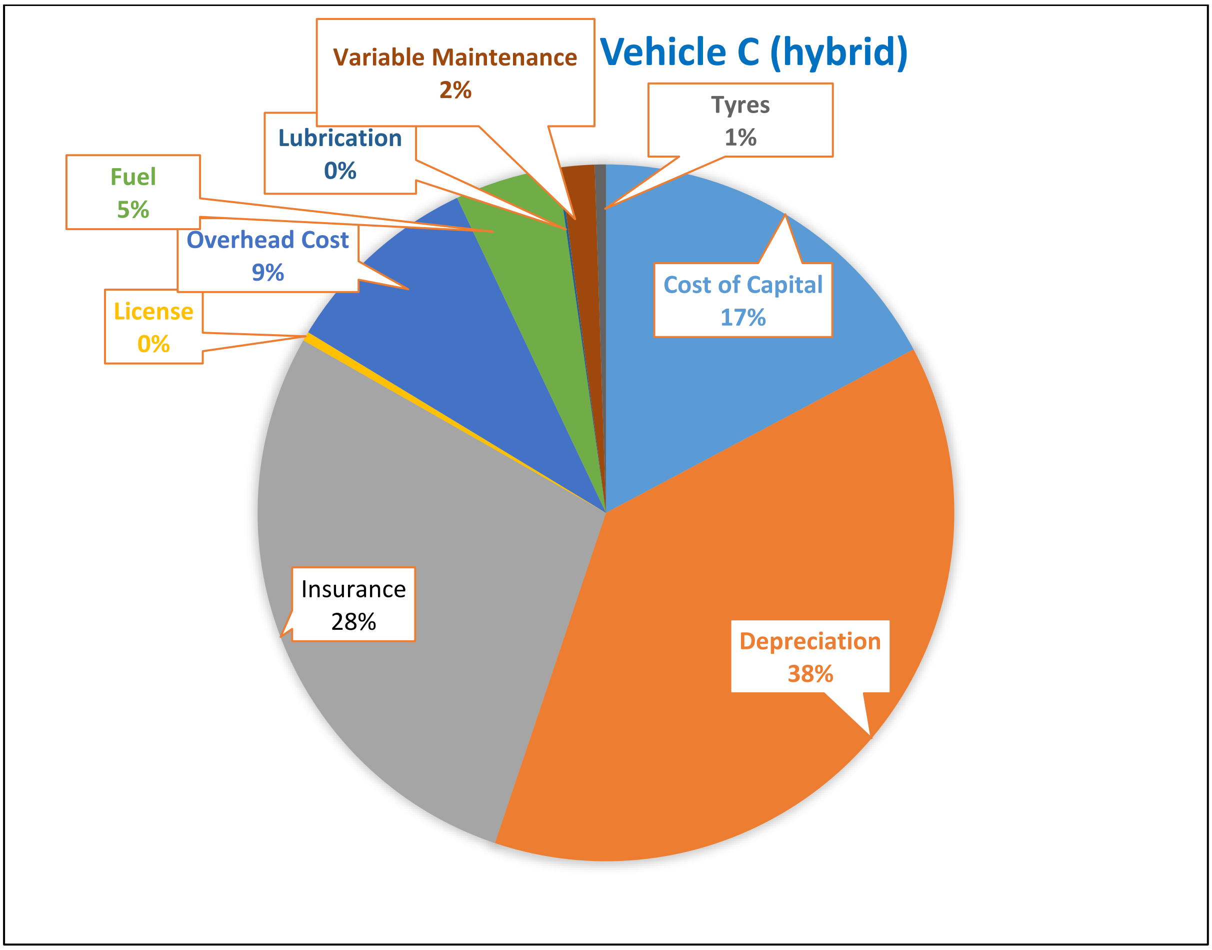
	Private car COST CALCULATION			Notes
	H Group NEW			
VEHICLE	TOYOTA PRIUS HYBRID 1.8			
New				
	ASSUMPTIONS			Notes
	Replacement cost (VAT excl)	(R)	471800	1
4x2	Finance cost	(%)	13.50%	
	Depreciation	(Yrs)	5	
	Residual value	(%)	25.00%	
	Insurance (% of cost) OR	(%)	11.00%	2
	Insurance: Total (Rand/yr)		0	
	Licence (1000-1250kg - Tarra)	(R)	800	3
	Number of tyres	(No)	4	
	Price per tyre: New	(R)	800	4
	Price per tyre: Retread	(R)	0	
	Number of tyres (front)	(No)	2	
	Number of tyres (rear)	(No)	2	
	Tyre life (front)	(Km)	50000	5
	Tyre life: Rear	(Km)	50000	5
	Tyre life: Retread: Front	(Km)	0	
	Tyre life : Retread : Rear	(Km)	0	
	Number of steering axles	(No)	1	
	Number of other axles	(No)	1	
	Number of retreads: Front	(No)	0	
	Number of retreads: Rear	(No)	0	
			10	
Drivers	Number of	(No)	1	
	Monthly salary of driver	(R)	0	
Assistents	Number of	(No)	0	
	Monthly salary of assistant	(R)	0	
		(R)		
Overhead cost	Per year OR	(R)		
	% of fixed cost	(%)	10.00%	
Maintenance	% of Fixed cost	(%)	0.00%	
	% of Running cost OR	(%)	0.00%	
	Variable maintenance cost	(c/km)	19.55	6
Fuel/electricity	Usage (l/100km)	(l/100km)	3.7	
	Cost per litre (Petrol)	(c)	1600	7
Lubrication	% of fuel cost	(%)	2.50%	
Other variable operating costs		(R)	0	
Additional provision for tyres per year		(R)	0	
Average distance per return trip		(km)	80	
Average distance per single trip		(km)	40	
Return trips per day		(No)	1	
Working days per week		(No)	5	
Return trips per week		(No)	5	
Weeks per year		(No)	45	
Return trips per year		(No)	225	
Passengers per trip (return)		(No)	1.5	
Passengers transported per year		(No)	337.5	
Yearly kilometres		(Km)	15000	
Working days per year		(Dae)	200	

