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The readiness of the South African automotive industry for the Fourth Industrial Revolution

Poswa, Singathwa

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The readiness of the South African automotive industry for the Fourth Industrial Revolution

Name: Singathwa Poswa

A research report submitted to the Wits Business School in the University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in the field of Innovation Studies

Johannesburg, 2024

ABSTRACT

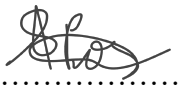
The Fourth Industrial Revolution (4IR) represents a paradigm shift marked by the rapid evolution of technologies such as artificial intelligence, robotics, and the Internet of Things, with profound implications for the automotive sector. The Fourth Industrial Revolution has the potential to fundamentally change how vehicles are designed, manufactured, and serviced. South Africa's automotive industry is a critical sector of the country's economy, employing over 110,000 people and contributing over 7% to the country's gross domestic product (GDP).

This study examines the level of preparedness of the South African Automotive Industry for the Fourth Industrial Revolution. The research employs semi-structured interviews with 12 industry participants. Findings indicate that while South African companies have begun integrating 4IR technologies, significant hurdles such as skill shortages, low investments in Research and Development (R&D), and implementation challenges persist. However, 4IR presents an opportunity for South Africa to transform its automotive industry and position itself as a global leader in the production of advanced, technology-enabled vehicles. The implementation of 4IR in the South African automotive industry will require significant investment in research and development, education and training of workers, and a comprehensive strategy for the adoption of 4IR technologies.

Keywords: *Industrial Revolution, Industry 4.0 automotive, technology, innovation, catch-up, Secondary Innovation Artificial Intelligence*

DECLARATION

I, Singa Poswa, declare that this dissertation is my own unaided work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of Innovation Studies at the Wits Business School in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other University.

Signature: ……..

On this 29…… day of ……March……20 …24……..

Singathwa Poswa

Name

DEDICATION

To my family and the people who have supported me throughout my academic journey. Your constant encouragement and belief in me have been the driving force behind my success. I dedicate this thesis to you, and I hope it makes you proud.

ACKNOWLEDGEMENTS

I would like to extend my sincere gratitude to my mentors who have been a constant source of guidance and support throughout my academic journey. I would also like to express my heartfelt gratitude to my supervisor, whose encouragement and feedback have been invaluable in shaping the content of this thesis.

Moreover, I would like to extend my appreciation to my friends and family, whose love and encouragement have been a constant source of inspiration. Their unwavering support during the ups and downs of my academic journey has been a significant factor in helping me reach this milestone.

I would also like to recognise and thank my classmates and colleagues for the valuable feedback that helped enhance the quality of this thesis.

Finally, I would also like to thank the research participants, whose valuable insights and perspectives have helped me gain a deeper understanding of the topic. Without their participation, this research would not have been possible.

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LIST OF ABBREVIATIONS AND ACRONYMS

1IR	– First Industrial Revolution
2IR	– Second Industrial Revolution
3IR	– Third Industrial Revolution
4IR	– Fourth Industrial Revolution
AI	– Artificial Intelligence
AITF	– Automotive Industry Transformation Fund
APDP	– Automotive Production and Development Programme Authority
CPS	– Cyber-Physical Systems
GDP	– Gross Domestic Product
HHCL	– Hangzhou Hangyang Co., Ltd.
ICT	– Information and Communication Technology
IoT	– Internet of Things
IR	– Industrial Revolution
merSETA	– Manufacturing Engineering and Related Services Sector Education and Training
MIDP	– Motor Industry Development Programme
MNC	– Multinational Corporation
NEV	– New Energy Vehicle
OEM	– Original Equipment Manufacturer
OES	– Original Equipment Supplier
PLC	– Programmable Logical Controller

R&D – Research & Development

SA – South Africa

SAAM – The South African Automotive Masterplan

SME – Small and Medium Enterprise

VAA – Vehicle Assembly Allowance

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CHAPTER ONE: INTRODUCTION

This chapter provides an overview of the purpose of the study, the problem statement, the significance of the study, and the research questions.

