Original equipment manufacturers' perspectives of barriers to the adoption of electric vehicles in South Africa

Research Report,

Submitted in fulfilment of the requirements for the degree of

Master of business administration (MBA)

to

Wits Business School,

Faculty of Commerce, Law, and Management

University of the Witwatersrand, Johannesburg, South Africa

Student: Ramaabele Yolanda Kupa

Student number: 568600

Supervisor: Prof Milford Soko

Ethic Protocol number: WBS/BA568600/933

First submitted: 21 April 2023

Revised report submission: 06 November 2023

Word count: 18 354 (Previously 22 548) – excluding questionnaire, cover pages, declaration and Appendices

DECLARATION

I Ramaabele Yolanda Kupa, Student number 568600 declare that this is my own unaided work. I submit this work in fulfilment of my Master's in Business Administration research report component to the University of Witwatersrand.

Signature: _____ Date: 28 February 2023

Ramaabele Yolanda Revised version: 02 November 2023

Final submission : 01 April 2023

Nominated Journal:

The nominated journals are on a basis of relevance of content and audience. For example, the research would fit into the *"Development of Southern Africa"* as the scope of the research is limited to South Africa. The country falls in the Sub-Saharan Africa and its development on EV would be of interest to the audience. The last journal, "Strategic Review for Southern Africa" is well suited for the research at hand as the research content mainly touches on strategic topics which would need to be discussed at executive levels of OEM's, at government level, at policy development and revision level or even parliamentary level.

	Title	ISSN	Publisher	Country	Subject
1	Development Southern Africa	0376-835X	Taylor & Francis Ltd.	United Kingdom	BUSINESS AND ECONOMICS--INTERNATIONAL DEVELOPMENT AND ASSISTANCE
2	Economics of Innovation and New Technology	1043-8599	Taylor & Francis Ltd.	United Kingdom	BUSINESS AND ECONOMICS
3	Transportation	0049-4488	Springer Nature B.V.	Netherlands	TRANSPORTATION
4	Transportation Science	0041-1655	Institute for Operations Research and the Management Sciences	United States	TRANSPORTATION
5	Strategic Review for Southern Africa	1013-1108	University of Pretoria	South Africa	POLITICAL SCIENCE--INTERNATIONAL RELATIONS

FOREWORD

I would like to thank my parents, Mr Solomon Kupa and Mrs Diphala Kupa, my mentors who I cannot single out; thank you for their continued support on my career and academic pursuits. Most importantly I would like to thank my supervisor, Prof Milford Soko, his guidance and patience with this report has been unwavering. To a degree I took on with no funds and support at sight, I hope my late grandfather remains proud in his last resting place. This has indeed been a journey of faith and truly redefining oneself. To my loving husband, Given Mashego, we have made it best friend. I am forever thankful for Wits Business School administration staff for everything they have assisted me with. The world can learn something from your selfless service and ambition to keep the Wits brand going post 100 years. To the engaging conversations and insights gained from the academic staff, nothing is as breath-taking as being in a room of brilliant minds, in that moment my "*WHY*" made sense.

ABSTRACT

The introduction of EV's to the automotive industry is not new, there is evidence that the first electric vehicle was developed more than three decades ago (Chege, 2021), however the pursuits of its development at the current moment have become increasingly aggressive due to some of the technological breakthroughs and environmental advantages it brings forth. The environmental degradation due to global warming caused by greenhouse gas emissions has become a global concern and mission to address. Automotive vehicles are amongst the highest contributors to these emissions. EV's offer solutions to environmental degradation.

Electric vehicles offer less noise pollution, smaller carbon footprint through the life cycle of the vehicle compared to their combustion engine counterparts. Furthermore, EV's have challenged countries to rethink their energy distributions entirely. Due to the benefits EV's bring forth, adoption has thus increased across the world over the years. Much of this increase in adoption numbers is owed to assistance offered by government and OEMs in the form of incentive schemes during the purchase phase and in ownership costs. There are however challenges which continue to hinder other countries from adopting electric vehicles, especially developing countries such as South Africa.

This paper unpacks issues around the poor adoption of EV's from an OEM's perspective in South Africa. The seven local OEM's stakeholders are some of the greatest enablers for the adoption. South Africa is known as the gateway to Africa through its diversified supply chain, it further houses the highest number of OEMs in Africa. Studies from the 2022 Delloitte's consulting report shows that combustion engine vehicles are still leading in sales locally, and government's focus is more on the export market (Deloitte , 2019). The EV market might be growing globally post Covid-19 throughout the world but local sales contribution is small.

The study uses semi structured qualitative interviews conducted with 15 industry experts from different OEM's, government, and academia. It then uses the TOE framework and literature from published papers and journals to unpack these findings. Issues which emerged from the analysis include lack of charging infrastructure, energy complexities with regards to an overloaded energy grid which cannot further support EV adoption or home charging. Other issues included government support with regards to regulations, enforcement and enabling policy development. Lack of public acceptance of EV's due to high ownership costs such as import tax. Other issues noted include lack of incentives as compared to countries with leading EV sales. Product development issues such as batteries and driving range were noted.

This study is aimed at enabling decision makers in the academic institutions, automotive OEMs, and government bodies on key topics that could promote EV sales locally if addressed. It further identifies the linkages and relationships of the issues. These recommendations made stand to benefit OEMs through improved sales which can drive production volumes and thus employment in the automotive industry. Future studies can be conducted to rank the identified issues for a more focused approach. They can also examine issues from a customer's perspective, drawing on Insights from the business vs customer, or simply demand vs Supply.

Contents

1. CHAPTER 1: INTRODUCTION

An OEM, which stands for original equipment manufacturer is an organisation that produces and assembles components to create products to either be sold in the value chain of creation of another product or to be sold for use by end-user in its current state (Lin, 2007). Automotive OEMs vary in scale but commonly take advantage of large volumes to reduce production costs. The automotive industry OEM's have evolved from traditional batch production to highly customised parts and products which are made on order, in sequence (JIS) and in time (JIT). This has allowed better and efficient production systems by reducing waste in the form of transportation, inventory, overprocessing amongst many other types of waste (Jaffar, Kasolang, & Ghaffar, 2015).

Manufacturing OEMs definition is better explained in the schematic diagram below which shows the three-level tier of suppliers. In the example below, a car manufacturer is referred to as an OEM as they source different parts, components and modules to assemble vehicles for an end-user (customer). They may outsource and purchase services and products that are not within their area of expertise to ensure the successful assembly of the vehicle whereas Tier 1-3 may use raw materials or source parts from other suppliers in the lower tiers to make models and subunits for the OEMs (car manufacturer). Example is Tier 1 sourcing bolts and modules to make an engine which is then assembled and sold to the car manufacturer who ultimately fits into the chassis, tests and sells it to an end-user.

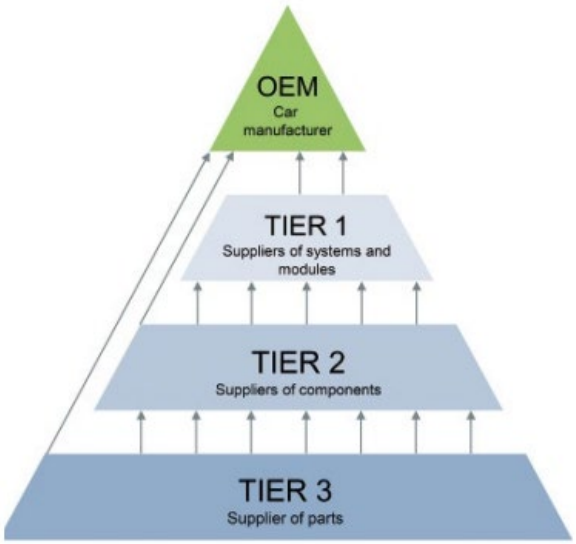


Figure 1: Pyramid showing the 3 tier suppliers who feed into the OEM value chain with an example of a car manufacturer. Picture adapted from (Bey, 2019).

According to NAAMSA, the South African automotive industry consists of twenty-two companies involved in the production of vehicles. This figure comprises of seven automotive assemblers /manufacturers of low car vehicles (LCV and small cars) and fifteen assemblers of medium to heavy commercial vehicles (MCV, HCV, and buses). The end-to-end supply chain also comprises of 500 automotive component suppliers (Tier 1,2,3 from the figure above) who supply the seven main OEMs namely Volkswagen, BMW, Nissan, Isuzu, Mercedes Benz, Ford, and Toyota (NAAMSA, 2023). These seven OEMs have traditionally produced combustion engine LCV's and are now transitioning into electric vehicles production which also means tier 1 to 3 needs to equally adapt their supply chain, production and systems for this change (supply -demand integration dynamics).

Electric vehicles, better known as EV's (which will be used as a common term for both battery electric vehicles (BEV) and (Plug-In Hybrid electric vehicles (PHEV's) have become the new automotive trend in multiple countries over the world, with different automotive assemblers and producers producing a wide range of these products as they transition from combustion engine to EV's. This growing trend is due to various advantages that come with the adoption of EV's which include but are not limited to the efficiency, climate, environmental and legislation advantages (Ashkrof, Homem de Almeida Correira, & Van Arem, 2020). Battery powered and electric vehicles also offer additional advantages in terms of efficiency such as compact engines (offer more space within vehicles), fewer components which foster more reliability, easy debugging and less carbon footprint from supplier to production processes, better comfort due to absence of vibrations and noise amongst many other advantages (Sanguesa, Torres-Sanz, Garrido, & Martinez, 2021).

With growing world population and globalisation there has been a great increase in the demand for vehicles across the globe as mobility has become an enabler of inclusive economic growth, thus deeming the automotive industry a vital economic growth player in most countries. Conversely the increased demand which support export and import activities cross countries has led to the transport industry being one of the greatest contributors to increasing levels of carbon dioxide emissions and greenhouse gas emission worldwide Sanguesa et.al (2021). BEV and PHEV's are deemed to be better than combustion engine vehicles as their emissions of greenhouse gases are far less (to zero) and thus a better alternative.

However, a lot of developing countries are yet to adopt electric vehicles to a satisfactory level due to some of the challenges in both the product and governance such as policies and legislation (Deloitte , 2019), (Chaturvedi, Nautiyal, Kandap, & Yaqoot, 2022)& (Duan, et al., 2020). Over the years different efforts have been made to encourage adoption. With this said, different variations of electric vehicles have been developed to cater for different customer needs such as battery electric vehicles (BEVs), Plug-In Hybrid electric vehicles (PHEV's), Hybrid Electric vehicles (HEV's), Fuel Cell electric vehicles (FCEV's) and Extended-range Electric Vehicles (ER-EV's) (Verma, et al., 2021). These wide range of product options should have accelerated adoption of electric vehicles and increased sales; however, some regions are still lagging. In 2019, the global market reported two million vehicle sales, EV's claim only 2.5% share of total sales. Although there is a notable 6% increase from 2018 sales, the 2019 percentage contribution is due to stringer legislation such as the *European emissions standards* which persuaded consumers to buy more EV's and the automotive manufacturers to ramp up EV production. However, the industry is still falling behind projections and sustainability goals interms of market penetration across different global markets. Some of the leading market include China, Germany, Norway, Australia and (Razmjoo, et al., 2022). Most of these markets were affected by Covid-19 but managed to recover, however the sales figures have not improved for developing countries (Breetz & Salon, 2018). According to a study conducted by Nel and Inlelsi-Lots based on data from 2021 sales ,South Africa is lagging by atleast 5 to 10 years in EV sales compared to EU (Nel & Inlelsi-Lots, 2022).

The measures to increase adoption have varied from country to country, depending on available resources. The adoption of policies and agreements such as the Paris Agreement is one of the contributing motivators for growing sales volume. It further fostered commitment by governments of different countries to provide public aid which fosters adoption of electric vehicles to fast track the complete switch or hybrid mobility (combustion and EV). Other types of support include discounts on purchase of electric vehicles tax exemption, reduced VAT exemption, reduced licence tax, tolls exemption and free parking payable in various European countries Sanguesa et.al (2021). These initiatives are intended to encourage adoption at different levels for users and thus benefit OEM's as they have increased production and sales as per the global market report (Breetz & Salon, 2018). These initiatives have also not improved developing countries adoption of electric vehicles as they are still lagging.

This research paper focuses on the South African automotive landscape as a developing country which also hasn't adopted electric vehicles in greater quantities. It particularly focuses on *the seven main OEMs* and the challenges they encounter in integrating electric vehicles into South Africa from their perspective. The paper will unpack the challenges of integration of EV's into a combustion engine designed market and industry from an OEM's perspective. The paper uses academic literature and qualitative approach through use of semi structured interviews of industry experts to explore these issues.

.

1.1. PURPOSE OF STUDY

The automotive industry is one of the great contributors to inclusive economic growth in South Africa as it allows swift trade to take place between countries and internally with local stakeholders. As such, the transport system remains central to global competitiveness, inclusion, and globalisation. Furthermore, it creates jobs, deepens local and neighbouring countries' value chain, and advances technology (Deloitte , 2019). The seven automotive OEM's serve both the national customer market and several other markets globally. It is for this reason that this transition from combustion to EV's which cements its competitiveness across the world is important.

Electric vehicles present multiple advantages such as clean technology with less carbon footprint from production to use. There are challenges which customers, businesses, and the automotive sector face currently which hinder adoption, and these vary from country to country. These challenges in research and development, product design and policy amongst many other are outlined in greater detail in the literature review and survey in chapter 2 with a reference to a South African context. A comparison will be drawn with other countries which are far ahead in terms of implementation and adoption and also developing countries which have similar conditions as South Africa. The aim is to highlight possible solutions businesses and government has developed around this innovation and thus implemented into their transport system which South Africa can adopt as good practise. Furthermore, how these have hindered or assisted OEM's interms of moving forward with the innovation. These findings will be instrumental in forging a way forward specific to south African conditions.

The purpose of this study is to draw findings and industry developments from academic research, current legislation and policies, industry experts' knowledge through interviews in order to fully analyse the hinderances of electric vehicles adoption and challenges from an OEM perspective. In essence to unpack the issues OEM's are facing which hinder nationwide adoption. Furthermore, it will also look at infrastructure and product development progress in the form of published case studies which are encouraging or discouraging adoption particularly in third world countries such as South Africa. The interviews will be done with a qualitative approach as there are new issues to be unpacked to understand this phenomenon.

1.2. RESEARCH OBJECTIVES:

Therefore, in summary the research objectives are as follows:

- To make transparent the challenges experienced by OEM's which hinder high adoption of EV integration in South Africa.
- Explore what other automotive industries are doing across the globe with regards to EV integration and adoption strategies in recent years.
- Put forth solutions unique to the South African landscape and infrastructure which ensures a higher EV adoption.

1.3. RELEVANCE OF STUDY

The following study is relevant at this current moment as the automotive industry transitions into increased pressure to produce new clean technology and processes for both export market and import market. Businesses are more than ever measured on sustainability and efficiency, electric vehicles and their production processes offer this from the production process to the end user through less carbon footprint. This is due to use considerations such as fewer engine components and less carbon dioxide emissions.