COST CALCULATION: SUMMARY	(R/yr)	(C/KM)	(%)	(%)
Fixed Cost				
Cost of Capital	31,847	212	18.53%	17.23%
Depreciation	70,130	468	40.81%	37.94%
Insurance	51,898	346	30.20%	28.07%
Vehicle personel	-	-	0.00%	0.00%
License	800	5	0.47%	0.43%
Fixed maintenance	-	-	0.00%	0.00%
Overhead Cost	17,186	115	10.00%	9.30%
Total Fixed Cost R/yr)	171,861	1,146	100.0%	93.0%
Variable cost				
Fuel	8,880	59	68.34%	4.80%
Lubrication	222	1	1.71%	0.12%
Variable Maintenance	2,933	20	22.57%	1.59%
Tyres	960	6	7.39%	0.52%
Other	-	-	0.00%	0.00%
Total Variable Cost (c/km)	12,995	87	100.0%	7.0%
TOTAL COST	184,855	1,232		100%

		Total costs		
Single trip distance	40			
Return trip distance	80			
FIXED COST PER DAY	859.30			
FIXED COST PER YEAR	171860.56	Day	Week	Month
TOTAL COST PER YEAR	184855.06	R 506	R 3,545	R 14,181
RETURN TRIP LEARNERS P/YR	338			
TOTAL COST: RETURN TRIP	**928.61**			
RATE RETURN TRIP	**1067.90**			

1 Recommended Retail Price for a Standard 1.6 Toyota Corolla Professional (excluding VAT)
2 Source: AA
3 Source: Western Cape Government
4 Unit price for 195/65 R15 tyre (excluding VAT)
5 Typical Tyre Damage Insurance schemes extend cover up to 50000km.
6 Maintenance cost for 1600cc vehicle (excluding VAT). Source: AA
7 Source: AA