1.1 PURPOSE OF THE STUDY

On a global scale, societies have been going through drastic shifts because of technological advances, which are referred to as Industrial Revolutions (IR). The global economy has already experienced three major Industrial Revolutions, and it is now part of the Fourth Industrial Revolution (4IR) (Cunningham, 2018). Schwab (2016) describes the Fourth Industrial Revolution as the fourth major industrial era since the First Industrial Revolution (1IR) of the 18th century, where new technologies merge the physical, digital and biological worlds. These have an impact across disciplines, economies and industries, giving rise to novel forms of productivity and innovation. This technological revolution is transforming various industries, including the automotive industry, and has implications for manufacturing, production processes, and supply chain management (Kagermann et al., 2013). In South Africa (SA), the automotive industry is a critical sector, contributing significantly to the country's gross domestic product (GDP) and creating employment opportunities for thousands of people (Naicker & Singh, 2020). The South African automotive industry is also facing the challenges and opportunities presented by the 4IR as it adapts to new digital technologies and processes (Meyer & Wesson, 2020).

Furthermore, the 4IR is changing traditional understandings of communication, production, and consumption through combining human and machinery capabilities. The disruptions brought about by the 4IR provide an opportunity for developing countries to increase economic development. However, this rests on the innovativeness of domestic firms in an industry. This pertains specifically to the ability of domestic firms to implement new ideas. It also pertains to their ability to improve current offerings in an industry, which determines the economic benefits of 4IR in a country (Dolfsma & Velde, 2014). While the South African government has committed to harnessing the financial as well as societal benefits of the 4IR, a critical question is around the innovativeness of domestic firms to fully benefit from 4IR. As a result, the purpose of this research is to critically investigate the readiness of SA's automotive domestic firms and their technological capabilities to adopt and exploit 4IR technologies. In so doing, this research adds to the developing body of literature that seeks to unpack the various benefits, challenges and opportunities of the 4IR.

In the context of existing literature, the following gaps concerning the topic of the 4IR and the South African automotive industry are as follows:

- Lack of empirical studies on the implementation of 4IR technologies in the South African automotive industry: While Alexander (2022) has examined the readiness and potential of the industry for the 4IR, there is a need for more empirical studies that investigate the actual implementation of 4IR technologies and their impact on the industry.
- Limited research on the socio-economic impact of the 4IR in the South African context: While some studies by Alexander (2022) have examined the impact of the 4IR on employment and skills requirements, there is a need for more research that investigates the broader socio-economic impact of the 4IR in the South African automotive industry, such as its impact on income inequality, regional development, and social cohesion.
- Lack of research on the ethical and legal implications of the 4IR in the South African automotive industry: As the industry adopts new technologies such as autonomous vehicles and AI, there is a need to investigate the ethical and legal implications of these technologies, such as issues related to liability, privacy, and human rights.
- Limited research on the role of collaboration and innovation networks in the South African automotive industry's transition to the 4IR: There is a need for more research on the role of collaboration and innovation networks in supporting the industry's transition to the 4IR.
- Lack of research on the impact of the 4IR on the environmental sustainability of the South African automotive industry: As the industry adopts new technologies and materials, there is a need to investigate the impact of the 4IR on the environmental sustainability of the industry and identify strategies to mitigate any negative effects.

1.2 CONTEXT OF THE STUDY

IRs are periods that bring about change and disruption in the socio-economic structure of a society and its economy (Bogner et al., 2016; Crnjac et al., 2017; Peters, 2017). At the root of IRs are the evolution of knowledge, ways of living, and values in society (Oztemel & Gursev, 2018; Xu et al., 2018). The literature identifies three major IRs that the world has gone through. The First Industrial Revolution (1IR) occurred between 1760 and 1840 and was characterised by the invention of the steam locomotive power that changed textile industries globally. The 1IR was a shift from heavy manual labour to more mechanical labour processes. The end of the 19th century and the beginning of the 20th century signified the Second Industrial Revolution (2IR) that came with the development