South Africa is well known in sub-Saharan Africa as the "hub of automotive" as it has over seven world class manufacturing assembly plants in two provinces. The automotive industry contributes 6.8% to GDP growth, employing 110 000 people nationally and producing over half a million passenger vehicles. This makes South Africa the largest automotive producer in Africa, with Morocco as the second largest. South Africa has thus developed an economic hub in the manufacturing and automotive industry exporting to different markets across the world (Deloitte , 2019). Conversely, with the evolving customer needs and increasing EV demand in the developed countries which South Africa exports to, the OEM also needs to respond to this change as the South African automotive industry thrives in the export market. This means the seven OEM's also need to fight for customer share by adapting to their changing customer needs in order to retain their global market share and sales.

The recent impact of climate change such as floods, sinking bedrocks, heavy rains and rising sea levels on the environment due to decades of heavy industrialisation and growing population have an added pressure for the country to also find clean technologies, systems and methods to reduce environmental impact (Verma, et al., 2021).It is for these reasons that

the study is relevant currently and suits the global agenda to transition to clean technology as per the Paris Agreement.

1.4. IMPORTANCE OF THIS STUDY

The electrification of vehicles worldwide brings an added advantage of decarbonising transportation systems. The world has become more interconnected with complex supply chains that depend, among others, on combustion engine trucks, small vehicles, and ships. These transport modes are great contributors to the greenhouse gas emissions in the world and which are, in turn, responsible for climate change. The adoption of electric vehicles stands to reduce these significantly thus offering a solution to environmental degradation and reduction of greenhouse gas effect hence they are linked to sustainability goals (Yang, 2021). The damage from environmental degradation can take decades to reverse, if reversable at all. The adoption of EV's is a step closer to decarbonisation.

According to the Paris Agreement, the 55 countries that have ratified the agreement aim to work together to reduce the world's temperature by 1.5 degrees Celsius (amongst its other goals). Electric vehicles are an enabler of the Paris Agreement goals. The agreement also says that the international Energy Agency's sustainable development scenario concluded that at least 230 million electric vehicles are necessary to meet the climate goals (IEA, Accelerating ambitions despite the pandemic, 2021a) & (IEA, Global EV Data Explorer, 2021 b). Whereas there were only 20 million electric vehicles reported on the roads across the globe in 2020 ((Koch, Ritter, & Rohlf, 2022). South Africa is one of the countries that have signed the Paris Agreement. The adoption of electric vehicles over combustion engines therefore supports this movement. By tackling issues hindering the adoption and offering solutions the adoption is likely to improve and thus the Paris agreement moves steps closer to its goal attainment.

The number of countries which offer incentives and reduced taxes for purchases of EV's for both personal and business purposes has also been increasing in an effort to increase adoption. There is also evidence from academic study reports titled "*studying A Comprehensive Study on the Expansion of Electric Vehicles in Europe*" and *" Commercialization of Electric Vehicles in Hong Kong*" which shows that these measures are effective in leading early adopter countries such as Hong Kong, Germany and Norway (Razmjoo, et al., 2022) & (Mo, et al., 2022).

Therefore, this paper evaluates what EV's could bring to the South African landscape and what is its current barriers, bearing in mind that SA is a country built on industrialisation and manufacturing from the 1994 and is currently the trade doorstep or gateway of Sub-Saharan Africa as it boosts off multiple airports, harbours, railways and small and large vehicle travelling to and from Africa for trade purposes. Therefore, with this in mind adoption of EV's will benefit the country and continent from this perspective, i.e., increase decarbonisation of the country's heavy transport system starting with small passenger vehicles. From an OEM's perspective, how can adoption be increased thereof? The incentives include ADPD, MERSETA grants, AITF and AIS scheme which all support the seven OEM's and its value chain to be sustainable and profitable (DTI, 2023).The country already has incentive programmes for the automotive industry and its supplier network. These can thus be restructured to support or be inclusive of EV penetration. The study is therefore important interms of showing incentives offered worldwide which have fostered EV adoption growth.

Against all these arguments, the study fills the gap of identifying factors limiting the adoption currently from an OEM perspective and therefore outlining enabling conditions or considerations for adoption of this innovation. A study of a developing country heavily built on industrialisation and combustion engine transportation could benefit immensely from the switch from a full combustion engine transport system to a hybrid solution with plans for a full electric system in future. Most of the studies in research have been on first world European and American countries, with the exception of India and Thailand (both of which are leaders in automotive assembly and transport sector in their regions). Therefore, this study closes the gap of analysing a developing country.

The study intends to offer some guidance to policymakers in South Africa, decision makers in the transport, trade and automotive sector (OEM's), as well as private entities and investors, Individuals and businesses which are looking into diversification of fleet or green individual mobility (EV considerations), who review policies, who also invest in initiatives at both regional and national scale in the energy or transport divisions. In the long-term, it puts into context how early adopters can and should be encouraged by different policies, levies and legislation to try different solutions and analyse macro level issues with different lenses.

1.5. PROBLEM STATEMENT

The adoption of electric vehicles is not a standalone problem, instead it is a topic which is multi-dimensional. The linkages of the issues affecting the adoption remain central to resolving it. These linkages are unique to each country and its circumstances. This paper seeks to unpack the linkages that exist specifically for South Africa.

The problem to be addressed through this study is to unpack issues inhibiting widespread adoption in South Africa by unpacking OEM barriers or main challenges to market penetration. To further show the links between these issues.

Poor EV adoption in South Africa and infrastructure to facilitate this transition from combustion engine will lead to high penalties from carbon emissions particularly from the markets the sector exports to such as Europe and USA where there is high regulations. It will further lead to the inability for OEMs to remain competitive locally and globally. Poor adoption also affects the supply chain and SMME's who equally would lose business. Poor adoption also puts the country at further behind interms of reducing carbon emission through transportation and throughout the product lifecycle. Studies show that combustion engine vehicles are the highest contributors of carbon monoxide emissions (Chege, 2021), (Deloitte , 2019) & (AutoTrader, 2022). The country would lose on an opportunity to reach its Paris Agreement goals and environmental goals too. The problem is therefore the missed opportunity seen through low EV Volume adoption locally. This problem starts with barriers experienced by OEMs to support the innovation and thus stalls the entire process chain.

The current body of literature has not evaluated the poor adoption in South Africa from an OEM's perspective. The study is necessary to ensure an evaluation is done for future resource deployment, policy decision making and strategic planning at macro level. The study is restricted to an OEMs perspective. The audience of the study is academics, government, and industry decision makers.

1.6. ASSUMPTIONS AND LIMITATIONS

Assumptions of the study are mainly around the semi-structured interviews and data collection. Interviewees are assumed to be honest and didn't feel the obligation to give feedback based on employer status and relationship.

According to Kulinska, (2016), axiology is one of qualitative research limitations, it argues that there could be potential bias from not only the interviewees but the interviewer, the assumption is therefore that the interviewer was not bias but took the responses as is and their interpretation of the responses. Therefore, the research assumes that there was no conflict of interest between interviewer and any of the OEM's, therefore the assumption is that the views of the respondents of the interviews were truthful, not biased (Consciously) and taken as they are. The use of face-to-face interviews with the industry experts and open-ended questions with allowance to elaborate was to minimise ambiguity and misinterpretation of results (Kulinska, 2016).

Another limitation of the study is that there is a limitation in this qualitative study as the researcher uses common words to draw patterns from the semi structured interviews. There will be an element of generalizability and a need for a more indepth investigation into emerging themes. These themes however can be used to guide future researchers and lays groundwork of this broad emergent industry. With this said, qualitative studies also offer insights through follow-up questions which quantitative wouldn't offer. The limitation of misinterpretation was minimised through open ended questions and follow-up questions. This would have not been the case with digital-based interview as the interviewee would not have the opportunity to ask the responded clarifying questions.

1.7. DELIMITATIONS OF STUDY

This section seeks to outline the topics which will not be covered i.e., the scope of the research. This gives the reader clear indication of what to expect in subsequent chapters and shows opportunities for future research on the same or similar topic.

The study will only be limited to the seven South African OEMs mentioned in the introduction section namely (Toyota, Nissan, Isuzu, BMW, Ford, and Volkswagen). The producers are car manufacturers or assemblers who are competing within the electric vehicle sector whether through export or import products within the local market. This means the study will not only look into the production facility but end-to-end. This therefore means the Tier 1-3 manufacturers will be highlighted where they affect or hinder the OEMs from full EV integration, but the core focus is not on the tier 1-3 supplier's operations.

Secondly, due to South Africa's active export and import market, the seven OEM's also have dealerships which sell EV's to different end-users within South Africa which are produced in other countries. These products are not produced locally but form part of the national EV sales figures or landscape and therefore will be reported and covered in the scope of the research. Furthermore, the vehicles are registered and driven locally thus benefiting from all infrastructure and development that national government would have implemented. For example, BMW i3 is not assembled in the local BMW Rosslyn in Gauteng, however the product forms part of the OEMs product catalogue and offerings provided for customers within South Africa and EV sales report.

1.8. RESEARCH QUESTIONS

The following study therefore seeks to answer the following research questions:

- What are the key issues hindering EV adoption?
- How has the South African automotive landscape transformed to accommodate the introduction of EV designs in the market, if any? i.e., policy, business models, infrastructure etc,
- How can the current South African transport landscape be adapted to encourage higher adoption in the future?

The paper will unpack the following research questions and propose way forward or solutions.

1.9. DEFINITION OF TERMS

The following definitions will be used across the study (Verma, et al., 2021),

a. EV – electric vehicles, in this paper it will be used to refer to both electric vehicles and hybrids.

b. PHEV (Plug in electric vehicle) – electric vehicles capable of zero emissions, can be supplemented with petrol or diesel for long distance trips. They need to be charged (electric supply) to maximise their zero-emission capacity.

c. BEV (Battery electric vehicles) – powered by batteries, use electric motor to turn the wheels and produce zero emission. No petrol or gasoline supplement necessary.

d. Fuel cell electric vehicle (FCEV) – Similar to BEV however in the place of battery there is a fuel cell which uses hydrogen as a transport fuel.

2. CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

This section of the research report is divided into two. First section will investigate the management theories used to address the research questions and the second section is the preliminary factors identified which were used to draft the questionnaires of the semi structured interview.

The first section will also compare these theories to show why TOE framework was chosen and what are some of its limitations. It will also dissect key challenges noted in research and development which have affected the adoption of electric vehicles in South Africa which will be a basis for proposition development for TOE framework. A lot of reference will be made to literature, particularly in countries which are early adopters, businesses which are interested and conducting research, automotive assemblers who are at the forefront of this innovation, and parties which are against adoption. Comparisons with the South African context will be drawn.

2.2. THEORIES ON INNOVATION ADOPTION

Innovation is a practical implementation of an idea, method or new /improved way of doing things. It is a step further than an idea as it has an action and plan behind it. Electric vehicles are thus considered innovations as they have moved past an idea, prototype and now are commercialised.

The rate of adoption of innovation in society has been one of the core studies in academia in social studies over the last two decades. There have been multiple adoption models which have been used to describe, explain and predict this phenomenon (Hart, Ojiabo, & Bartholomew, 2016). Such models include but are not limited to the following,

- Technology- Environment-Organisation, T-O-E (Tornatzky & Fleischer, 1990).
- Technology acceptance model, TAM (Davis 1989)
- Diffusion of Innovation, DOI (Rogers, 1962)

2.2.1. COMPARISON OF RELEVANT THEORIES OF INNOVATION

All these following frameworks have one thing in common: they all look at *Technology adoption or diffusion within a specific group of people*. Of these aforementioned models, only one will be explored and used for the current study namely, the TOE framework model. According to Hart, Ojiabo, & Bartholomew (2016), the TOE model is said to be the common choice because it is broad as it explores constructs in the technological, organisation and the environmental aspects (Gangwar, Date & Raoot, 2014). This has also been noted as both a weakness and strength (Oliveira & Martins, 2011). TAM is one of the common choices of evaluation of technology adoption readiness; however, it only explores the organisational aspects to technology adoption. TAM model was developed in 1989 by Davis (Hart, Ojiabo, & Bartholomew, 2016). It evaluates two primary factors for an individual to accept new technology namely "Perceived ease of use" and "perceived usefulness". TAM however does not consider the environmental aspect. DOI theory is the third common choice of model used to evaluates how fast new ideas can move past an organisation's culture over time (Rogers, 1995). This theory has been used to explain the stages of innovation penetration in an organisation or society as it transitions from innovators, early adopters, early majority, late majority and later adopters. According to Olivier, the first 2,5 % of the people to adopt the ideas are innovators (as shown in figure 2 below), as they are actively involved in shaping the technology i.e. countries at the forefront of EV development (Germany). The most important are early adopters (the 13,5% in fig 2 below) who show the remaining population group that the technology functions, can improve livelihood and give inputs to development for improvements such as Norway, Ireland, China and USA (Oliveira & Martins, 2011).

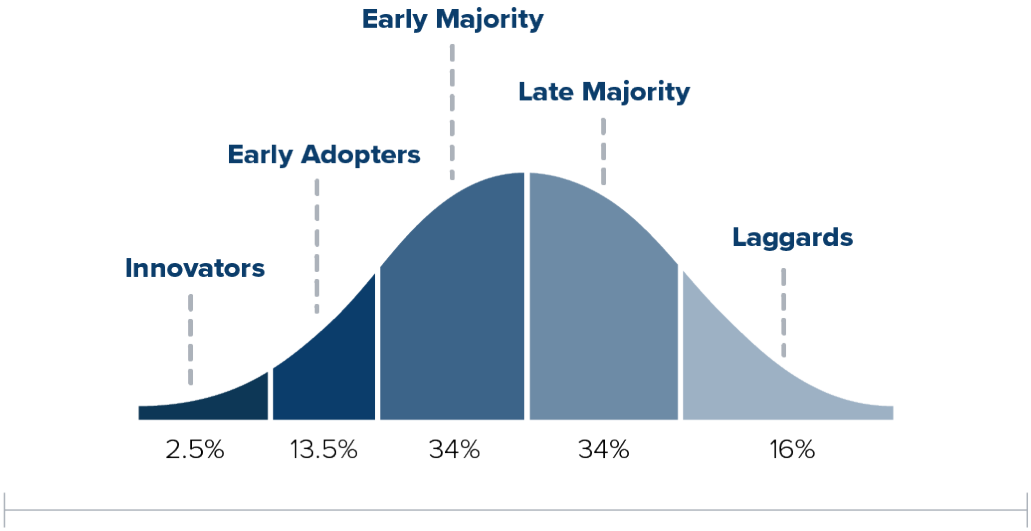


Figure 2: Innovation adoption cycle (Diffusion of innovation model)

DOI has been widely used successfully to evaluate Information technology innovation diffusion in healthcare, military and manufacturing (Brian & Zuva, 2021). However, it doesn't include the environmental aspect like TAM. Only TOE covers the three components of technology, organisation and environmental in its framework.