7.1 Vehicle C (hybrid)



8. Vehicle D (conventional)

Private car COST CALCULATION

	H Group NEW			
VEHICLE	TOYOTA PRESTIGE 1.8			
New				
	ASSUMPTIONS			Notes
	Replacement cost (VAT excl)	(R)	328000	1
4x2	Finance cost	(%)	9.50%	
	Depreciation	(Yrs)	5	
	Residual value	(%)	25.00%	
	Insurance (% of cost) OR	(%)	7.50%	2
	Insurance: Total (Rand/yr)		0	
	Licence (1000-1250kg - Tarra)	(R)	800	3
	Number of tyres	(No)	4	
	Price per tyre: New	(R)	800	4
	Price per tyre: Retread	(R)	0	
	Number of tyres (front)	(No)	2	
	Number of tyres (rear)	(No)	2	
	Tyre life (front)	(Km)	50000	5
	Tyre life: Rear	(Km)	50000	5
	Tyre life: Retread: Front	(Km)	0	
	Tyre life : Retread : Rear	(Km)	0	
	Number of steering axles	(No)	1	
	Number of other axles	(No)	1	
	Number of retreads: Front	(No)	0	
	Number of retreads: Rear	(No)	0	
			0	
			10	
Drivers	Number of	(No)	1	
	Monthly salary of driver	(R)	0	
Assistents	Number of	(No)	0	
	Monthly salary of assistant	(R)	0	
		(R)		
Overhead cost	Per year OR	(R)		
	% of fixed cost	(%)	10.00%	
Maintenance	% of Fixed cost	(%)	0.00%	
	% of Running cost OR	(%)	0.00%	
	Variable maintenance cost	(c/km)	19.55	6
Fuel/electricity	Usage (l/100km)	(l/100km)	6.4	
	Cost per litre (Petrol)	(c)	1600	7
Lubrication	% of fuel cost	(%)	2.50%	
Other variable operating costs		(R)	0	
Additional provision for tyres per year		(R)	0	
Average distance per return trip		(km)	80	
Average distance per single trip		(km)	40	
Return trips per day		(No)	1	
Working days per week		(No)	5	
Return trips per week		(No)	5	
Weeks per year		(No)	45	
Return trips per year		(No)	225	
Passengers per trip (return)		(No)	1.5	
Passengers transported per year		(No)	337.5	
Yearly kilometres		(Km)	15000	
Working days per year		(Dae)	200	