of electricity, mass production, and the division of labour. The Third Industrial Revolution (3IR) began in the early 1950s with advances in electronics, information technology, and automated production (Appiah-Osei et al., 2020). A common feature of Industrial Revolutions is shifting the production process in pursuit of more effective methods. Recent developments in the digital advances of the 3IR have combined the digital and biological worlds. According to Schwab (2017), parts of the world are currently passing through the 4IR, which is signified by the integration of physical, digital, and biological worlds (Liao et al., 2017). The combination of these various elements has serious implications for businesses as well as industries (Crnjac et al., 2017). The advancements in technology that came with each revolution have not been fully attained in some developing countries such as SA. SA still has some catching up to do in the areas of digital transformation, innovation, internet accessibility and quality. These are the foundations of the 3IR. Access to basic necessities such as electricity and the Internet continues to be a struggle for a portion of the population, especially in rural areas (Commission on the Fourth Industrial Revolution, 2020).

The 4IR concept was first introduced by the German Government to explain its high technology (Liao et al., 2017; Xu et al., 2018). The concept is made up of various technological developments such as automation robotics, the Internet of Things (IoT), artificial intelligence (AI), big data, and the internet of systems (Bogner et al., 2016). These distinct concepts of the 4IR are rooted in enabling the continuous exchange of information between humans and machines. The technological advances associated with the 4IR provide an opportunity for organisations and industries to increase efficiency in the production process. Furthermore, these technological advances provide industrialising countries an opportunity to catch up with industrialised countries through developing new capabilities for humans and machinery (Adendorff et al., 2018; Appiah-Osei et al., 2020).

In 2019, the first 4IR digital economy summit was held in South Africa. The president stated that the 4IR presented an opportunity for the country to plough R5 trillion in value over the next decades (Commission on the Fourth Industrial Revolution, 2020). The 4IR within the South African context was positioned as a strategy to unlock new economic opportunities, thereby addressing socio-economic issues (Adendorff et al., 2018). Notably, South Africa has high rates of unemployment, poverty and inequality that are matched with slow economic growth. The 4IR has the potential to create new jobs that require new skill sets, thus providing South Africa with an opportunity to address its socio-economic issues.

The Presidential Commission on 4IR task team identified four key industries in the country that could benefit from 4IR, those being agriculture, mining, manufacturing, and the finance sector

(Commission on the Fourth Industrial Revolution, 2020). This research will focus on the automotive industry because vehicle manufacturing is the largest subset of the manufacturing sector in the South African economy (Automotive Industry Export Council, 2018). The manufacturing sector is perhaps the most affected by 4IR through the shift towards a more machine-based production process that requires high technology. Research has noted a trend towards reshoring of manufacturing to developed countries due to the high technological demand (Lee, 2019). As such, for the South African manufacturing sector to benefit from 4IR, it would have to "catch up" with the systems and technologies of developed countries. How this sector adapts to the disruption of 4IR will have a significant impact on how South Africa benefits (Mukwawaya et al., 2018). Furthermore, while the identified sector may have the potential to adapt to the disruptions of 4IR, the readiness of the industry will determine if it benefits from 4IR. It is against this backdrop that this research seeks to investigate the readiness of domestic firms in the automotive industry to adapt to 4IR through their technological capabilities.

1.3 PROBLEM STATEMENT

Research shows that the world is currently adopting 4IR technologies in various forms. This means shifting the traditional ways and ideas of production and those of labour (Appiah-Osei et al., 2020; Mukwawaya et al., 2018; Olaitan et al., 2021). The 4IR is rooted in the combination of human and machine intelligence to create sophisticated and highly efficient production and consumption processes (Sima et al., 2020). Some developed countries have fully embraced and adapted to the technologies that come with the 4IR (Oztemel & Gursev, 2018). However, research has shown that for developing countries, adapting to the 4IR is not merely about shifting systems but rather the country's industries' technological innovation capabilities (Oztemel & Gursev, 2018).

The usage and adoption of 4IR technologies is most prevalent in developed countries and is only starting to grow in developing countries (Oztemel & Gursev, 2018). A dominant argument within the discourse on 4IR is that by adopting emerging technologies, developing countries could benefit from more competitive production processes (Xu et al., 2018). 4IR offers developing countries the chance to enter markets previously dominated by developed countries through "leapfrogging" (Lee, 2019). Leapfrogging is the idea that countries that have poorly developed technology or economic bases can achieve economic catch-up by developing their technological capabilities or through the adoption of modern systems without following the path of their forerunners (Lee, 2019). Lee (2019) explains that by developing their technological capabilities, latecomer firms would have the opportunity to enter new industries and thus compete with incumbent firms.