2.2.2. TOE FRAMEWORK MODEL

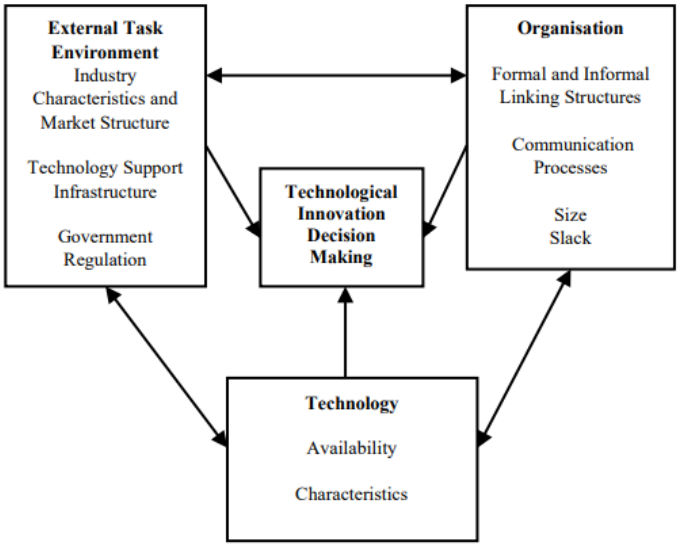


Figure 3. The TOE framework (Tornatzky & Fleischer, 1990)

The *Technology-Organisational-Environmental framework (widely known as TOE)* was first developed by Tornaszky & Fleischer. This is an organisational level theory , as shown in figure 3 above is used to explain the preparedness of an organisation to adopt new innovations by

exploring both internal and external environment (Tornatzky & Fleischer, 1990). It will therefore be used in this research paper to evaluate how the OEM's have prepared themselves for the diffusion of the Electric vehicles technology within the automotive industry. Research shows that the model has been tested in different industries such as manufacturing, logistics, Information systems, retail or health care in different continents such as Europe, America and Asia (Baker, 2011). This therefore shows that the framework has broad applicability and is widely accepted in research as it has been tested through numerous studies and disciplines.

2.2.2.1. REASONS FOR USING TOE FRAMEWORK AS A STANDALONE

TOE has been used in conjunction to other models such as TAM and DOI, as such studies of its suitability for this wide range of application to different fields have thus been conducted. Oliveira (2011) conducted a study evaluating past studies which had been conducted with the intend of evaluating frameworks used for e-commerce or technology diffusion in different parts of the world. Majority of these used qualitative approach (i.e., surveys, interviews etc). He used academic reports, journals and published books. The first section compared studies which used TOE alone and the following section compared studies which used TOE and DOI to evaluate e-commerce adoption at firm level. This study showed that although TOE can be paired with DOI to evaluate technology adoption at firm level, TOE is more than sufficient as a stand-alone model as it incorporates the environmental aspect and has consistent theoretical support (Oliveira & Martins, 2011).

Brian & Zuva (2021) have conducted a study on the comparison of TOE and TAM as standalone theories of technology difussion and also how far they intergrate. Both these studies conducted by Brian and Zuva (2021) and Oliveira (2011) argue that TOE is more than sufficient for evaluting technology difussion as a standalone model as it covers all aspects more adequately than TAM and DOI. The addition of the latter would be optional. Therefore this study only uses TOE framework for evaluation of EV adoption in South Africa.

2.2.2.2. THREE CONTEXTS OF TOE FRAMEWORK AND PROPOSITION DEVELOPMENT

The TOE framework unpacks an organisation's readiness for technology adoption at three levels namely the Technology, Organisational and External environment. In this case the organisation is the South African OEM's. The three levels are explained in this chapter with development of propositions under each subsections.

1. The *technological contexts* of the TOE framework seeks to explain the OEM's ability to not just acquire but use relevant technology. The former is important for process integration whilst the latter is said to be important as it questions the organisation's culture of adoption of new processes and technologies. (Hart, Ojiabo, & Bartholomew, 2016). Firms can develop or buy innovative technology but not necessarily use it which diminishes the benefit it would gain over its competitors. Technology adoption can be a firm's distinctive way of building competitive advantage over its competitors.

   Electric vehicles can be classified as disruptive innovation as they bring about new products, and they now fight for market share with combustion engines and change how client experience mobility altogether. These therefore means OEM's have to build new firm level capabilities and skills. There are new technologies which will therefore be used or implemented to convert from combustion engine assembly plant to an EV assembly facility such as battery production facility or storage area. Also, the EV is a new product itself in this context. This paper will look at EV's entirely from product to process under this category of the TOE framework. Some of the measures under "Technological context" include complexity, reliability, availability of EV's in the context of this paper.

   As already argues in the first paragraph the two factors of importance is ability to acquire and use the technology by an organisation. According to Hart et al (2016), the Technological aspect of TOE framework is related to the user's ability to exploit available resources to explore the potentials of the proposed innovation(s). Hart further argues that technology factors include the availability of internal and external factors such as software and hardware (e.g., EV models, user friendliness and convenience, batteries, reliability, capability, cost implications, quality of software, availability of spare parts, multiple vehicle variants and options available from different OEM's etc.). A study conducted by Zhu et. Al (2003) shows that consumer's adoption leans towards businesses which offer strong and sophisticated technology (state of the art), with good financial competences but still user friendly. Studies show that there is a perceived negative relationship between complex systems and adoption, whilst there is a positive correlation between perceived simplicity, perceived compatibility,

perceived observability, and perceived values (Hart, Ojiabo, & Bartholomew, 2016). These following studies then reinforces that technology remains central to technology adoption as consumers need simpler designs, which are compatible with their values, lifestyles and needs, but is also affordable with latest user-friendly technological advancements. This also means from an OEM perspective how do they then make assemblies simpler for their facilities and tier 1-3 suppliers (supplier development). With these in mind, the following question proposition 1,

H1: How do Challenges in technology development of electric vehicles affect widespread adoption?

2. The *organisational context* of TOE framework seeks to explain the OEM's internal-resources and structures to facilitate innovation adoption such as employee information of the new technology and modes of communication (emails, word of mouth or face to face), organisational boundaries and structures which enable the adoption or even the size of the company. These aforementioned affect adoption as the firm's ability to reorganise its staff structures such as establishment of cross-functional teams working on new capabilities, links of information fostering flexible responsibilities and innovation adoption enablers (e.g., product researchers or analysts) can be change agents in a firm (Baker, 2011). Communication processes and leadership's support can influence adoption of new processes and technology positively. Employees are more likely to come up with innovation if the leadership sets up the culture and environment which encourages it. This is in line with the CEAI model which identifies the top five factors of driving innovation through corporate entrepreneurship in any organisation as the following: *Top management support, worker discretion, time availability, work boundaries, rewards and reinforcement* (Kurakto.D. Hornsby.J, 2014)

   The firm size and work capacity affects innovation adoption as overloaded workers are less likely to think of innovation or implement it. Baker (2011) shows various studies which argue that in the past there was a belief that larger organisations are more likely to adopt innovation than their smaller counterparts, however this argument has been widely disputed by researchers with evidence on multiple organisations of smaller sizes

which have overtime proven to be more innovative than their larger counterparts (Baker, 2011). With this in mind, size will not be considered a factor in this study. This is important as the majority of the 7 OEM's which have facilities in South Africa are much smaller than their larger counterparts in the country of origin.

H2 : How does OEM management age, education and lifestyle (small town or big city living) affect innovation adoption in organisations?

Which then supports the following follow-up hypothesis,

H2.1: The business model of the South African model still appeals to old consumer needs and not the future consumers: How has the model moved or transitioned relative to the direction the world is taking in the automotive industry (i.e EV adoption)?.

This is linked to the argument above which argues that South African business models are still focused on combustion engine vehicles instead of electric vehicles inclusion based on the sales and production facilities output, does this therefore have to do with management support of innovation in the OEM's, the boundaries of work structure and level of autonomy given to employees. Are OEM's organising their facilities for future innovations such as battery plants construction, marketing strategies, use of employees to give input on products and innovate further for the south African market? The reason for H2 proposition is because innovation adoption is made at executive level, and different factors can affect this. As argued using the CEAI model, the OEM workforce can be fairly innovative however only 5 factors have been proven to be effective in fostering an innovative environment. Therefore, according to Kurakto and Hornsby (2014), the model then questions if the lack of change to EV model is at OEM executive level within the organisation.

3. The *environmental context* seeks to look at both the internal and external factors which affect or create an environment which fosters high adoption of new technology. One of these influences is the government's ability to create a conducive environment for trade. The South African automotive industry relies heavily on subsidies from the government and different funds with subsidies such ADPD, AITF etc. (DTI, 2023). This

is common for the most successful automotive industries in the world as they rely on multiple external stakeholder support and those that have not been afforded this benefit have thus perished over time (Deloitte , 2019). This argument is in line with the *Triple helix model* which argues that for successful innovation to take place within a country there needs to be a solid collaboration between the national players (government, regularities), universities and industries (Figueiredo, Fernandes, & Abrantes, 2022). This collaboration ensures skills development, innovation, knowledge building and sharing at three levels in the triple helix model in figure 4 below. Other benefits are seen in the development of enabling policies and infrastructure as it takes a bottom-up approach rather than a top-down approach.

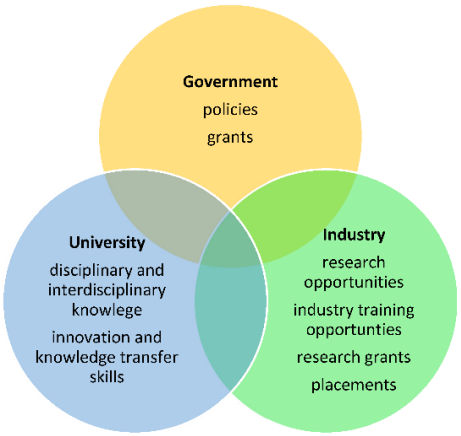


Figure 4: Triple helix model which supports the environmental aspect of TOE.

As argued previously, technology adoption can be a way for a company to build competitive advantage however this can also attract more competitors (i.e., when other companies see innovation from their competitors, this can be a trigger to innovate too) (Baker, 2011). Industry life cycle changes such as a decline or growth stage can trigger strategy re-evaluation initiatives which can lead to innovations (Baker, 2011) . Examples would be OEM's seeing a growth opportunity through a growing EV market and thus expanding their product range to include hybrids or BEV's. Conversely, OEM's could be selling in a stagnating market and thus seek innovative ways to save the brand by venturing into EV's. The triggers for innovation can vary however for enabling environmental conditions remain central to a strategy's success (both internal and external). For example, government can come in handy in fostering relationships for export purposes, facilities such as harbours for swift supply chain and industrial

parks, export and import tax quotas and reductions or even building beneficial international relations with key players in the economy.

The external environment context therefore explores both the micro and macro environments i.e., the different internal and external stakeholder support. This includes government entities and departments, private institutions, investors, partners, amongst many others as noted in the triple helix above. It further looks at competitors' pressure onto the current system. In this instance, does South Africa get pressure from its competitors to adopt electrical vehicles locally and for the markets they assemble vehicles for internationally?

This is closely linked to proposition above on the linkages between multiple stakeholders which would be derived from the multidisciplinary analysis showing their engagement with each other to achieve the same vision within different structures.

H3. How does the lack of a multidisciplinary relation from different stakeholder negatively affected adoption of electric vehicles in South Africa?.

The TOE framework further argues that government's role also affects innovation adoption within a firm. In this context, OEM's that operate within environments where government has setup regulations, clearly defined constraints on industries such as fair competition rules, law enforcements, stringer safety standards, testing or counterfeits restrictions tend to be more innovative. Government play a vital role in setting up policy's and rules of play for industries which can enable innovation adoption. Furthermore, government programmes and incentives can support innovation by developing new skills in the industry which inturn supports the mandate of OEM's, the lack thereof can strip away profitability for OEM's and thus diminish their strategy and ability to innovate. Universities, as external stakeholders can bring about innovative research on alternative materials, efficient processes, knowledgeable workforce, amongst many others.

2.2.3. CRITIQUE OF TOE MODEL

The TOE model has been criticized by researchers to be very generic and hence it is highly adaptable for many industries. It can therefore vary a lot of factors and it would still be applicable (Oliveira & Martins, 2011). This however also remains its strength, as it is a generic

tool which can be adapted to different industries as a basis of refining factors which should take priority interms of focus (Baker, 2011). It is also important to note that finding a universal tool that is as generic as the TOE is also still difficult. Other frameworks that have been developed from TOE or been used to supplement it can therefore address aspects of it which researchers have critiqued. However, TOE still offers a holistic study of innovation penetration at firm level.

According to Brian & Zuva, the drawback of the model is also that it assumes the size of the organisation to be large (Brian & Zuva, 2021). The size of an organisation is however relative because the 7 OEM's are large in South Africa, however on a global scale there is larger units which build larger capacities than the local OEM's. In this context, these 7 OEM's are not small medium enterprise scale based on size of workforce and turnover as per the definition provided by government (South Africa Banking association, 2023).

Brian and Zuva argued the comparability of models such as DOI with TOE as one of the key reasons for its advancements from the time it was published and accepted to the current age. In their study they used TAM (Technology Acceptance Model) and TOE as it was tailored around the IT environment and some of the aspects it needed to cover are not covered in TOE. This is true for many studies in research whereby TOE is used a baseline research tool and a complimentary framework can be deployed to address specific industry factors of the interest of the researcher (Brian & Zuva, 2021). This can be explored in future for a more detailed study tailormade for EV's.

2.3. PRODUCT CHALLENGES

Electric vehicles are mainly classified into four categories based on their source of electricity as described in section 1.9 of chapter 1 (definition of terms), namely:

- Battery electric vehicle (BEV),
- Hybrid electric vehicle (HEV),
- Plug in hybrid electric vehicle (PHEV),
- Fuel cell electric vehicle (FCEV),

The main benefits of the electric vehicles have already been noted in Chapter 1. Amongst the comprehensive list of benefits, this green technology offers consumers with less carbon dioxide as compared to combustion engines ,compact engine (thus offering more space within vehicle), fewer components which foster reliability and easy debugging, less carbon footprint in production and usage (end to end) (Ashkrof, Homem de Almeida Correira, & Van Arem, 2020). As such, this innovation presents consumers a sustainable, efficient, and green alternative as compared to combustion engine vehicles Sanguesa et.al (2021). This section of the paper will look into some of the technological characteristics of EV which affect the OEM's market penetration in south Africa. It will also show what infrastructures are in place such as policies and infrastructures that are in place. Lastly it will develop further propositions for the TOE framework.