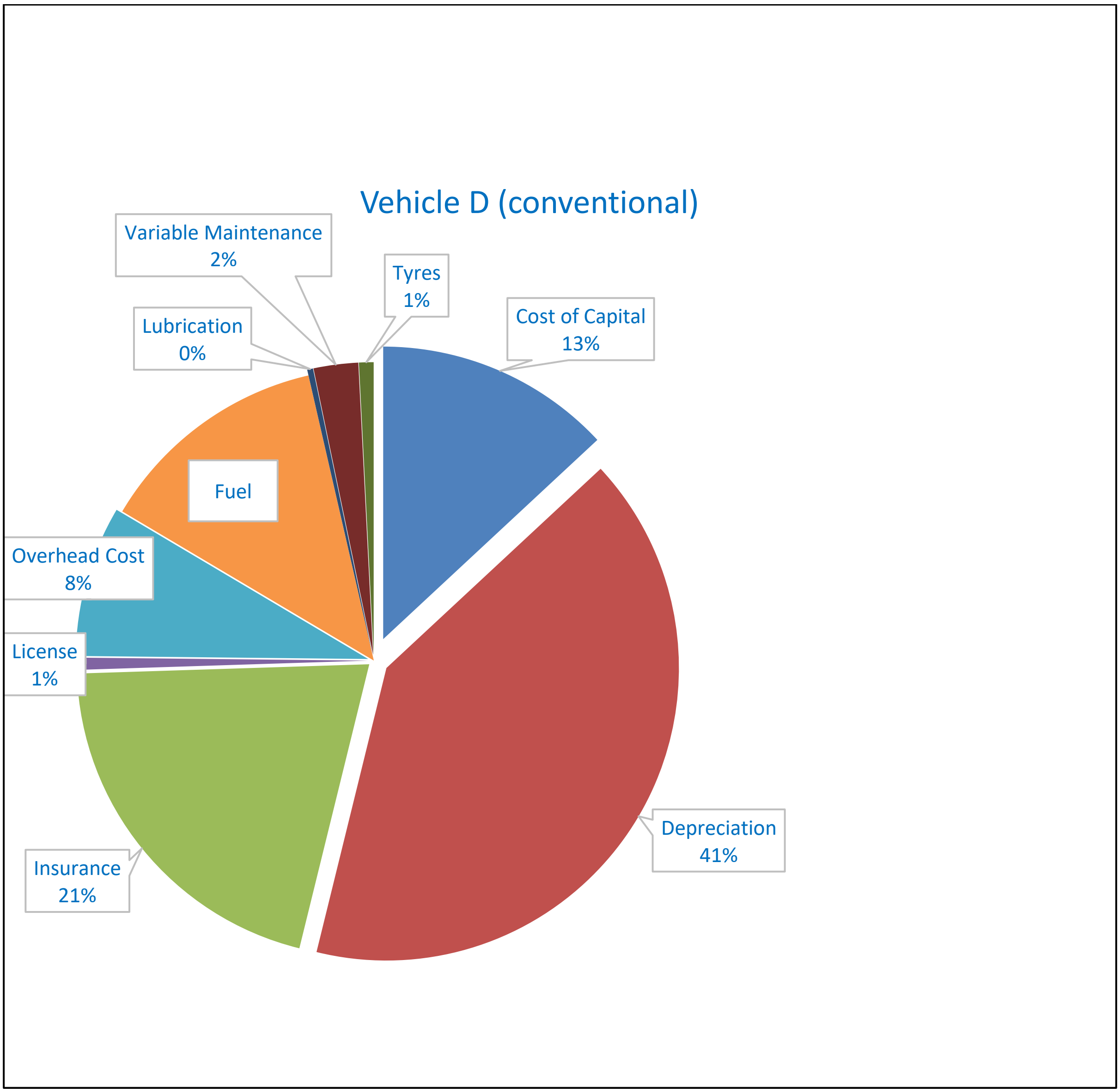
COST CALCULATION: SUMMARY

	(R/yr)	(C/KM)	(%)	(%)
Fixed Cost				
Cost of Capital	15,580	104	15.66%	13.08%
Depreciation	48,560	324	48.81%	40.76%
Insurance	24,600	164	24.73%	20.65%
Vehicle personel	-	-	0.00%	0.00%
License	800	5	0.80%	0.67%
Fixed maintenance	-	-	0.00%	0.00%
Overhead Cost	9,949	66	10.00%	8.35%
Total Fixed Cost R/yr)	99,489	663	100.0%	83.5%
Variable cost				
Fuel	15,360	102	78.22%	12.89%
Lubrication	384	3	1.96%	0.32%
Variable Maintenance	2,933	20	14.93%	2.46%
Tyres	960	6	4.89%	0.81%
Other	-	-	0.00%	0.00%
Total Variable Cost (c/km)	19,637	131	100.0%	16.5%
TOTAL COST	119,125	794		100%

Single trip distance	40			
Return trip distance	80			
FIXED COST PER DAY	497.44		Total costs	
FIXED COST PER YEAR	99488.89	Day	Week	Month
TOTAL COST PER YEAR	119125.39	R 326	R 2,285	R 9,138
RETURN TRIP LEARNERS P/YR	338			
TOTAL COST: RETURN TRIP	**602.17**			
RATE RETURN TRIP	**692.50**			