However, researchers have argued that adopting 4IR in developing countries may not result in the expected benefits if viable resources such as digital technologies, I.T infrastructure and digital literacy required for its success are not present in that country (Xu et al., 2018; Peters, 2017). As such, adopting 4IR without adequate resources may worsen the economic and development challenges of a country. For example, if the technological advances of 4IR are adopted in a country with low levels of digital literacy, the new job markets created by 4IR will only benefit those with digital literacy, thereby increasing inequality gaps (Olaitan et al., 2021).

The South African government is committed to harnessing the full potential of the 4IR in addressing the socio-economic issue. The automotive manufacturing industry has been identified as one of the key drivers towards the adaptation to 4IR in the country (Commission on the Fourth Industrial Revolution, 2020). As such, providing a readiness assessment on the domestic firms in the automotive industry provides an opportunity to better prepare for transformations towards a 4IR industry. The research problem guiding this study is, therefore, that while the country has committed to transforming towards 4IR industries, the adoption of the 4IR technologies is very low in the automotive sector. This research will provide a readiness assessment placing emphasis on the technological capabilities in the automotive industry.

1.4 SIGNIFICANCE OF THE STUDY

Studying the 4IR and its impact on the South African automotive industry is significant as outlined in the following manner:

Understanding the impact of 4IR on the automotive industry: The 4IR is changing the way industries operate, and the automotive industry is no exception. This study will help industries understand how 4IR technologies such as automation, artificial intelligence, and the Internet of Things (IoT) are transforming the automotive industry in SA.

Identifying challenges and opportunities: The adoption of 4IR technologies presents both challenges and opportunities for the automotive industry in South Africa. This study will help identify these challenges and opportunities, enabling policymakers and industry leaders to make informed decisions about how to respond.

Improving competitiveness: SA's automotive industry is an important sector of the country's economy, contributing significantly to GDP and employment. Understanding the impact of 4IR on the industry can help improve its competitiveness by identifying ways to leverage 4IR technologies to enhance productivity, reduce costs, and improve product quality.

Informing policy: Policymakers need to understand the impact of 4IR on the automotive industry in SA to develop policies that support the industry's growth and competitiveness. This study can provide valuable insights into the policy implications of 4IR for the industry.

Enabling skills development: 4IR requires a highly skilled workforce, and the automotive industry in South Africa will need to develop the skills of its workforce to take advantage of 4IR technologies. This study can provide insights into the skills that will be required and the training needed to develop them.

1.5 DELIMITATIONS OF THE STUDY

The following delimitations of the study are worth noting:

- This research is limited to the South African automotive industry.
- The research will only be limited to manufacturing due to its importance in the era of the 4IR.
- The findings of this study may not be applicable in other South African sectors and therefore cannot be generalised.

1.6 ASSUMPTIONS

In conducting the proposed study, the following assumptions were made:

- The participants will have a basic awareness and understanding of 4IR concepts and technologies.
- The readiness for 4IR will vary significantly across companies due to differences in organisational resources, technological infrastructure, and strategic priorities.
- Openness to 4IR Adoption: The chosen participating companies will freely provide their experience in the adoption of 4IR
- The participants will be open and honest in discussing their perceptions and company readiness for 4IR. However, sensitivity to competitive or confidential information may limit some responses.
- Larger companies with more resources may demonstrate higher readiness levels and a greater capacity for 4IR adoption, while smaller or resource-constrained companies may face more challenges.

- External factors, such as regulatory requirements, economic policies, and supply chain influences, as critical factors that affect a company's readiness for 4IR

1.7 DEFINITION OF KEY TERMS

Industrial Revolutions: Periods that bring about change and disruption in the socio-economic setup of a society and its economy (Schwab, 2017)

The Internet of Things (IoT): A system of internet-connected objects that transfer and collect data without human intervention (Bogner et al., 2016).