2.3.1. GEOGRAPHY DILEMMA IN SOUTH AFRICA

The technology has already been noted to bring notable advantages to end-users and to the environment. The hybrid electric vehicles (HEV) challenges include its energy storage capability, which is limited. It also has longer charging times compared to petrol/gasoline refueling, which deters consumers. This means that HEV's need high specific power (watt/kilogram) and high specific energy (watt. hour/kilogram) to increase the distance travelled and shorten the time for charging (Verma, et al., 2021). Battery electric vehicles challenge is the low distance travel range (range from 100-400 km) depending in the type of battery installed. For longer distances, Verma et al (2021) suggests a PHEV and FCEV. This still presents challenges for geographically dispersed communities such as those in South Africa but are ideal for clustered cities. In South Africa, the provinces are isolated and far apart from each other as per the Group Areas Act of 1950 which placed citizens based on race in specific

residential and business districts. The segregation of one town to the next also presents issues with availability of charging points or the infrastructure in between travel destinations. The ability to charge vehicles at the comfort of one's home present convenience to the customer (Habib, Kamran, & Rashid, 2015). However, the issue for OEM's and consumers is the ability to charge fast in-between travel points.

2.3.2. MATERIALS AND DISPOSAL

Energy sources for electric vehicles vary, these include lithium-ion battery, nickel-metal hydride battery, nickel-zinc battery, nickel-cadmium battery, lead-acid battery, electrical energy storage (capacitors, supercapacitors), hydrogen storage, mechanical energy storage (flywheel), generation systems (fuel cell, solar PV cell, wind turbines, regenerative braking system) (Verma, et al., 2021,pg 15). Their capability and handling is equally different, with lithium-ion and nickel being the most common and preferred battery due to its material availability, costs and high energy capacity (Wang, Wang, & Yang, 2020). The concern for most manufacturers and environmentalists is the after use of batteries and disposal particularly in pure electric vehicles as they do not use any petrol or diesel to supplement energy source, thus using large rechargeable batteries (Mishra, Verma, & Chowdhury, 2021) & (Chen, Cong, & Yang, 2009).

Furthermore, the availability and increasing costs of materials such as platinum, lithium and cobalt for battery production has become a concern. The ability to meet the demand of battery production as electric vehicles ramp up will soon become a concern for battery manufacturers. From the projected demand, a production of 20 million 50 kW fuel-cell vehicles annually will require 250 000 kg of platinum, which is more than the yearly world production. The recycling of materials such as platinum, which is used for battery production, helps to regulate demand and price increase as the mineral is not scarce (more countries have reserves and recycling maintains the system afloat). The scarcity and sudden increase in demand of materials such as lithium (which historically have trivial value) has opened new markets and economic boosts for countries such as Bolivia and Chile (Delucchi, Yang, Burke, Ogden, & Kurani, 2006). The non-renewable factor of these minerals also becomes a concern because once depleted they cannot be regenerated. OEM's are then put under pressure to fund R&D to find alternatives materials for battery production for the future or find ways to recycle and reuse current ones to prolong the current reserves.

With this said, South African platinum reserves contribute 80% of global world reserves. It is recorded to have 63 000 metric tons of platinum reserves as of 2021 statistics, thus ranking number one across the world (Garside, 2022). This is a huge market for the country to invest in battery production in future and battery manufactures supply across the world.

2.3.3. CHARGING

Electric vehicles use any grid power or external energy source using a charging plug. Depending on the watts, it can charge for 6 – 8 hours on a slow charge or 20-40 minutes with a fast charger (Ashkrof, Homem de Almeida Correira, & Van Arem, 2020). This presents a higher refuelling time compared to pouring petrol or diesel. Vehicle charging times varies based on capacity of battery, charging schemes, series/parallel connections used (Verma, et al., 2021). The battery has a battery management system which regulates and controls various parts of the battery such as temperature control, cell equalisation, charging, monitoring; all of which inform the lifespan of the battery and solve the broader safety issues (Duan, et al., 2020). Battery developments remain central to ensuring driving longer distances can be achieved particularly for geographically dispersed communities in countries such as South Africa. From the above arguments, the following question arises,

H4: How has EV adoption been affected by Product development challenges?

2.3.4. PROJECTED DEMAND INCREASE WITH EV ADOPTION

Road and rail are South Africa's biggest means of transportation for trade. Electric vehicles will consume a significant amount of power on the grid. According to a study conducted on the impact of mass-scale deployment of electric vehicles and benefits of smart charging in 28 European countries which form part of the European union; there will be on average a 35-51% increase in power utilisation on the grid if electric vehicles are adopted uncontrollably. All these countries do not have the high population and growth rate that South Africa has, thus the projected range is likely to grow. Furthermore, the study shows that there are smart charging strategies to curb this increase. However various factors such as charging infrastructure, variation in countries power grid capacity, number of electric vehicles and battery densities play an important role (Mangipinto, et al., 2022) & (Habib, et al., 2015). Another study argues that the real benefit of electric vehicles, will only be realised if electric vehicle charging is achieved through renewable energy sources (Kumar & Alok, 2020). This is because, whilst the electric vehicle can achieve zero emission, the vehicle battery still relies on coal generated

electricity to charge/refuel. This therefore defeats the purpose of greener and sustainable technology adoption.

2.3.4. GOVERNMENT POLICY AND INCENTIVES

The automotive industry is considered to be part of the manufacturing sector, and many emerging economies and markets in developing countries use these to advance economic growth. Majority of them rely on extraction and beneficiation of minerals, exports of these goods and transport, industrialisation to create jobs and cultivate local skills (Deloitte , 2019). South Africa is no exception to this notion.

The south African automotive industry has recently adopted a policy which aims to deepen local value chain and embed industry into the local market and economy. In simpler terms, this is to be achieved through expansion of current local industries, investment into existing businesses, localisation of suppliers and increment in exports. This policy adopted by the South African Automotive Masterplan (SAAM) shows that the government and policy makers support innovation and productivity (Deloitte , 2019). This has also been seen in the adjustments made in the criteria for BBBEEE policy for manufacturers and businesses, whereby they are challenged to source more materials, labour, and services locally to access specific score points and avoid penalties. Furthermore, an incentive is given for manufacturers who invest in small and medium enterprises locally to supply for manufacturing (South African department of Trade and Industry, 2019)

According to the Deloitte study, there is a symbiotic relationship between government and automotive industry across the globe: the automotive industry depends on government incentives to improve viability, and the government supports the industry to create economic development (Deloitte , 2019). The lack thereof, can have dire consequences as it was evident in Australian automotive manufacturers, Toyota, Holden, and Ford who closed their production plants due to lack of government support and the inability to survive with low net profit margins. Local suppliers also followed suit and closed shop as their business model was built on supplying for these automotive assemblers (Australian Government Department of Industry Innovation and science, 2018)

Numerous countries have reviewed policies and incentivised companies and individuals to switch to electric vehicles. Norway and Germany are classic examples of countries which offer

these types of aids (i.e. discounts on purchase of electric vehicles as most consumers argue that EV's are more expensive, tax exemption, reduced VAT exemption, reduced license tax, tolls exemption and free parking payable in various European countries Sanguesa et.al (2020). These initiatives are intended to encourage adoption as they reduce the overall running costs of EV's.

Thailand is also another case study which shows great growth over the past 60 years due to increased government support. The country transitioned from being an assembler to being one of the top automotive manufacturing and export hub in its region, by increasing its production by 383% from 2000 to 2017. It has over 31 assemblers and 2000 suppliers thus employing 850 000 workers to produce 2.2 million vehicles per annum for local consumption and export. The key to this growth was through government policies and long-term strategies that are simple, aligned, targeted and dynamic (Deloitte , 2019). Currently, Thailand is amongst the few countries to also be evaluating electric vehicles integration into their production portfolios as they export to foreign markets where demand is rising such as Europe (Suttakul, Wongsapai, Fongsamootr, Mona, & Poolsawat., 2022)

The South African automotive industry enjoys incentives from the government such as the AIS (Automotive investment scheme) which offers a 20-25% non-taxable grant for qualifying investment in productive assets and further 5% for projects such as research and development in South Africa, value addition, tooling or strengthening the industry (Department of trade and Industry, 2021). The automotive policies from the government does not explicitly encourage electric vehicle adoption or production. The SAAM and ADPD (Automotive production and development programme) policies encourages localisation and increased volume through initiatives such as VALA as an extension of the ADPD. VALA, which is short for *Volume Assembly Localisation Allowance* is a policy adopted by SAAM in 2018 which seeks to support local value chain for high volume production to secure more jobs and exports which were estimated to be 14.3% of overall exports and valued at R180 billion in 2018 (Deloitte , 2019). Adoption of electric vehicles is seen when alignment between multiple government departments seek collaboration such as the Green Transport System Strategy between trade and industry, transport department and geography & environment department. On a lower scale, the National association of automotive manufacturers of south Africa (NAAMSA) have a roadmap on how the adoption of electric vehicles will be integrated into the current value chain. This is

the core of the triple helix model. Its initial crucial step is to import more electric vehicles into the country to create more awareness, and establish a market (the 13,5 % of early adopters as per the DOI model shown in figure 2). Current electric vehicles in the country include BMW i range, Nissan Leaf, Jaguar-pace, Mini SE just to name a few. From the literature presented thus far in this section it is evident that:

- Incentives and policies are currently still built around combustion engines production, volume increase and supplier qualification/localisation.
- There is an awareness and plan from industry players and decision makers around the inevitable introduction of electric vehicles in large numbers to the global market, thus affecting the current local automotive market and export sales. South African automotive market exports to all markets, this introduction will take their current market share. Furthermore, as the automotive manufacturing lead in Africa, when does production integrate EV's?
- Lastly, it is evident from NAAMSA's EV roadmap that there is an awareness of the low sales volume of electric vehicles and challenges impeding the adoption locally, this is seen in their roadmap on EV introduction to the south African market.

However, it was already argued through the Australian automotive industry collapse and Thailand automotive industry takeover that government and automotive industry relationship remains central to adoption of technology changes and innovation adoption, economic growth, and job creation. These adoption in these countries was mainly led by research and analysis specific to the conditions of the country. Therefore, the following proposition about the last of studies on South African conditions,

H5: The lack of structured analysis, identifying linkages of implications of EV adoption including poor policy development and adoption in the South African context has affected the adoption of EV.

2.3.5. BUSINESS MODELS OF ELECTRICAL VEHICLE

The business model for electric vehicles market penetration in South Africa across all car dealers, businesses and automotive manufacturers remain central to the objectives of this paper. This informs how much knowledge transfer they invest in the public (i.e., above the line and below the line marketing), customer awareness initiatives and business positioning for

transitioning. The model is also further informed by the business capabilities such as the product innovation and progress in resolving issues in research and development. This section will show some of the selling points of the current automotive dealers with electric vehicle variants and what literature proposes as selling point for market penetration.

A cost comparison study conducted in fourteen cities in the United States over various electric vehicles, hybrids and combustion engines showed that in order for electric vehicles (BEV) to maintain a cost competitiveness, it needs government incentives and subsidies. The hybrid vehicle costs over its lifecycle were supplemented by the petrol usage and were still cost competitive compared to combustion engines. The fuel savings made from battery vehicles is diminished by the high purchase price and the rate of depreciation e.g., battery replacement. Both these issues can be solved by higher scaling which will reduce the average unit price of electric vehicles and its components (economies of scale), and innovation which will prolong lifespan and depreciation of the vehicles (Breetz & Salon, 2018). The aim would be to get EV's to be affordable and more maintenance friendly.

Electric vehicles charging dilemma can be packaged differently with a system thinking to customers, businesses and government. The vehicle to grid (V2G) charging method allows the vehicle to power households and businesses when there is power outages, or feed back to the grid when there is peak demand (thus operating as a storage for electricity) (Habib, et al., 2015). & (Kalwar, Aamir, & Mekhilef, 2015). Therefore, this solves majority of inner-city power challenges and creates a smart city which incentivises power back to grid actions to encourage consumers. This would mean customer incentives to take power back to grid needs to be attractive and electricity pricing would be crucial to achieve this. The initial investment by government to setup charging infrastructure and supplement energy grid with renewable is still necessary before V2G benefits can be realised.

In a quest to reduce the high EV costs thus opening it up to middle class, a study was conducted by Reinhardt et al (2019) to evaluate the use of battery second use (B2U). This was identified as one of the ways to create value and generate revenue for EV manufacturers. The concept allows a new market of second-hand batteries which can be procured at low costs and potential market for suppliers and dealers for remanufacturing, with intention to sell and reuse (Podias, et al., 2018) & (Uttam, Iftekhar, & Daryoush, 2014). This will reduce running costs for EV owners thus making the product more competitive as replacement costs and running costs

are one of the many concerns. The battery life cycle is prolonged through refurbishment and can be sold to customers as it has multiple compatible uses in homes and industries and will ultimately be recycled at the end of cycle. One of the benefits of this method is better resource management which comes from battery second use as less minerals will be consumed in battery manufacturing, thus delaying the uptake and depletion (Reinhardt, Chrstidoulou, Gasso-Domingo, & Garcia, 2019). Furthermore, this delays the disposal of batteries before they reach full potential and also creates jobs in the recycling and refurbishment market.

One of the challenges with the market for electric vehicles is that it is still not growing as expected even with the benefits it offers. One of the reasons for this could be the incompatibility of conventional cars model positioning and electric vehicle's business models positioning. Businesses and dealers, including suppliers need to evaluate the value chain again to integrate electric vehicles as they bring a new business case altogether. The electric model is informed by different factors such as environmental friendliness, charging infrastructures, acquisition costs and driving range.

The segmentation and positioning of electric vehicle product is different altogether to combustion engines. Researchers propose that one of the ways to look at this market infiltration is "electric vehicles aren't replacement of combustion engines, they provide access to revised and wholly new values" (Delucchi, Yang, Burke, Ogden, & Kurani, 2006). An angle of sustainability and green economy creation – which only exists when the charging infrastructure is from renewable energy. South African market is largely still based on fuel engine vehicles which makes up 98% of the total automotive sales, therefore.

H6: How are business models of south African automotive manufacturers, which are still based on combustion engine vehicles impacting EV adoption and market penetration.

2.4. CONCLUSIONS OF LITERATURE

This chapter introduced the management theories and showed how TOE was better suited for the study. It showed the critics in literature of the usage of TOE such as its broad applicability. It further argued the key topics around the adoption of the electric vehicles including product challenges. It further used these challenges to develop propositions for the TOE framework. Electric vehicles bring many benefits to business, economy and environment, however, from literature and different case studies presented there is a need for structured analysis, proper

implementation and policies revision. This section used the triple helix and Innovation adoption cycle to argue the relationship and importance of the three contexts of the TOE (Technology, Organisational and Environmental). The figure below shows how the propositions evaluations will help answer questions of increased technology adoption and diffusion.