1 Recommended Retail Price for a Standard 1.6 Toyota Corolla Professional (excluding VAT).
2 Source: AA
3 Source: Western Cape Government
4 Unit price for 195/65 R15 tyre (excluding VAT)
5 Typical Tyre Damage Insurance schemes extend cover up to 50000km.
6 Maintenance cost for 1600cc vehicle (excluding VAT). Source: AA
7 Source: AA

8.1 Vehicle D (conventional)



9. Attributes of EVs

Attributes	Response (n=29)	(%) Count	Std. Dev	Mean
Most people in South Africa have little or no information on electric vehicles.	19	65,52	0.48	4,7
The government and automobile industries in South Africa are not doing enough to create public awareness of electric mobility and its benefits.	14	48,28	0.91	4,3
Electric vehicles are more environmentally sustainable than internal combustion engine vehicles	17	58.62	0.81	4.4
At a national level, electric vehicles can help to reduce the country's dependence on crude oil as the main source of energy for the transport sector	18	62.07	0.68	4.5
The government should invest in renewable energy sources like solar and wind to support the mass uptake of electric vehicles.	18	62.07	0.89	4.4
Electric vehicle technology can stimulate innovation and create new job opportunities.	18	62.07	1.02	4.3
Tax breaks, capital subsidies and free charging facilities can support electric vehicle uptake.	18	62.07	0.56	4.6
Electric vehicles are not demand-driven but incentive-driven, which explains the low uptake in South Africa.	16	55.17	0.9	3.9
Electric vehicles may worsen South Africa's electricity problem.	8	27.59	1.25	2.6

10. EXPERT SURVEY

PART 1

GENERAL INFORMATION

*(1). In which sector do you predominantly work?

Vehicle sales

Vehicle manufacturing

Transport infrastructure provision

Consultancy, NGO or research

Government

Transport operator

Other

*(2). With which gender do you identify?

Male

Female

Other:

*(3). How old are you?

18 - 25

26 - 35

36 - 45

46 - 55

56 or older

*** PART 2**

COST FACTORS ASSOCIATED WITH ELECTRIC VEHICLE OWNERSHIP

This section deals with some of the important cost factors that potential electric vehicle buyers should consider when purchasing an electric vehicle in South Africa.

*(4). On a scale of 1 to 5, where 1 = Unimportant and 5 = Very important, how do you RATE and RANK the vehicle ownership cost factors provided below? You may also indicate that you do not have an opinion on a certain cost factor by choosing option 3.

1=Unimportant

5=Very important

Capital cost (purchase price)

Maintenance cost
Charging (electricity) cost
Vehicle depreciation
Overhead cost, which includes the cost of charging equipment such as cables.

*(5). In your opinion, what are the other vehicle ownership cost factors that electric vehicle owners may face in South Africa?

*(6). On a scale of 1 to 5, where 1 = Least appealing and 5 = Most appealing, how do you RATE and RANK the strategies provided below that government can implement to lower electric vehicle ownership cost and stimulate the uptake of electric vehicles?
1=Least appealing
5=Most appealing
Provision of capital subsidy on retail prices
Reduction in import duties
Subsidization of electricity costs
Lowering of annual licence and registration costs
Provision of free parking in city centres
Provision of exemption tolls

*(7). In your opinion, what other strategies could the government implement to lower electric vehicle ownership cost and stimulate the mass uptake of electric vehicles in South Africa? Please provide your opinion in the space below.