Artificial Intelligence (AI): Computer systems that perform tasks that traditionally require human intelligence, for example, language translation software (Mukwawaya et al., 2018).

Big Data: Complex data sets that are analysed by computer systems to show patterns and trends (Anderson, 2012).

The Internet of Systems: A system of interconnected devices that allows for the transfer of data over a network without human interaction (Bogner et al., 2016)

Developing Country: A country that has a low industrial development rate and human development index compared to other countries (Commission on the Fourth Industrial Revolution, 2020).

1.8 RESEARCH QUESTIONS

The core research question guiding this study is: what is the level of readiness of the South African automotive industry for 4IR? In trying to answer this broad question, the following sub-questions have been created:

- Is the South African automotive industry primed for the technological competitiveness inherent in maintaining relevance in the Industry 4.0 era?
- What are the challenges and opportunities associated with the adoption of 4IR in the South African Automotive Industry?
- How can the South African automotive industry prepare for Industry 4.0 implementation to fully exploit the opportunities of 4IR?

1.9 OUTLINE AND STRUCTURE OF THE REPORT

Chapter One: Introduction

Chapter One explores the background of the study and the significance of the study. The chapter also outlines the research problem, delimitations, study assumptions and research questions. Lastly, it also consists of the definitions of key terms.

Chapter Two: Literature Review

The chapter reviews literature by providing critical descriptions of previous research regarding the current phenomenon being studied.

Chapter Three: Research Methodology

This chapter outlines the research methodology, procedures of the study and data analysis.

Chapter Four: Presentation of Results

This chapter focuses on the presentation of study findings.

Chapter Five: Discussions

This chapter focuses on data analysis and interpretation of findings.

Chapter Six: Conclusions and Recommendations

This chapter discusses findings and makes conclusions and recommendations regarding the phenomenon being studied.

1.10 CONCLUSION

This chapter provides a clear and concise introduction to the study, explaining why it is important and what the research questions are. This sets the scene for the rest of the research and helps the reader understand the context and significance of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

The previous chapter provided an introduction and background to the study. This chapter concentrates solely on the literature that is relevant to the current phenomenon being studied to gain a thorough understanding of the current disputes pertaining to it. It is important to note at first that building on the technological advancements of the first three industrial revolutions, the 4IR is said to provide developing countries with the opportunity to unlock economic growth and address unemployment. The 4IR, which is sometimes referred to as Industry 4.0 in the automotive sector, emphasises the combination of the physical and digital realities, and the creation of new business and production models (Pereira & Romeo, 2017). As such, this current revolution is seen as a transformation of industrial society and offers the possibility of creating more sustainable social benefits. The basis of the 4IR is the ability of countries and companies to adapt complex technologies that require a specialised workforce.

This chapter addresses the following research questions:

- What is the level of readiness of the South African automotive industry in adopting industry 4.0 technologies?
- What are the challenges and opportunities associated with the adoption of 4IR in the South African automotive industry?
- How can South African companies prepare for Industry 4.0 implementation to fully exploit the opportunities of 4IR?

In trying to address the above research questions, this chapter is divided into five sections that pay attention to scholarship that engages these concerns. The first section broadly covers the automotive industry, both global and domestic. The second section further introduces the notion of 4IR and its technologies. The third section looks at Industry 4.0 in developed economies, while the fourth section briefly touches on the theory of economic catch-up. The fifth section of the chapter discusses the theoretical framework that will guide the study at hand, specifically the Secondary Innovation Framework and Readiness Model.

2.2 THE GLOBAL AUTOMOTIVE SECTOR

The automotive industry refers to all enterprises and activities that involve the manufacturing and design of all motors and their component parts (Sommer, 2015). The automotive value chain

involves three main segments: (1) original equipment manufacturers (OEM) who assemble the vehicles; (2) original equipment suppliers (OES) who supply motor component parts to OEMS (3) independent aftermarket who supply accessories to dealers and repair shops (Spena et al., 2016). The automotive sector further includes 1st, 2nd, and 3rd tier manufacturers, who supply manufacturing parts to OEMS, OESs and independent aftermarkets.