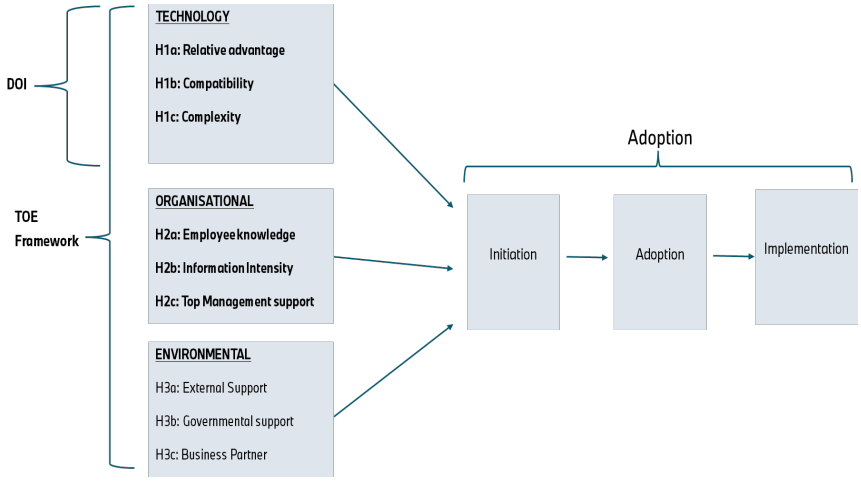


Fig 5. Example of how the DOI and TOE will be used to address key issues in adoption.

Other challenges have been explored such as infrastructure, product and policy. Furthermore, the road transport system, which is at the heart of the country's GDP and inclusive growth strategies is mainly combustion engines. The limitations of EV's in the product itself such as charging infrastructures, depreciation rate, high purchase price, lack of models' variety have been central to business model creation for automotive businesses and suppliers or lack thereof. This is also seen in the current incentives which are still volume based such as APDP. The paper will therefore use the interviews to evaluate how has business models for combustion engine evolved over time and adoption can be improved from an OEM's perspective. The propositions developed will be used for the TOE framework alongside academic literature to understand the impact on OEM's and adoption.

CHAPTER 3: METHODOLOGY

The research will use a qualitative approach to address the research questions. A qualitative research methodology is more concerned with understanding phenomena by obtaining data through open-ended and conversational communication such as focus group discussions or semi structured interviews. It is more suitable for this study as the study seeks to identify and understand reasons for poor EV adoption In South Africa. Qualitative studies are non-statistical and thus can't be ranked /measured, however they bring great insights on topics with little research background, breakthroughs or which researchers have little understanding on (Creswell, 2012).

In summary there are two methods to be used to answer the research questions.

- Semi structured interviews of industry experts (a key component to the methodology for data collection).
- Academic literature to draft questionnaire and find some of the barriers experienced by OEM' which were used as follow-up questions in interviews.

The data will be analysed using thematic approach and a *Mind map visualisation* will be used to show the interlinks. The semi structured interview data will also feed into TOE framework answering the propositions created in the previous chapter.

3.1. SEMI STRUCTURED INTERVIEWS

Semi structured interviews of industry experts, government personnel, and OEM stakeholders will be used to identify and unpack the gaps in South Africa. The number of participants will be limited between 15-20 from different sectors relevant to the research on EV adoption. The experts come from the different OEM's, various government offices, automotive and energy regulators, and academia. The different departments are added to appendices. Their names cannot be divulged due to the ethical consideration. The sample was more targeted based on their current roles and industries they are in (mainly energy, governance, and transport sector).

The semi structured interview is deemed as the best method for the study as it allows flexibility in terms of asking questions of clarity, as opposed to an online survey where participant interaction is limited. Due to the fact that there is no solid base in terms of knowledge of what exactly "widespread adoption of electric vehicle could bring to South African landscape" – challenges with clarity and format were anticipated as such the questionnaire was made as

simplest and elaborate as possible with open ended questions. The interviews will not be done electronically, questions will be open-ended, and participants have time to elaborate on answers and give their views. However, the format, clarity of question was ascertained through testing it on 5 non-experts' participants to gauge conciseness of questioning. The semi structured interviews are important as they address the business and industry level rather than specifics of an organisation.

3.2. MIND MAPPING

The paper has thus far tried to capture the complexities of the EV designs and its implementation implications. To gain a better high-level view, once the semi structured interviews are conducted and comparisons are drawn, a mind mapping visualisation of the emergent themes from multidimensional trends, perspectives, and factors of adoption of electric vehicles and its complexities will be done. A mind map visualises the insights on specific subject matter and builds relationships with other concepts or identifies connections which might not be obvious (Gupta & Kumar, 2022). It is best used for problems which are complex and multifaceted, such as this study. These subfactors are critical to addressing the core themes which then improve successful adoption. However, the list is not exhaustive. This methodology also facilitates concept formulation which is critical in this study as it identifies key stakeholders, actions, and considerations which are not obvious from a western context.

Softwares have been used before such as Mind manager X5 software for mind mapping of smart cities in European union countries (Somers, Passerini, Parhankangas, & Casal, 2014), however no software will be used for this study. The mind mapping will be guided by the semi structured interviews, literature, and proposition findings under the TOE framework.

3.3. RESEARCH PARADIGM

The research at hand uses an interpretivist or constructivism research paradigm. The reason for this is because the adoption of electric vehicles and its improvement does not rely on a single factor but multiple variables/realities. These variables cannot be predefined nor have one single truth but a combination. Therefore, the research seeks to find a guide to what has worked elsewhere and explores what could work for South Africa based on current standing of the country. It explores and constructs recommendations on the combinations of the variables

that readers can use. Furthermore, the research is also based on human interpretation and perspective of the automotive industry.

3.4. POPULATION, DATA SAMPLE SIZE AND SAMPLING METHOD

The population for the study is people in the transport, energy, and automotive manufacturing industry at the time of research. It was limited to relevant sample of people knowledgeable on the topic. This was established through preliminary questions at the beginning of the questionnaire.

The sample size or number of respondents to be used for the study is 15 (minimum) up to 20 (maximum, if necessary), their industry/dept are attached in appendices. According to literature, a qualitative study sample size is determined by the research paradigm to be investigated hence it is decided by the researcher as /opposed to a quantitative study which has more rigid upper and lower statistical limits to be satisfied (Boddy, 2016). According to Eriksson & Kovalainen, it is nearly impossible to know before conducting the qualitative study how much data or information would be needed to adequately formulate themes, this all depends on the richness of the respondents' responses (Eriksson & Kovalainen, 2015). Therefore, the researcher would scan the data at points in time to check if adequate data had been collected to reach conclusive themes or draw conclusions which address the research paradigm.

Creswell argues that five to twenty-five respondents are adequate number of respondents for a qualitative study (Creswell, 2012). Therefore, based on the arguments put forth thus far, the 15 participants knowledge on the matter was more important than the minimum number needed in the sampling. Based on Creswell's argument the 15 respondents are also sufficient.

The participants were rather more targeted and homogenous. They are affiliated with specific industries, automotive OEM's, employers within the auto sector, in related fields in academia, within the transport industry and government organisations too.

3.5. DATA ANALYSIS

The chosen method of data collection is through semi structured interviews with experts. The data will be collected in the form of indepth face to face interviews with allowance for follow-up questions and notes will be written down. These questions will be a mixture of open ended and guided questions in order to formulate and extract essential information for the

benefit of the study. The use of the sample interview questions provides repeated rhythm which allows for themes to be drawn out of the interviews more easily.

The paper uses both inductive and deductive data analysis methods to derive themes from the data collected (Guest, MacQueen, & Namey, 2012). According to Boyatzis, inductive data is related to the data collected without preconceived theories/data whilst the latter is linked to theory and is usually identified prior to data analysis (Boyatzis,1998). As such a thematic approach will be used for data analysis. The emergent themes from the analysis will be used to further identify subfactors of the mind-map and to answer the research questions.

The six-step thematic process is used to analyse the data and derive meaningful themes. The process is as below,

Table 1: Thematic Analysis process (Braun & Clarke, 2006)

	Action description	Expected outcome
Stage 1	Read manuscripts, pay attention to patterns	More detailed noted, refined data, Preliminary codes words/themes.
Stage 2	Analyse where patterns occur and use these to construct codes/ emergent codes	Attention to be paid to how data and emergent patterns address the research questions
Stage 3	Construct themes through combination of similar data	List emergent themes for further analysis
Stage 4	Look at how emergent themes support the theoretical perspectives, identify links if any	Start connecting how the themes are linked and interconnected
Stage 5	Define themes, identify key points which standout, clear interlinks should now have emerged	Indepth Analysis of the themes and contribution to data
Stage 6	Decide which themes make meaningful contribution to the data and interlink based on the patterns and reiterations	Detailed description and interlinked picture of the themes, theories and research questions in desired results

The approach is aimed to take explicitly what the experts have said in the interviews and do a content analysis but also incorporate deduction and use of theories to draw up conclusions.

The reiterative analysis is what will be used to draw links and themes which will be depicted on the mind map visualisation. This above table shows clearly how the research questions will be answered through the qualitative approach.

3.6. MEASURE OF TRUSTWORTHINESS OR VALIDITY

According to Noble & Smith, validity and reliability is hard to ascertain in qualitative studies, however one can assess the trustworthiness of the study (Noble & Smith, 2015). The trustworthiness of the study can thus be ascertained through the use of scientifically accepted theories and methods which have been utilised and tested over time. The TOE framework is a widely accepted theory.

The experts are handpicked due to their long-standing service in the industries they are in and current positions/ work in the relevant industry (energy, automotive, transport etc.). Their profiles are screened to check for relevance to the study at hand. As a second layer of validation, they are asked proof questions initially to ensure they are knowledgeable about the content and thus relevant for the study, though their personal information is not collected or is their position in the chosen sectors Is not captured as per the ethics clearance. Some researcher's use matrices showing participants relevance to study through experience, age or occupation. These will not be used in this study as it will be easier to identify the participation and thus contravening the ethics consideration. The questionnaire was also submitted prior and critiqued by 3 academic staff panelist during the proposal stage to understand how it will adequately answer the research questions. Cypress argues that reviews made by senior experienced academics or peers on questionnaires for qualitative research strengthens its validity (Cypress, 2017).

Noble & Smith argue that the research findings congruency to reality represents their credibility (Noble &Smith, 2015). The use of reliable and well accepted methodologies and/or theories to collect and analyse the data addresses another part of the trustworthiness component. Thematic analysis is a widely studied method used in academia (Braun & Clarke, 2006). The verbal assertion of the participants relevance to the study also gives the study credibility even if their identity or occupation cannot be disclosed. This can be seen from the quality of their responses to the questions.

The specificity of this topic to South Africa makes it hard for it to be transferable to other countries or parts of the world due to different conditions, setups and variables at play. However, there are a lot of insights and knowledge which can be deduced from it which can support other studies or ventures.

3.7. ETHICAL CONSIDERATIONS

In line with the ethical standards upheld by the university of Witwatersrand, and the conditions of the issuance of the ethical clearance – the researcher cannot disclose the identity of the participants. Furthermore, participation was voluntary and all information about the research was provided beforehand. The

3.8. SUMMARY OF METHODOLOGY

This chapter presented the methods to be used for the research. Due to its qualitative nature, it will use semi structured interviews with 15 experts from different sectors. The questionnaire constitutes of a mixture of open-ended questions and closed questions; however, it allows for follow-up questions as it will be conducted in person and not online. The study uses an interpretivist research paradigm. The semi structured interviews will be instrumental in the development of themes using the thematic method of data analysis as shown in table 1 above, which will then be used to answer the TOE framework propositions and draw up a mind map showing linkages of topics which hinder adoption alongside literature survey. These findings will ultimately be captured in a mind map as per figure 5 below.

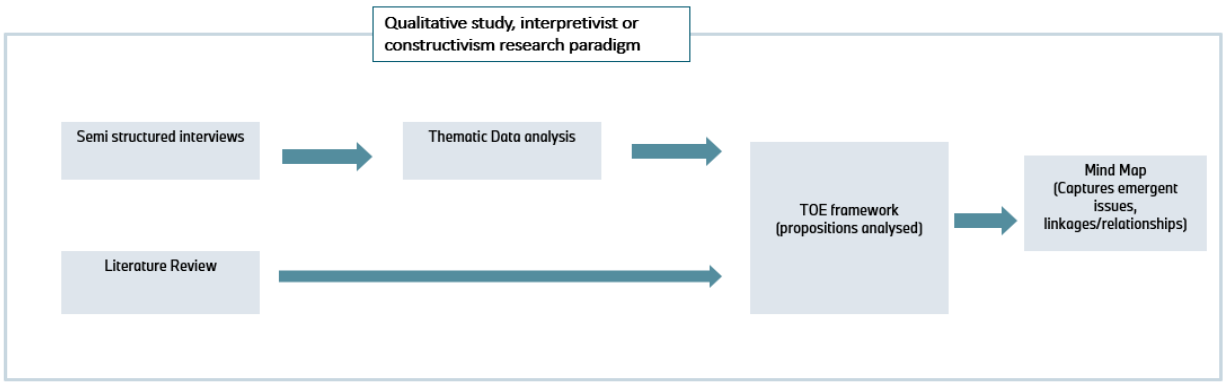


Figure 5: Schematic diagram of methodology followed.

Transferability cannot be ascertained as the study is very specific to the South African landscape at a specific point in time, however the study insights can be used as a starting point

for further study or for reference. The ethical considerations which needed to be observed were also noted and participants occupations and identity cannot be disclosed to ascertain their relevance for the study due to the issues of anonymity. The validity of the research and trustworthiness is ascertained in the repeatability of the methodology for each respondent, and the validation of responses through literature review.

4. CHAPTER 4: RESULTS

This chapter captures the results of the semi structured interviews and literature survey which will then form basis for the emergent themes using the research design and method outlined in the previous chapter. The following section will unpack the findings and discuss them indepth. The emergent themes from the semi structured interview will then visualised into mind map to show some of the key connections identified from the interviews with the different participants as per the thematic methodology.

The questionnaires notes were run through the thematic process to come up with core themes, identifying key points which standout, clear interlinks. The structure of the chapter is to go through the questionnaire findings in relation to how they answered the three TOE factors (Technology, Organisation and Environment). In essence , the section answers the propositions formulated in chapter 2 as per figure 5 under methodology.

4.1. TOE FRAMEWORK

The following TOE framework shows the initial draft of the framework presented in chapter 2. The framework presents multiple factors which can be possible factors for adoption diffusion.

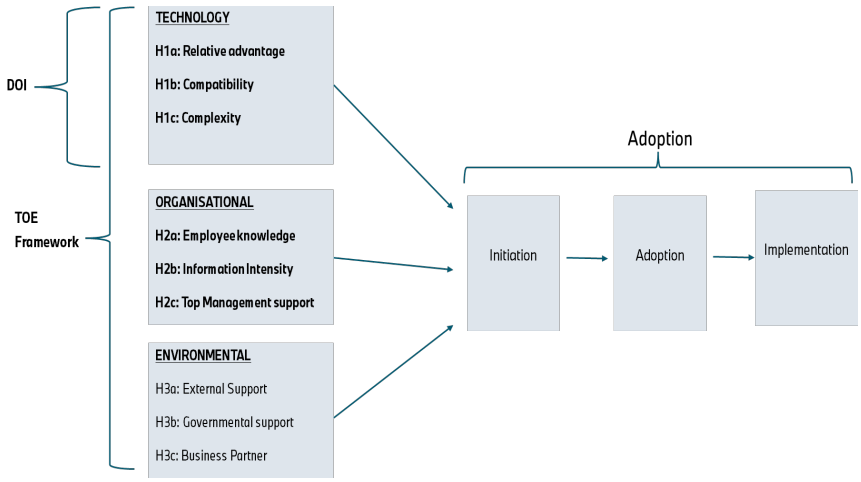


Figure 6.1: Original TOE framework

The following figure 6.2 below shows the TOE framework with emergent themes which are core to improving EV adoption in SA. The propositions developed can be summed up in the following key factors namely – energy complex, charging infrastructure, affordability, government support and policy deployment as per figure 6.2 below.