*(8). Do you strongly agree, Agree, Disagree or strongly disagree with the statement "Electric vehicles currently have a high ownership cost structure compared to that of internal combustion engine vehicles"?
Strongly agree
Agree
Disagree
Strongly disagree

*(9). In your opinion, how do they cost factors provided below compare between electric vehicles and internal combustion engine vehicles for 2018 and what do you expect to happen in the next five years?
Please indicate whether you think the costs are/will be Much lower, Equal or Much higher.
NOW (2018) NEXT 5 YEARS

Capital cost (purchase price)
Maintenance cost
Charging (electricity) cost
Vehicle depreciation
Insurance cost
Licence and registration cost
Overhead cost
Privacy Information

***PART 3**

GENERAL AWARENESS OF ELECTRIC VEHICLES IN SOUTH AFRICA

This section deals with public awareness of electric vehicle innovation and acceptance in South Africa.

*(10). On a scale of 1 to 5, where 1 = Disagree strongly, 3 = Disagree and 5 = Agree strongly, how do you RATE each of the statements provided below?

Most people in South Africa have little or no information on electric vehicles.
The government and automobile industries in South Africa are not doing enough to create public awareness of electric mobility and it's benefits.
Electric vehicles are not demand-driven but incentive-driven, which explains the low uptake in South Africa.
At a national level, electric vehicles can help to reduce the country's dependence on crude oil as the main source of energy for the transport sector.
Electric vehicles may worsen South Africa's electricity problem.
Electric vehicles are more environmentally sustainable than internal combustion engine vehicles.
The government should invest in renewable energy sources like solar and wind to support the mass uptake of electric vehicles.
Electric vehicle technology can stimulate innovation and create new job opportunities.
Tax breaks, capital subsidies and free charging facilities can support electric vehicle uptake.

***PART 4**

TRENDS IN ELECTRIC VEHICLE SALES

This section deals with the trend in electric vehicle sales and adoption in South Africa over the past five years compared to that in the rest of the world.

*(11). On a scale of 1 to 5, where, and 1 = Lower than expected, 3 = Average and 5 = Higher than expected, how do you RATE the statements provided below regarding electric vehicle sales and adoption in South Africa compared to those in the rest of the world? Please feel free to provide any further comments that you may have.

- The number of electric vehicles sold in South Africa over the past five years.
- The pace of electric vehicle adoption and uptake in South Africa compared to that in the rest of the world.
- Government support, such as policies and incentives, to improve electric vehicle uptake in South Africa.
- Electric vehicle infrastructure development and roll out in South Africa.
- The availability of electric vehicle models in retail outlets in South Africa.
- Knowledge of the benefits of electric vehicles among the public.

***PART 5**

CHALLENGES AND OPPORTUNITIES FOR ELECTRIC VEHICLE UPTAKE

This section deals with some of the CHALLENGES and OPPORTUNITIES for electric vehicle adoption and innovation in South Africa.

*(12). Please, RANK, in order of importance to you, the following CHALLENGES that could be faced by electric vehicle owners in South Africa:

1. High purchase costs
2. Poor road conditions
3. Range anxiety (shorter travel ranges)
4. Lack of charging infrastructure
5. Electricity costs
6. Lack of maintenance technicians
7. High maintenance and insurance costs
8. Long charging times
9. Limited vehicle models
10. Uncertain retail value

*(13). Please, RANK, in order of importance to you, the following OPPORTUNITIES illustrating possible national and consumer benefits of electric vehicle technology in South Africa.

1. Electric vehicles can stimulate innovation
2. Electric vehicles can boost employment in the manufacturing industry.
3. Electric vehicles can foster economic development by lowering transport costs.

4. Electric vehicle technology can lower carbon-emissions.
5. Electric vehicles can lower the high cost of transport in South Africa.
6. Electric vehicles can decrease South Africa's dependency on fossil fuel.
7. Electric vehicles can improve air quality
8. Electric vehicles can stimulate technological innovation.
9. Electric vehicles are cheaper to operate and offer lower running costs.
10. Electric vehicle technology offers safety improvements.

*(14). In your opinion, what could be other potential CHALLENGES and OPPORTUNITIES for electric vehicle owners and South Africa in general?