The automotive value chain relies on high technology, from production techniques to materials and processes. Furthermore, the industry requires high levels of labour and capital.
Emerging technologies and market requirements are driving a dramatic transformation of cars (smaller, safer, greener, connected, driverless) and their use (shared cars and new, disruptive business models for mobility services (Layton & Rustandie, 2017). For both large and small businesses to keep up with the transformations within the sector, they thus need to adopt Industry 4.0 technologies.

Lejarraga et al. (2016), outlines that the automotive industry is highly concentrated, with few countries and companies leading world production. Its value chain is increasingly complex and characterised by a growing number of players operating in different sectors and located in different geographical areas." As such, the automotive value chain is producer-driven by OEMs and their OES suppliers, who yield more power in the chain (Layton & Rustandie, 2017). Countries and companies that have more power in the automotive value chain perform the bulk of activities that yield high economic returns, including determining innovation activity, branding and marketing and vehicle specifications.

The global automotive industry has grown with each Industrial Revolution, as has the production of vehicles (Lejarraga et al., 2016). The production of vehicles has, however, shifted from leading countries such as the United States, Japan, and Germany (which own global vehicle brands) to more emerging countries such as China. In 2004, China produced only 8% of the world's vehicles; however, by 2014, China produced one-fourth of the world's vehicles (Lejarraga et al.., 2016). The pursuit of cost-saving production systems, as well as mergers, has pushed OEMS to expand into developing countries. The automobile sector is extremely concentrated, with a few huge companies producing most vehicles. SMEs within the automotive industry work within parameters set by larger OEMS and thus become invisible. According to Ambe and Weisi (2011), the automotive industry relies on just-in-time manufacturing processes and their supporting technologies. However, the cost of such technologies means only OEMS may be able to implement these and keep up with market

demands. Industry 4.0 thus provides SMEs with the opportunity to localise production of mass products and implement business models that are customer-focused.

2.3 THE SOUTH AFRICAN AUTOMOTIVE INDUSTRY

The South African automotive industry is the largest manufacturing sector in the country and plays a vital role in the nation's economy (Lamprecht, 2021). With the presence of major European, American, and Japanese motor vehicle manufacturers, South Africa has become an attractive investment destination and a production base for products to be exported to global markets (Lamprecht, 2021). The industry is concentrated in three provinces – Gauteng, Eastern Cape, and KwaZulu-Natal – with tiers of associated supplier businesses (DTI, 2018). The industry comprises seven light vehicle OEMS, several medium and heavy capacity vehicles and over 400 automotive component firms (DTI, 2018). The sector further includes 1st, 2nd, and 3rd-tier manufacturers who supply manufacturing parts to OEMs, OESs and independent aftermarkets (Spena et al., 2016).

The automotive sector is dominated by foreign-owned firms, and Black (2020) argues that this means that this sector lacks a high level of local technological development as it lacks large local firms. This system also benefits Multinational Corporation (MNC) exporters through import rebates, which has led to significant use of downstream imports and reduced opportunities for tier 2 and 3 producers (Lorenz et al., 2019). The medium and heavy vehicle sector is small, with multiple brands which operate semi-knocked-down plants that involve importing almost-finished trucks and doing minor assembly in South Africa (Lamprecht, 2021). Most first-tier automotive suppliers in South Africa are foreign-owned MNCs, and this proportion is growing (Lamprecht, 2020). However, Lorenz et al. (2019) argue that the technological capabilities of automotive sector OEMs are much higher than first- and second-tier suppliers. Domestic first-tier component suppliers use a mix of local and imported content in their own supply chains. South Africa has produced relatively few examples of automotive sector product innovation in recent decades, with most firms producing simple products mainly for the aftermarket (Black, 2020). This is evidence of the low-level R&D capacity that the suppliers have (Black, 2020).