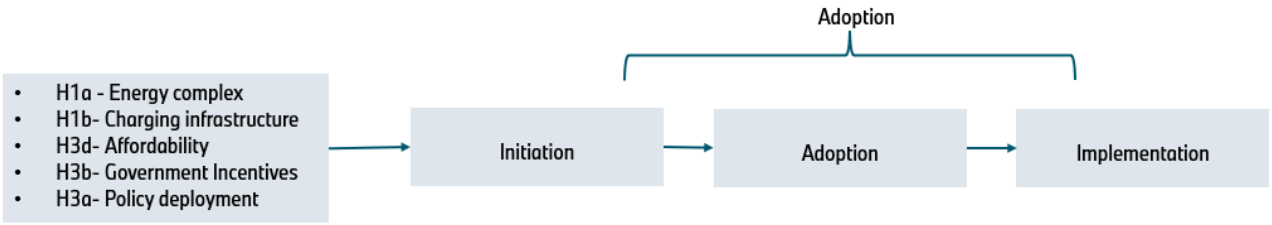


Fig 6.2: TOE framework

The subsequent chapter unpacks what respondents answered the core themes as and main issues derived from them. They are also grouped as the respondents also noted the interlinks and these were emergent from the thematic analysis also. One needs to address both these challenges to make considerable progress towards adoption.

4.1.1. H1a - Energy complex and H1b Charging infrastructure:

On the issues of the energy complex and infrastructure – these were closely interlinked by the respondents. The interviewees noted that the country has good environmental conditions to explore renewable sources of energy such as sun, wind, and water to generate electricity. This is to enable electric vehicle charging using renewable source as the national electricity is overloaded- this is a key component for this adoption to take place locally. They noted that the main reason most consumers don't go for electric vehicle sale is the lack of widespread charging infrastructure across the country. These two issues were noted as the key components for widespread adoption. The charging structures were also noted as an issue because of the geographical dispersion of towns and cities from one another specifically in south Africa, this means consumers need to find charging facilities before a long-distance trip. Sixty percent of respondents suggested hybrid vehicles instead of full electric vehicles as an alternative whilst the country invests in adequate charging infrastructure. Hybrid means consumers can switch between electric and combustion engine vehicles. They noted this as a more feasible model for South Africa than full electric models. The participants noted that if more charging infrastructure was available and not affected by loadshedding then more consumers would then consider the innovation. Three participants identified home charging as a solution but noted that this would still affect consumers if they were affected by loadshedding from the national grid. Only offgrid users can therefore sustainably consider electric vehicles and home charging solutions.

From an OEM perspective, there is a barrier in terms of licencing and investment for nationwide rollout of charging facilities and installation of renewable energy powered systems to ensure reasonable availability. One of the participants noted that this is more of government's role as these charging stations could be universal to all electric vehicles irrespective of model type or brand thus ensuring OEM's can take advantage of the same facilities. Consumers would pay for charging but the service would be available across high-density and low-density areas. The OEMs are then viewed to be impacted by the governments failure to secure large investment to lead such projects (infrastructure) during the early adopter stage as per the innovation cycle presented in chapter 2. This then puts the country under a burden to explore catch-up scenarios for technology development.

4.1.2. H3d -Affordability and H3b-government support:

These two factors, affordability and government support were closely linked to each other throughout the interviews. The participants noted that the government conducts census which show the average affordability results of single households or income earners. Therefore, these can be a good basis for structuring incentive programs for consumers to push adoption. One of the government participants highlighted the key relationship of government in the auto sector and its success. The lack or delayed EV support is evident from the incentives for EV programs. According to the interviewees, affordability is also linked to wide range of models available in the market. Electric vehicles available in the market does not present consumers with a wide range of options for different affordability levels. Ten participants noted that the business models of vehicle sales are still largely still based on combustion engines based on the poor representation of electric vehicles on the consumer market or marketing. The marketing is also still based on combustion engine and a few hybrid models.

4.1.3. H3a- Policy deployment

There were 15 participants interviewed of different backgrounds and from all their responses it is apparent that there is lack of clear EV transitionary policies in trade, automotive industry and manufacturing. They also noted the lack of enforcements in both automotive regulations and government policies. Majority of active policies are still combustion vehicles based and are focused on volume to ensure OEM's remain profitable and the country retains high employment numbers. They therefore need to be reviewed as the combustion market will

soon diminish in the markets the OEM's export to. The respondents had a fifty percent split around whether the government officials background and age affect their bias on issues such as electric vehicle innovation. This was to assess if older generations would push for innovation adoption just as younger generation. Education, upbringing, and career background were noted as more of a factor than age. The other fifty percent noted that the state bodies such as NAAMSA and AITF have younger leaders who give the industry more direction and implement strategies with the OEM's. Therefore, age does affect innovation adoption as the country is more receptive of new technologies now more than ever. This was noted to be evident with the fourth industrial revolution initiatives. Though the country is said to be lagging and playing catch-up, more companies and campaigns are done to fasten the process and develop skills in technology, IT and robotics.

In conclusion the five emergent themes discussed stood out from the semi structured interviews. Other factors which were emergent but did not stand out include management support. The respondents noted that the OEM's have clear strategies to transition and are fostering training and technology adoption in their facilities to change. Therefore, this was not identified as a barrier. Technology complexity was also an emergent theme. However, most respondents mentioned outsourcing until local suppliers can be fully developed. They mentioned focus should go to product development such as batteries to enable full EV transition. The next section shows the key topics and their emergent factors or subfactors in a mind map visualisation.

4.2. MIND MAPPING

The following sections shows a mind map visualisation of some of the key barriers of EV adoption from the 20 participants of the semi structured interviews.

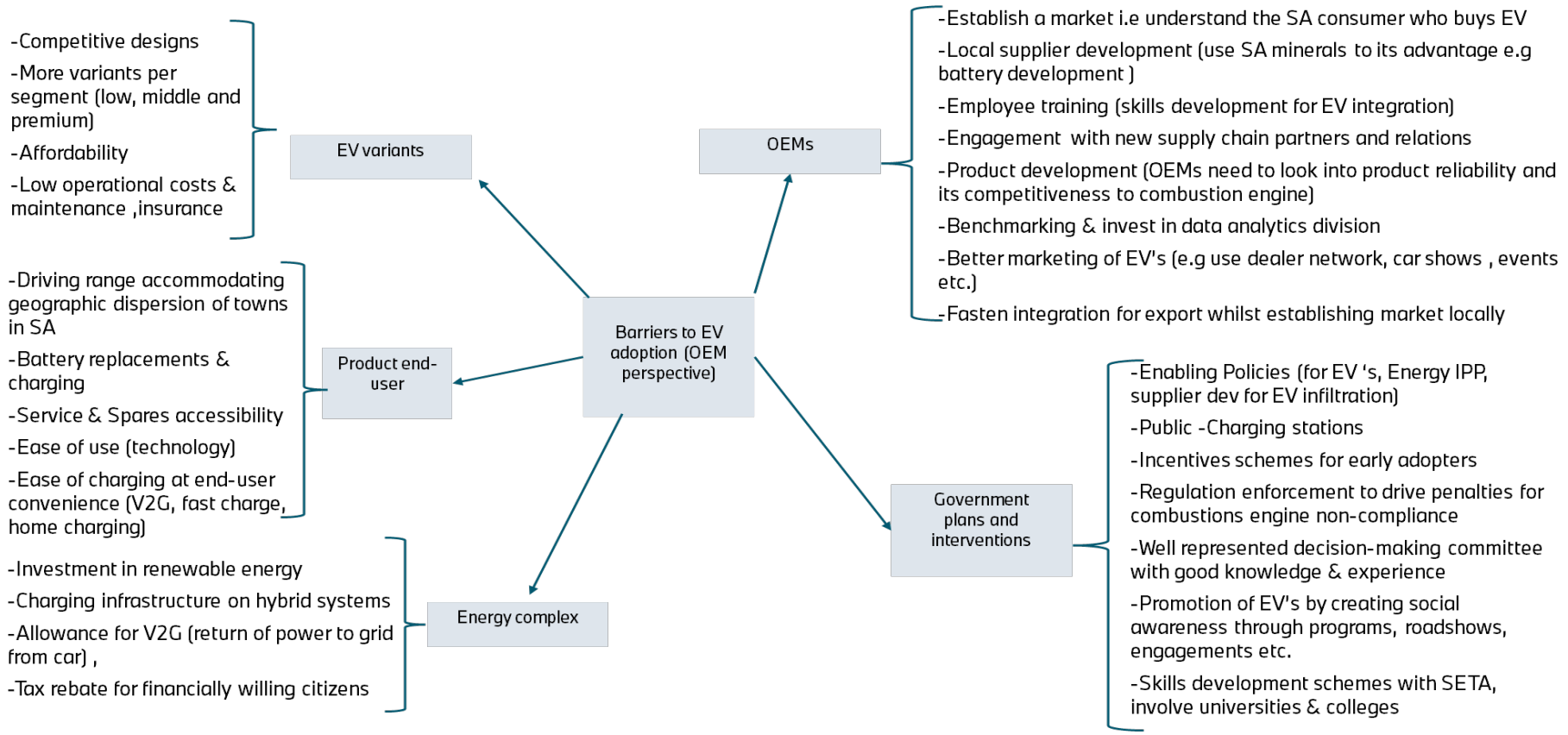


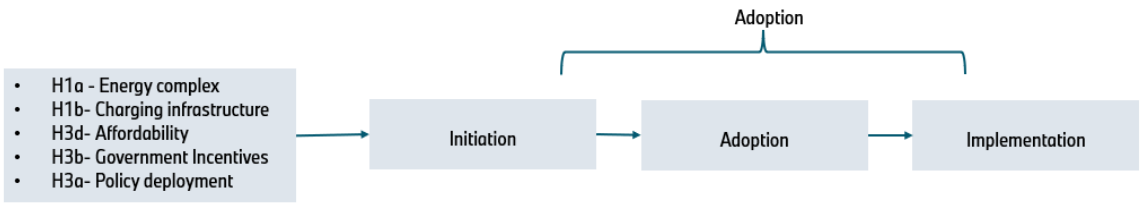
Fig 7. Mind map visualisation of the core barriers to EV adoption from the semi-structured interviews respondents.

In conclusion, the chapter showed the emergent topics from the semi structured interviews identified through thematic analysis. The mind map captured and grouped the issues into the core themes. From figure 6 above we can deduce that the core issues are however these are not ranked according to importance or severity – which is one of the limitations of qualitative studies and future prospect study. The following topics will be unpacked indepth in the subsequent chapters for further analysis.

5. CHAPTER 5: DISCUSSION OF RESULTS AND ANALYSIS

The following chapter will unpack the results presented in chapter 4. It will further look at literature survey to understand how some of the findings can be explored further and implemented successfully.

With reference to fig 6.2 in chapter 4, which is also shown below, these key issues need to be addressed in the context of South Africa i.e., find local solution for local conditions with reference to successes across the world.



Extract of fig 6.2 from chapter 4: TOE framework with only key emergent themes

H1a-Energy complex:

The TOE framework and interviews identifies the **overloaded energy grid** as a barrier to adoption, it however offers opportunities for the country to develop alternative energy sources. The solution of implementing renewable energy sources is a noble one from respondents. Affordability and high gap in wealth distribution in South Africa presents a challenge. The new tax relief incentive programme offering rooftop solar installers for residential homes and businesses tax break is a step forward for affording citizens (Department of Treasury, 2023) This newly passed law seeks to support homeowners and businesses which can afford the installations to install solar panels thus generating power for their consumption and to feedback to the energy grid. In turn this reduces reliance of municipal electricity in order to allow for economic activities to take place, the effectiveness of this tax however is yet to be measured and results might be short to medium term. The above approach also favours EV adoption as less pressure will be put onto the grid thus giving allowance for charging infrastructure and homeowners to consider EV purchase or charging (for those who already have EV's). The paper also argued what leading countries such as Germany and Norway are doing to supplement the energy requirements which come with EV implementation such as

Vehicle-to-grid (V2G), vehicle-to-vehicle amongst others (in chapter 2). Other solutions include IPP enabling and regulation, South Africa has not implemented these in large quantities thus far and can put them in long term strategy.

Charging infrastructures are one of the limitations noted by studies as a key enabler. Respondents noted the lack of charging infrastructure as one of the main barriers for OEMs to sell the idea of EV's to consumers. Chege (2021) argues that this is not the case for south Africa at all but just a perception issue. According to Chege 2021, there is 250 public charging infrastructure in the country in 2021 which are commissioned for public use (Chege, 2021). These infrastructures will not match up to the historical petrol stations across the country, therefore a strategic placement of charging stations need to be done. According to Chege, the number of charging stations however shows that charging infrastructure is not a concern as countries with far less infrastructure for charging have reported higher sales of EV's. The stations may not be small in quantities in the country as per the argument put forth by Chege however geographical dispersion is a factor relative to European countries (Chege, 2021). The respondents further argued the battery driving range and South Africa's dispersed landscape as concern for most consumers. Participants noted that "EV's work best inter-cities or in closely packed metropolitans such as Johannesburg, Pretoria, Ekhurleni and Witbank areas, hence implementation in smaller countries is faster. The town planning or layout affects this and therefore reliable battery technology can be introduced or more infrastructure is implemented to compensate for the geography". The areas further than these inner cities might be an issue as the customer does not have easily accessible public charging infrastructure and the charging kit compatibility to residential home power is affected by loadshedding schedules as per the previous argument. Hence they further suggested hybrid models as the first steps of technology adoption suitable for south African conditions.