***PART 6**

IMPACT OF ELECTRIC VEHICLE UPTAKE ON GOVERNMENT REVENUE AND EMPLOYMENT

This section deals with government revenue from fuel levies and the impact of the electric vehicle on government revenue and employment.

*(15). On a scale of 1 to 5, where 1 = Disagree strongly and 5 = Agree strongly, how do you RATE each of the statements provided below? You may also indicate that you do not have an opinion on certain statements by choosing option 3.

1. Electric vehicle adoption in South Africa will negatively affect road funding, which is currently partly sourced from fuel levy.
2. Electric vehicle adoption is seen as a strategy to mitigate the impact of increasing fuel prices on individuals and countries.
3. To replace fuel levies, electric vehicles should be taxed on every unit of electricity used
4. Electric vehicles should be taxed on the distance that they travel, that is per kilometre of road usage.
5. Electric vehicles should be taxed less because they are emission-free.
6. Electric vehicle innovation can lead to job losses for fuel attendants, fuel tanker drivers and refinery jobs for example.
7. Electric vehicle adoption will negatively affect South Africa's automotive manufacturing industry.

Please feel free to provide any further comments that you may have.

We would like to reach as many experts as possible. Could you provide us with the contact details of one or two industry experts who would also complete this survey?

NAME & SURNAME   EMAIL ADDRESS

11. General population survey

*1. With which gender do you identify?

Male

Female

Other:

*2. What ethnicity best describes you?

White

Coloured

Black African

Indian

Asian

Other:

*3. How old are you?

18-25

26-35

36-45

46-55

56 or older

* 4. In which sector do you predominantly work?

Education sector

White-collar job

Business sector

Agriculture sector

Transportation sector

Other:

*5. Please indicate your highest level of education

Elementary/Primary

High school/Secondary

Diploma/Post diploma

Graduate degree

Postgraduate degree

Other, please specify:

*6. What is your annual income before tax (gross income)?

Under R100 000

R100 000-200 000

R200 000-300 000

R300 000-400 000

R400 000-500 000

R500 000 and above

Not applicable

*7. What mode of transport do you predominantly use?

Private car

Public transportation

Company car

Walk

Motorbike

Cycling

Ridesharing

Other please specify:

*8. In which Province in South Africa do you live?

PART TWO- ELECTRIC VEHICLE INNOVATION AND ADOPTION

*9. Which of the three electric vehicle types are you aware of?

Hybrid electric vehicle (HEV)

Plug-in hybrid electric vehicle (PHEV)

Battery electric vehicle (BEV)

All the above

None

*10. On a scale of 1 to 5, where 1 = Least appealing and 5 = Most appealing, how do you RATE the following characteristics of an electric vehicle? You may also indicate that you do not have an opinion on a certain option by choosing option 3.

RATING: 1=Least appealing; 5=Most appealing

Electric vehicles have a lower maintenance cost than conventional vehicles.

Electric vehicles are more environmentally friendly than conventional vehicles.

Electric vehicles can help reduce the high-cost burden of fossil fuel in the country.

Electric vehicles can improve urban air quality.

Electric vehicles can lower vehicle ownership cost.

*11. On a scale of 1 - 5 where 1 means no interest and 5 means high interest, how will you RATE your interest in cars that use alternative energy sources such as electricity and biofuel? You may also indicate that you do not have an opinion by choosing option 3.
1=No interest 5=High interest

*12. Please, RANK, in order of importance to you, the following CHALLENGES that could discourage you from buying an electric vehicle in South Africa. Where 1= Most important and 7=Least important.