Automotive clusters – key automotive features – 2020

Key automotive features	Gauteng	KZN – KwaZulu-Natal	EC – Eastern Cape
Number of OEMs (manufacturing plants)	BMW SA Nissan SA Ford Motor Company of Southern Africa	Toyota SA Motors	Volkswagen Group SA Mercedes-Benz SA Isuzu Motors SA Ford Motor Company of Southern Africa engine plant
Medium, heavy, extra-heavy commercial vehicle and bus companies	Babcock, Fiat Group, Ford, Hyundai Automotive, Iveco, JMC, MAN Truck & Bus, MarcoPolo, Peugeot Citroen, Powerstar SA, Scania, Tata Trucks, UD Trucks, VECV South Africa, and Volvo Group Southern Africa	Bell Equipment, MAN Truck & Bus and Toyota (Hino)	FAW Trucks, Isuzu Motors, Daimler Trucks and Buses Southern Africa (Freightliner and Fuso) and Volkswagen Group SA
Number of automotive component companies	200	80	150
Motor vehicle parc as % of South Africa's total vehicle parc of 12,70 million vehicles	38,3%	13,4%	6,7%
Passenger car sales as % of total 2020 passenger car sales of 246 541 units	36,7%	15,2%	4,5%
LCV sales as % of total 2020 LCV sales of 110 912 units	31,2%	12,7%	5,5%
MCV/HCV sales of 22 753 units	37,2%	14,3%	3,7%
Light vehicle production by OEMs in the province as % of total 2020 light vehicle production of 423 907 units	32,6%	24,6%	42,8%
Light vehicle exports by OEMs in the province as % of total 2020 light vehicle exports of 270 730 units	36,4%	15,4%	48,2%

***Figure 2.1**: The Automotive cluster and the key automotive features.*

Source: Automotive Export Manual (2021)

The South African automotive industry has excellent manufacturing bases, access to various logistics corridors and links to established distribution networks, producing about a third of South Africa's GDP (Lamprecht, 2021). Despite this, the industry faces challenges such as budget constraints, inadequate infrastructure, limited R&D investments, and a shortage of skills, and these are mostly observed in Small and Medium Enterprises.

Moos and Sambo (2018) conducted a research study on SME's that are operating in the space, identifying challenges faced by SMEs in the South African automotive sector. The researchers conducted 11 qualitative interviews with owners of automotive companies. The findings showed that SMEs within the sector faced challenges related to a lack of funding, poor management skills, and little to no infrastructure. These challenges acted as a barrier to these SMEs taking full advantage of Industry 4.0 benefits. Similarly, a study was conducted by Muyengwa et al. (2013) on the perceived barriers faced by SMEs in the South African motor repair sector. The researchers conducted 30 survey interviews with small business owners. The study found that infrastructure and access to funding were the number one barrier. The participants added that the acquisition of appropriate repair equipment from the original equipment suppliers as well as the certified training of the original equipment manufacturers dictated the type of work they performed. The last study reveals that OEMs set value chain requirements and parameters other actors must abide by. The two

case studies highlight that while the South African automotive sector may be a huge economic contributor, local SMEs may not be benefiting from this. As such, for South Africa to fully unlock the economic benefits of Industry 4.0 within the automotive industry, more research is needed that highlights the position of SMEs within this sector.

2.4 THE POLICY ENVIRONMENT – TIMELINE OF POLICY INTERVENTIONS

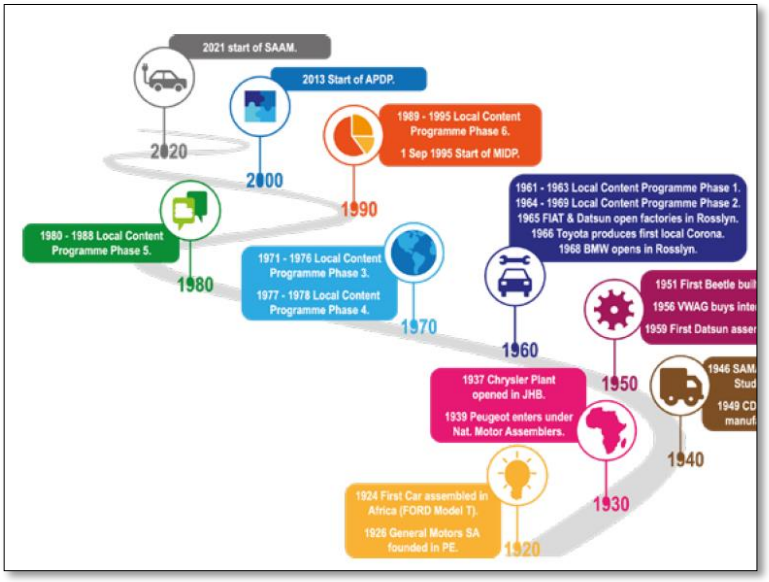


Figure 3.2: *Timeline of policy interventions*

Source: Lamprecht (2021)