<u>H3d Affordability and H3b -Government Incentives</u>

EV affordability is one of the highest barriers to EV adoption. Social factors such as high unemployment rates affecting affordability, which is reported to be at thirty percent in quarter four of 2022 (Trading Economics, 2023). High EV ownership costs has been noted as one of the factors which deter customers to switch over, hence the incentives programs approach in early adopter countries is noted to be functional in the following studies (Suttakul, Wongsapai, Fongsamootr, Mona, & Poolsawat., 2022) (Koch, Ritter, & Rohlf, 2022) (Delucchi, Yang, Burke,

Ogden, & Kurani, 2006) (Razmjoo, et al., 2022) .According to the *Auto Trader Mid-Year Industry Repor*t which is run from Jan 2022 to June 2022, South African consumers of EV's are some of the highest paying vehicle customers due to the lack of incentives offered by the government and OEM's relative to other countries (AutoTrader, 2022). It compared cost of ownership of EV's to combustion engines and EV's purchase costs in SA vs other countries worldwide (both developing and developed). This is also noted as one of the reasons for the lack of acceptance of the innovation from the general public. The high costs of EV's reported by Auto trader above and the low-income per capita further cripples the adoption of EVs by ordinary South African's or the middle working class. Chege shows a study of how a low-middle income South African consumer is excluded in the EV market through these high costs and lack of variety catering for different affordability levels (Chege, 2021). Other countries with tax incentives, assist consumers by reducing cost of ownership. These can include preferential driving lanes and parking bays, reduced SANRAL and toll-fees, reduced licencing renewal fees or charging tariffs (Montmasson-Clair,2022). These have a proven record to work in various countries (Gupta & Kumar, 2022), (Koch, Ritter, & Rohlf, 2022) ,(Habib, et al., 2015), (Ziegler & Abdelkafi, 2022) (Reinhardt, Chrstidoulou, Gasso-Domingo, & Garcia, 2019), however this action needs to be supplemented with consumer studies and viability analysis specific to South Africa. These incentive programs are run between OEM's and government. Therefore, OEM's experience lack of enabling policy and incentives programs as a market barrier in this regard. OEMs can drive this agenda and start the discussions with relevant bodies.

South Africa's high import taxes reported at 25% for EV's and 20% for ICE also deter OEM's and add onto additional costs for consumers (Chege, 2021). Whilst OEMs are trying to challenge this stand, there is a price disparity argument which may open big pricing gaps between EV variants from the same OEM due to differences in policy accommodation. Policy seems to be excluding or rather creating favourable conditions for some EV variants over others (Nel & Inlelsi-Lots, 2022). Nel & Inglesi-lots argues that according to ADPD, local ICE producers qualify for tax rebate which can drive the tax low thus leading to low purchase prices for local consumers however other EV variants are charged the high import tax which inturn is expected to deter consumers even further (OEM's which import their products to South Africa experience high market entry barriers in this regard).

EV variants were noted as a major concern, participants noted that the "availability of options for the different affordability levels of south African consumers is a huge limiting factor. They further noted that operational costs such as services, spares and maintenance market development is also another topic to consider". Other participants corroborated this notion and further argued "there is a huge reliance of the South African market on demo/used vehicles more than newly purchased vehicles". With this said, the EV market will develop slower. Slow penetration will impact OEMs as there will be less spares for the early adopters, which can deter other adopter. Therefore, for OEMs to increase adoption they need to invest in the full end to end supply chain of the EV models, services and components to better support end-users. This affects tier1-3 suppliers and OEM's. The availability of variants and models which appeal to the variable affordability scales of south Africa can be addressed through comprehensive strategic business models by OEMs with the support of government. Participants noted affordability as the highest contributor followed by variants of EV's available on the market. These two factors are linked as an improvement in the available variants in the market would mean different customer segment would have vehicles thus appealing to different affordability levels. This requires collaboration between government, OEMs, and industry leaders (for training and development) corroborated by the triple helix model in chapter 2.

H3a - Policy Deployment discussion:

South Africa has multiple policies which address different aspects of EV adoption. The *Green Transportation Strategy* for South Africa: 2018-2050 and *SAAMP* (South African Automotive masterplan) all outline the manufacturing goals of South Africa and EV market in South Africa as an enabler of transport industry decarbonisation strategy (DTIC, 2021). These strategies have loopholes as they still do not provide a conducive trader environment even for existing OEM's through high import taxes and incentives for local production whilst OEM's deal with unskilled labour force, undeveloped supplier network to handle EV transition, high investment to adapt current facilities and consumers who battle with affordability. The policies therefore could be revised into phases to provide good trading environment for assemblers and consumers with the intention of developing the market prior to enforcing high entry barriers.

A study on leading EV adopter countries such as the US and China was conducted to understand what some of the motivating factors for customers are to switch from combustion

engines to EV was done, it was found that customers were more attracted to incentives as compared to tax rebates (Ou et al.,2019). There was a directly proportional relationship between increased incentives and increased sales. These arguments impact the demand and supply dynamics of the OEM to consumer. Policies in South Africa should therefore consider this inclusion of incentives to drive demand so that OEM's can take advantage of economies of scale and develop a market locally.

Thailand case study titled "*Rooting SA: Strengthening the local automotive industry*" Shows that dynamic policy initiatives by the government (i.e. regular reviews of effectiveness and suitability) have worked well for the country's automotive industry as it responds quicker to industry trends (Deloitte , 2019). The above arguments address two factors: the rigidity of policies for prolonged times in a VUCA era and the policies ability to address the core issues (customer demands thus enabling OEMs). South Africa can use this approach to establish key consumer insights to ensure high adoption takes place in years to come.

The semi structured interviews also showed lack of policy enforcement locally as a barrier. They argue that regulatory bodies do not use environmental push factors for the transition because there is no enforcement of set laws, an example is the need for the country to move from *EU 2 to EU 6* as a reason which could have been used to push EV transition. Multiple participants argue that the country is not pushing limits as it set an EU2 standard whilst other countries are already on EU 6. Furthermore, the EU2 is still not monitored nor are penalties enforced as compared to European countries. EU (Short for European emissions standards) is a set of standards which gives directive to automotive assembler on the acceptable levels of exhaust emissions in new vehicles. Local assemblers need to ensure their vehicles are complaint if they export to European markets, however local markets could be using these to push the green alternative mandate.

In a study conducted by Nel & Inglelsi-lots (2022), it is argued that perhaps policy deployment from the supply side instead of the demand side might yield more results interms of cost reduction for consumer through incentives. This would mean attracting direct foreign investment into the auto sector to resolve these key issues. These can be targets such as adaptation of OEM facilities and their supplier to enable local assembly of EV's over time and assemblers can use EV integration as diversification).

South African government has good infrastructure in terms of media and communication structures. Some of which are also owned by the state. These can be used to drive awareness and acceptability through marketing on national events, sports, etc. In conclusion South African landscape has both enabling factors and areas of improvement which can support OEM's better. Therefore, a prioritisation exercise of all the identified factors and their linkages would be more fitting and yield more results.

The paper has already shown case studies of automotive industries in Thailand and Australia and how the government role is crucial (Australian Government Department of Industry Innovation and science, 2018), (Deloitte , 2019). These sentiments were echoed by the participants as eighty percent of them argued that the government skills development initiatives, SMME development and tax incentives for OEM's indirectly bring positive net effect to the customers and workers of the industry. Fifty percent of the participants argued that the government structure and putting younger people in innovation and technology decision making committees might drive change faster. Hence most respondents argued that government officials career background, education and upbringing played more of a role to innovation adoption than age. They also had young individuals in their offices to drive such topics. The rest of the participants were more inclined to good representation and extensive experience as a good criterion for decision making committee members as opposed to age criteria.

In conclusion, the semi structured interviews, TOE framework and mind mapping, showed the key emergent issues as follows:

From this framework it is evident that Issues that are the most prevalent and believed to lead to higher adoption are the following:

- *Energy complex* which creates uncertainty in consumers ability to charge vehicle when needed. The issue is more on geographical dispersion of cities and batteries inability to cover the long distances. Hybrid models are suggested.
- *Charging infrastructure* which are not sufficient with high driving range. Chege's recent study shows that the charging infrastructure are more than other countries with leading EV adoption.

- Low *affordability* levels and high cost of ownership. *Incentives by government* from either supply or demand side can support this.
- Effective *policy development* and enforcement – Most policies are still argued to be combustion engine based. Available Policy enforcement needs to be prioritised, and development to be EV based can support adoption.

Further studies need to be conducted for the following factors to be unpacked and ranked interms of which ones to be prioritised.

6. CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

From the literature review it is evident that there is numerous policies which seek to address the increase of foreign trade, increased volume production within the automotive industry. There needs to be revision from combustion-based policies to EV. To address EV adoption this can come from either supply side (direct foreign investment for OEM's, Government tax rebates to OEM's, lower import taxes) or demand side (consumer incentives, lower purchase prices etc). This is very important as the policies need to be aligned and not contradictory. It is also evident that there are structures available for incentives and support for the adoption in south Africa such as AITF, APDP and VULA programmes. All of which are volume based and combustion engine based too. The effectiveness of policies needs to be evaluated regularly as the market changes and relevance of policy to south African landscape needs to be addressed at all times. This effectiveness, enforcement and review was noted as a great concern by the participants of the study.

The study also showed that one cannot discuss the EV adoption strategies without addressing the energy complex in the country. Different strategies have been deployed by both developing and developed countries to ease the pressure of the grid such as V2G(vehicle to grid), V2V (Vehicle to vehicle), or renewable energy. Therefore, these are considerations for SA to look into. The grid blackouts also affects both suppliers for parts, and assemblers at Tier 1-3 as much as it affects the consumer who relies on home-charging to charge their vehicle or businesses facilitating the vehicle charging. These are factors identified which inhibit adoption any further from an OEM perspective. Hybrids were identified to be a better alternative than full electric.

Affordability is one of the topics raised within the study. The OEM's high import taxes results in high consumer purchase prices. High purchase prices mean low sales from the market due to affordability issues fueled by high unemployment and unequal wealth distribution in the South African context. Furthermore, ICE and other BEV variants price disparities and high import taxes presents a market barrier for OEM's, which therefore diminishes case studies for other EV variant introduction from an OEM's perspective. Import taxes can be reduced through trade agreements such as AGOA. The lack of wide range variants means different consumer affordability cannot be explored or taken advantage of. Therefore, it is recommended that OEM's introduce a wide range of variants for different consumer segments, but above all else

government needs to look into enabling trade agreements for EV transition and reducing tax for buyers.

With regards to the research questions:

- How is EV adoption affected by stagnating or slow product development?

  The only product development issue which was raised as central to the EV adoption as per the semi structured interviews is the "battery development". This is a huge determining factor due to the dispersed geographical landscape of the country and the time spent charging vs driving range however it is a universal issue. The long driving ranges were argued more from a charging infrastructure as opposed to the battery development perspective. OEM's would need to also import different variants into the country and market the products to cater for different customer needs.

- How has South African automotive landscape transformed to accommodate the introduction of EV designs in the market? i.e., policy, business models, etc, ?

  The policies, incentives and plans in place to facilitate the transition are still combustion engine based. Therefore, they have not transitioned. Therefore, there is lack of transformation or slow transformation, the plans need to be fast tracked through awareness, education, public infrastructure such as bus running on EV technology, and also collaboration between industry and academia. There is a lot of inference South Africa can draw from other countries which can support its plans, the collaboration and inclusive approach will work best. Phase rollout is also another way to ensure a smoother transition coupled with policy effectiveness reviews.

This report echoes one thing throughout the pages, that the *EV market in South Africa might be marginal currently but it presents endless opportunities for businesses and investors if there is collaboration between industry, government, and education sector.* Yes, there is evident barriers to adoption however the study shows that an inclusive approach can help with market development. Approach for implementation needs to be stepwise and further studies need to be conducted to rank issues identified.

My recommendations would be for OEM;s to seek a bottom up approach to policy development particularly for EV in the relevant forums such as sittings with local /regional

government, NAAMSA (for EV market development and industry maturity), AITF and ADPD (for incentives). The trade industry and transport industry government officials would also be great collaborators with OEMs to address high tax for EV owners locally, trade breaks to enable more exports etc. The OEM's can pull the government and its state-owned entities in to enlighten them of current and future need through strategy meetings or already established forums. From a timing perspective, Policy development is more of medium term to long term strategy discussions.

Another recommendation would also be using public transport transformations to EV to build more awareness and marketing this will assist in market penetration and consumer education thus building a positive outlook on EV's. example would be making public buses hybrids, taxis etc. An immediate response for OEM's would also to ensure EV products form part of dealerships, car expos on displays, or drive testing etc. This will improve product education and give customers an EV experience. Furthermore, it will ensure the issue of affordability is addressed as the different income earners will be catered for. This would be short term to medium term timing implementation.

Energy complex could be resolved by OEM's by investing in charging stations that are powered by renewable energy thus ensuring 100% availability. Further to this, the OEM's and academic institutions can collaborate and develop universal chargers compatible with most models to ensure consumer convenience. This is a medium-term action implementation topic.

6.1. AREAS OF POTENTIAL FUTURE STUDIES

The following section seeks to guide academics and government or key industry decision makers on where to invest in research and development to further the study on electric vehicles.

The barriers for OEM's breakthrough the EV market into south African automotive industry can be broken down further. The study can be quantitative and rank these issues accordingly to ensure prioritisation.

Future studies can be conducted using the TOE framework on one of the seven OEM's looking at a qualitative approach which assesses the firm's appetite and ability to adopt innovation (EV or other future derivatives of EV). This qualitative approach will show instantly where the OEM's can start addressing issues and prioritisation of topics. Researchers would need access to employees for surveys/interviews, company information, and an acceptable sample to reach such a conclusion.

Customer perspective is also one of the areas of future studies for this research. As much as EV's have developed in western countries, it is important to understand the local customer and get their perspective on the adoption too. This study is important to understand and explain the low EV sales figures for years and therefore how they can be improved.

A lot of the arguments in academia have been centralised around enabling policy whilst the market is still being developed especially for countries such as India, Morocco and South Africa. Future studies can look at policy effectiveness of current adopted policies and design policies for EV adoption or how to ensure effective policy implementation for new technologies. To enable catch-up scenarios too.

References

Amit, R., & Zott, C. (2001). Value creation in E-business. *Strategy Management*, 493-520.

Ashkrof, P., Homem de Almeida Correira, G., & Van Arem, B. (2020). Analysis of the effect of charging needs on battery electric vehicle drivers route choice behaviour: a case study in the Netherlands. *Transportation research part D: Transport and Environment*, 78.

Australian Government Department of Industry Innovation and science. (2018). *Transitioning Australia's automotive manufacturing industry.* Retrieved from Automotive industry update: https://www.industry.gov.au/funding-and-incentives/manufacturing/transitioning-australias-automotive-manufacturing-

AutoTrader. (2022). *Car Industry report : Mid year report Jan 2022-June 2022.* Johannesburg: AutoTrader.

Baker, J. (2011). *The Technology-Organisation-Environment Framework.* Germany: University of Hamburg.

Bhakat, R., & Marroun, S. (2022). *Investigating the Viability of implementing Electric Freight vehicles in Morrocco: Using an intergrated SWO PESTEL analysis in combination with Analytical Hierachy process.* Morrocco: Abdelmalek Esaadi University .

Breetz, H., & Salon, H. (2018). Do electric vehicles need subsidies? Ownership costs for conventional, Hybrid and electric vehicles in 14 US Cities. *Energy Policy*, 238-249.

Brian, J., & Zuva, T. (2021). A Review on TAM and TOE Framework Progression and How These Models Integrate. *Advances in Science, Technology and Engineering Systems Journal Vol. 6,*, No. 3, 137-145.

Chaturvedi, B., Nautiyal, A., Kandap, T., & Yaqoot, M. (2022). Projected transition to electric vehicles in India and Impact- on stakeholder. *Energy for sustainable Development* , 189-200.