*13. On a scale of 1 - 5 where 1 means not at all likely and 5 means most likely, how likely would you be to consider buying or recommending a vehicle that uses alternative propulsion system such as electricity?
1=Not at all likely 5=Very likely

*14. On average, how far (in kilometres) do you travel a day?
0 - 30km
30 - 50km
50 - 70km
70 - 100km
Above 100km

*15. How much in (Rand/Litre) would petrol or diesel have to cost to persuade you to buy an electric vehicle?
R15 - R20
R20 - R25
R25 - R30
R30 - R35
R35 and above

*16. Do you perceive charging an electric vehicle as being convenient or inconvenient compared to fuelling a normal car in South Africa?
Convenient
Inconvenient
Other:

*17. “Quick-charging” means a higher voltage charging that is capable of charging your vehicle’s battery in a shorter period than a normal wall charger. If such chargers were available at public stations similar to fuel, outlets (garages), what is the maximum time in minutes are you willing to wait for your car to be charged from empty to full.

1–5 minutes

5–10 minutes

10–15 minutes

20-30 minutes

Above 30 minutes.

*18. Would you be more willing to buy an electric vehicle if the ownership of the battery and the vehicle were separated? Example, if you could purchase the vehicle without the battery for a lower price and instead pay for a monthly subscription similar to a cell phone contract, which covers the cost of the battery.

Yes No Not sure other:

*19. Will you like the idea of ‘‘battery swap stations” where your depleted battery could be taken out and replaced with a fully charged battery in a short time?

Yes No Not sure

*20. Do you currently have access to an electric vehicle charging facility at home, workplace or area where you stay?

Yes No

*21. When buying a vehicle, does the sustainability (environmental friendliness) of the vehicle influence your purchase decision?

No Yes

*22. "Electric vehicles are safe, cheaper to operate and emission-free mode of transportation". On a scale of 1 to 5, where 1 means Disagree strongly and 5 means Agree strongly, how do you RATE the statement provided above?

1=strongly disagree 5=strongly agree

*23. "Battery Electric vehicles are the most sustainable choice of transportation when compared to internal combustion vehicles and other alternatives". On a scale of 1-5 where 1= strongly disagree and 5= strongly agree, how will you rate this statement?

1=strongly disagree 5=Neutral strongly agree

*24. How common are electric vehicle charging stations or infrastructure in your province?

Very common Rare Very rare Not at all

*25. Choose any FOUR of the following conditions that can persuade you to buy an electric car instead of an internal combustion engine car (CLICK ON SELECT).

*26. In your opinion what are the Four (4) main advantages of an electric car over the normal combustion engine car?

*27. In your opinion, do you think electric vehicles will become as popular as conventional vehicles?

Yes No Not sure

28. Please COMMENT on your answer in question 31 above

THANK YOU FOR TAKING PART IN THE SURVEY.

12. Effect of 2018 fuel price increase

Fuel Price increase (inland)	**Date**	**Total cost c/km**	**Fixed cost c/km**	**Variable cost c/km**	**Total Variable cost /year.**	**Daily total cost (R)**	**Weekly total cost (R)**	**Monthly total cost (R)**	**Annual Total cost (R)**
14.76	31 Dec 17								
R14.42	03 Jan 18	918	797	121	18082	377	2639	10557	137615
R14.12	07 Feb 18	916	797	119	17787	376	2634	10534	137320
R13.76	02 Mar 18	913	797	116	17432	375	2627	10507	136966
R14.48	04 Apr 18	918	797	121	18141	377	2640	10561	137674
R14.97	02 May 18	921	797	124	18623	379	2650	10598	138156
R15.79	06 Jun 18	926	797	130	19430	381	2665	10660	138965
R16.02	04 Jul 18	928	797	131	19656	381	2669	10678	139190
R16.03	01 Aug 18	928	797	131	19666	381	2670	10678	139199
R16.08	05 Sep 18	928	797	131	19696	381	2670	10681	139229
R17.08	05 Oct 18	935	797	138	20699	384	2689	10758	140233
72 cents increase		**5**	**0**	**5**	**709**	**2**	**13**	**54**	**708**

Source: (South African Petroleum Industry Association, 2018)

13. Facebook page results