Chege, W. (2021). *Electric vehicles market intelligence report (Report No. EV MIR 2021 31 3 21).* 5 February 2023: Green Cape.

Chen, H., Cong, T., & Yang, W. (2009). Progress in electrical energy storage system: a critical review . *Progress in Natural science*, 291-312.

Creswell, J. (2012). *Qualitative inquiry and research design: Choosing among five approaches:.* Thousand Oaks,CA: Sage Publications.

Deloitte . (2019). *Rooting SA: Strengthening the local automotive industry.* South Africa: Deloitte Touche Tohmatsu Limited.

Delucchi, M., Yang, C., Burke, A., Ogden, J., & Kurani, K. (2006). An assessment of electric vehicles. Technology, infrastructure requirements, greenhouse gas emissions, petroleum use, material use, lifetime cost, consumer acceptance and policy initiatives. *Philosophical transactions.Series A, Mathematical, physical and engineering science*, 372 https://royalsocietypublishing.org/doi/10.1098/rsta.2012.0325.

Department of trade and Industry. (2021, July 01). *Automotive Investment Scheme Ammendment.* Retrieved from Automotive incentives: http://www.thedtic.gov.za/financial-and-non-financial-support/incentives/automotive-investment-scheme/

Department of Treasury. (2023). *South African Solar Tax incetive For individuals.* Pretoria: GovZA.

DTI. (2023, January 13). *AIS.* Retrieved from Automotive Incentive Scheme: http://www.thedtic.gov.za/financial-and-non-financial-support/incentives/automotive-investment-scheme

Duan, J., Tang, X., Dai, H., Yang, Y., Wu, W., Wei, X., & Huang, Y. (2020). Building safe lithium-ion batteries for electric vehicles : a review . *Electrochem Energy Rev*, 1-42.

Eriksson, P., & Kovalainen, A. (2015). *Qualitative methods in business research: A practical guide to social.* Thousands Oaks,CA: Sage Publications.

Garside, M. (2022, March 28). *Staistica, Chemicals and resources*. Retrieved from Mining, Metals & Minerals: https://www.statista.com/statistics/273624/platinum-metal-reserves-by-country/

Gupta, A., & Kumar, H. (2022). Multidimensional perspective on electric vehicles design: A mind map approach. *Cleaner engineering and Technology*.

Habib, S., Kamran, M., & Rashid, U. (2015). Impact analysis of vehicle-to-grid technology and charging strategies of electric vehicles on distribution netwroks- A review . *Journal of power sources* , 205-214.

Hart, O., Ojiabo, U., & Bartholomew, C. (2016). Using T-O-E theoretical framework to study the adoption of ERP solution. *Cogent Business & Management*, 30-45.

IEA. (2021 b). *Global EV Data Explorer.* Paris, France: International Energy Agency.

IEA. (2021a). *Accelerating ambitions despite the pandemic.* Paris,France: International Energy Agency.

IT-Web. (2022, Oct 20). Retrieved from State-owned EVs to pave way for SA's e-mobility future: https://www.itweb.co.za/content/dgp45vaBB3X7X9l8

Jasper Solar Power . (2020). Retrieved from Renewable Technology : https://www.renewable-technology.com/projects/jasper-solar-power-plant-northern-cape-kimberley/#:~:text=The%2096MW%20Jasper%20solar%20power%20project%20located%20in%20Northern%20Cape,of%20clean%2C%20renewable%20energy%20annually.

Kalwar, K., Aamir, M., & Mekhilef, A. (2015). Inductively coupled power transfer (ICPT) for electric vehicle charging - A review. *Renewable and sustainable energy reviews*, 462 - 475.

Koch, N., Ritter, N., & Rohlf, A. E. (2022). When is the electric vehicle market self sustaining? Evidence from Norway. *Energy Economics*, 110.

Kruger, S. L. (2015). Current issues in the transport and supply-chain. *Journal of Transport and Supply Chain* , 220.

Kumar, R., & Alok, K. (2020). Adoption of electric vehicle: a literature of reviw and prospects for sustainability. *Journal of cleaner production* , 45-52, https://doi.org/10.1016/j.jclepro.2019.119911.

Malinga, S. (2020, 07 April). *ITWeb*. Retrieved from Govt policy, range anxiety hinder EV adoption in SA: https://www.itweb.co.za/content/xnklOqzL5p974Ymz

Mangipinto, A., Lombardi, F., Sanvito, F., Pavicevic, M., Quoilin, S., & Colombo, E. (2022). Impact of mass-scale deployment of electric vehicles and benefits of smart charging across all European countries. *Applied Energy*, 312.

Mishra, S., Verma, S., & Chowdhury, S. (2021). A comprehensive review on developments in electric vehicle charging station infrastructure and present scenario of India. *Sustainability*, 1-20.

Mo, T., Lau, K.-t., Li, Y., Poon, C.-k., Wu, Y., Chu, P., & Luo, Y. (2022). Commercialization of Electric Vehicles in Hong Kong. *Energies* , 15(3):942. https://doi.org/10.3390/en15030942.

Nel, J., & Inlelsi-Lots, R. (2022). *Electric Vehicles Market and Policy Conditions: Identifying South African Policy "Potholes".* Pretoria: University of Pretoria.

Noble, H., & Smith, J. (2015). *Issues of validity and reliability in qualitative research. EvidenceBased Nursing,.* 34-35: 18(2).

Podias, A., Pfrang, A., Persio, F., Kriston, A., Bobba, S., Mathieux, F., . . . Boon-Brett, L. (2018). Sustainability assessment of second use applications of automotive batteries: Ageing of Li-Ion battery cells in Automotive and Gr0d-scale applications. *World Electric- Vehicle Journal*, 1-15.

Razmjoo, A., Ghazanfari, A., Jahangiri, M., Franklin, E., Denai, M., Marzband, M., . . . Maher. (2022). A Comprehensive Study on the Expansion of Electric Vehicles in Europe. *Applied Science*, 290, https://doi.org/10.3390/app122211656.

Reinhardt, R., Chrstidoulou, I., Gasso-Domingo, S., & Garcia, B. (2019). Towards sustainable business models for electric vehicle battery second use: A critical review . *Journal of Environmental Management*, 432-446.

Sanguesa, J., Torres-Sanz, V., Garrido, P., & Martinez, F. &.-B. (2021). A review on electric vehicles: Technologies and Challenges. *Smart Cities* , 373-405.

Somers, J., Passerini, K., Parhankangas, A., & Casal, J. (2014). Using mind maps to study how business school students and faculty organise and apply general business knowledge. *International Journal of management education*, 1-13.

South Africa Banking association. (2023, January 30). *SME*. Retrieved from https://www.banking.org.za/what-we-do/sme/

South Africa Energy. (2017, 07 21). *South Africa Energy* . Retrieved from South Africa Coal: https://www.worldometers.info/coal/south-africa-coal/#:~:text=South%20Africa%20holds%2035%2C053%20million,173.3%20times%20its%20annual%20consumption.

South African department of Trade and Industry. (2019). *Codes of good practice on Broad Based black Economic Empowerment.* Government Gazzette, no 41287.

Spalding-Fecher, R. (2002). *Energy and energy policies in South Africa: an overview.* Cape Town: National Energy research center .

StatsSA. (2022, June 06). *2020 Mid-year population estimates*. Retrieved from https://www.statssa.gov.za/?p=13453

Suttakul, P., Wongsapai, W., Fongsamootr, T., Mona, Y., & Poolsawat. (2022). Total cost of ownership of internal combustion engine and electric vehicles: A real world comparison for the case of Thailand. *Energy report*, 545-553.

Tornatzky, L., & Fleischer, M. (1990). *The Processes of Technological Innovation.* Massecheuts: Lexington.

Trading Economics. (2023). *South Africa Unemployment Rate*. Retrieved from https://tradingeconomics.com/south-africa/unemployment-rate

Uttam, K., Iftekhar, A., & Daryoush, H. (2014). Quantifying economic benefits of second life batteries of gridable. *Electric power and energy systems*, 577-587.

Verma, S., Mishra, S., Gaur, A., Chowdhury, A., Dwivedi, G., & Verma, V. (2021). A comprehensive review on energy storage in hybrid. *A Journal of traffic and transportation engineering*, 621-637.

Wang, L., Wang, X., & Yang, W. (2020). Optimal design of electric vehicle battery recycling network – From the perspective of the electric vehicle manufacturer. *Applied Energy*, 275.

WWF South Africa's policy and Futures Unit. (2017). *Transport emissions in south Africa .* South Africa, Cape Town: WWF.

Yang, A. &. (2021). A comprehensive review on electric vehicles intergrated in virtual power plants. *Sustainable Enerfy Technologies and Assessments*, 48.

Ziegler, D., & Abdelkafi, N. (2022). Business models for electric vehicles: Literature review and key insights . *Journal of cleaner production*, 330.

Appendices A

This is the list of respondent's industry /department. This is aimed at showing the relevance of these target group to study.

Respondent number	Industry/department
Respondent 1	Supply chain and logistics specialist
Respondent 2	AITF consultant
Respondent 3	Energy generation industry consultant
Respondent 4	OEM 1 – Business Strategy Manager
Respondent 5	OEM 2 – General Manager
Respondent 6	OEM 3 – Manager (Access to Market)
Respondent 7	OEM 4 – Production Manager (Assembly)
Respondent 8	Supplier development specialist (local parts)
Respondent 9	OEM 5 – Manager (Distribution)
Respondent 10	AGOA – Business profitability specialist
Respondent 11	Energy generation industry – consultant engineer
Respondent 12	OEM 6 – Business Optimisation and development Lead
Respondent 13	Academic – Transport (logistics and Supply chain -UJ)
Respondent 14	QMT – Local parts Management & supplier development
Respondent 15	ADPD specialist (OEM based)

APPENDICE B

B. QUESTIONNAIRE USED FOR SEMI STRUCTURED INTERVIEWS

This section is meant to sample the questions to be asked in the interviews.

Sample size – 15, population -20

Participants (in automotive industry (OEM's), Specialist, Industry analysts, government official involved within the automotive industry, academics knowledgeable on the subject matter, Automotive funding bodies such as AITF, ADPD etc.)

Time for interview – 45 minutes to 60 minutes

Format of interview: Semi structured interview

Generic

1. Do you know about electric vehicles or hybrid vehicles such as PHEV, BEV etc. (Yes/No)

(The aim of question is to determine relevance of participant to study – If the answer is No, then there is no need to continue, if yes, then interview continues).

Technology

2. What are the selling points of vehicles in south Africa? –
   a. Costs,
   b. Performance,
   c. Brand alignment,
   d. Technology

   2.1. How has technology affected the choice of vehicle choice for consumers?

   2.2. How has costs affected the choice of vehicle choice for consumers?
   -EV's are said to have high purchase costs and running costs if not subsidized? How would this affect EV penetration in the south African market?

   2.3. What measures have been put in place or should be put in south Africa which enable access to vehicles with higher technological advancements such as EV's?

   2.4. Is there relationship between simpler designs and technology adoption and or costs?

3. The charging infrastructure in south Africa is one of the top 5 in the world, which is higher than most countries with higher EV adoption, does charging infrastructure then form part of the reasons for poor adoption?

4. Have the current business models for the 7 South African OEM's and their partner network positioned themselves well to develop internal capabilities for this innovation? This includes suppliers, dealer network and assembly plants?

5. How has that been successful? In the reference to the Question above

The idea is great looking at global warming but from a customer 's perspective it is a process filled with a lot of uncertainty within a volatile environments/market.

Environment

6. Some of the major players in industry include the government as policy makers, industries leaders – how can these stakeholders play an active role in adoption of electric vehicles or green transport system?

7. How can the transport industry be decarbonised quicker, in order to achieve the green strategy?

    7.1. What stakeholders are necessary to achieve this?

    7.2. What kind of alliances and resources are then in place for achievement of the following?

8. How would electric vehicles and energy complex in South Africa work hand in hand, especially with an overloaded grid?

9. Charging technology for EV's offer convenience to users by offering a home charging package, how does penalties imposed onto off grid electricity users affect transition to greener society?
10. Green transport strategy and policies to decarbonise the transport industry are slowly being developed across the world and have played a major role in countries such as Norway and Thailand whereby adoption of EV's is high, how does effective policy development and enforcement play a major role in the adoption of EV's in South Africa,

    10.1. How does policy enforcers ensure success?

Organisation

11. In the past 4 years – the purchase of electric vehicles in the past years has been ranging between 50 – 158 across the whole country. What is your take on EV adoption in South Africa?

11.1. What is hindering the adoption of EV's in the South African market?

11.2. Of the following social factors which are affecting adoption the most in South Africa? - Rank highest to lowest

a) Income per capita
b) Level of education
c) Age

12. Please elaborate on the choice of the ranking above.

13. In your view, What are the main determining factors for new products and technology adoption? (Choose 1)
    a. Innovative features and design,
    b. Sustainable and Green technology,
    c. Cost effectiveness,
    d. social compatibility of innovation e.g compatibility with values

14. How does society's per capita income influence technology adoption?
    High capita is same, high or low (Choose 1)

    (In 2021, South Africa's per capita was $6.440, in 2020 it was $5.656 and in 2019 it was $6.625)

15. Given South Africa is ranked amongst the highest unequal countries in terms of wealth distribution, how does this affect the rate of new technology adoption?

16. According to Hart, Ojiabo, & Bartholomew (2016) The demographic composition of decision-making committees in policy development committees influences rate of technology development. How true is this statement?
17. Interms of innovation adoption, which one of the following ranks the highest in the South African society's middle class's choice of mobility or vehicle purchase? Bearing in mind that the bulk of South African's are ranked as middle class or poor.

    a. Design
    b. Variation of models available
    c. Availability of support (insurance, parts, services)
    d. Affordability
    e. Social class
    f. Per capita income (affordability)

18. Does the region or community setups consumers stay in affect their adoption behaviours? i.e. Inner city vs rural areas.

19. Does education levels inform consumers likelihood of technology adoption especially a technological innovation?

Policy & Business Model

20. How does the 7 automotive OEM's operating in South Africa and their supplier network including dealership position business strategy to be profitable? (* i.e selling strategy for combustion engine vehicles)
21. What stakeholders play an essential role in the achievement of the above question?
22. What role does enabling policies play in this sector given that transport plays a major role in the economy and trade and industry?

    a. With that said, How has South Africa tackled the implementation of enabling policies?
    b. Does poor policy implementation affect functionality and profitability of the transport sector, in this context?
    c. Is the poor EV adoption in South Africa affected by the poor policy implementation by government and policymakers?
23. How has South African automotive assemblers and dealers positioned their business for the introduction of the EV within the country?
24. In your view has the adoption of electric vehicles and their infiltration of current market been satisfactory ? (Yes/No)

25. If No, How do you perceive we can remedy the situation and sustainably transition towards higher adoption for the EV innovation? (rank in order of importance)
    a. Increased Social awareness (marketing),
    b. Better product development,
    c. Improved supporting infrastructure,