The South African automotive policy environment has undergone significant evolution since the first automobile graced its soils in 1897 (Lamprecht, 2021). The journey from import substitution strategies to the Motor Industry Development Programme (MIDP) and the current Automotive Production and Development Programme (APDP) illustrates a concerted effort by the government to nurture and develop a competitive automotive sector (Lamprecht, 2021). These policy interventions have been instrumental in shaping the trajectory of the industry, emphasising local content, export promotion, and technological advancement (Lamprecht, 2021).

2.4.1 Early developments and import substitution

Initially, the policy environment was characterised by high tariffs and import controls aimed at encouraging local assembly and manufacturing for the domestic market. This era of import substitution, beginning in the early 20th century, led to the establishment of several foreign OEMs' assembly plants in South Africa. However, this approach resulted in a fragmented industry that

produced a wide variety of models in small volumes, leading to high costs and low local content (Lamprecht, 2021).

2.4.2 Transition to export orientation and MIDP

The introduction of the MIDP in 1995 marked a significant policy shift towards guided integration into the global automotive market (Lorenz et al., 2019) programme focused on reducing tariffs, encouraging exports, and supporting productivity improvements to enhance the competitiveness of the sector (Lorenz et al., 2019). This phase saw the industry achieving record levels of domestic sales, vehicle production, and exports, underpinning its role as a major contributor to the country's GDP (Lamprecht, 2021).

2.4.3 APDP and the path towards global competitiveness

Building on the successes of the MIDP, the APDP was introduced in 2013 as a continuation of the government's efforts to further integrate the South African automotive industry into the global economy. The APDP aimed to increase local content, promote exports, and encourage investment in the sector (Lorenz et al., 2019). Notably, the programme introduced mechanisms like the Vehicle Assembly Allowance (VAA) and Production Incentive (PI) to incentivise local manufacturing and exports (Lorenz et al., 2019).

2.4.4 The South African Automotive Masterplan (SAAM) 2021–2035

The latest strategic framework, the SAAM, outlines ambitious goals for the automotive industry, aiming to double employment, significantly increase vehicle production, and raise local content levels by 2035. The plan emphasises the importance of technology, skills development, and transformation within the sector to achieve these objectives. The establishment of the Automotive Industry Transformation Fund (AITF) underscores the commitment to inclusivity and sustainable growth through the empowerment of black and historically disadvantaged entrepreneurs in the sector (Lamprecht, 2021).

2.4.5 Automotive production networks

The automotive industry in South Africa is predominantly influenced by international corporations focusing on the assembly and manufacturing of vehicles and their parts for multinational corporation brands (Lorenz et al., 2019). The primary buyers of these automotive components include South African OEMs, top-tier suppliers, and aftermarket consumers. Local firms mainly serve as

secondary and tertiary suppliers, providing globally recognised, high-value, and capital-intensive original equipment parts. Components such as powertrain systems and telematics, which are crucial and capital-heavy, are often imported into the country (Lamprecht, 2021).

In this sector, global companies establish manufacturing bases within South Africa, bringing along their primary suppliers and thereby integrating into the local supply networks. This setup facilitates technology transfer to local entities. Nevertheless, local businesses, particularly in developing countries like South Africa, find it challenging to ascend to first-tier supplier status. Instead, they are more likely to find roles as subordinate suppliers or to specialise in the production of aftermarket parts (Lamprecht, 2021).

Moreover, South African manufacturers could distribute their automotive parts in the aftermarket and have seen a growing export market to developing countries, with notable increases in exports to the Czech Republic, China, Mexico, and Singapore. Despite this, local suppliers face stiff competition from international manufacturers of similar products (Lamprecht, 2021).

This competition necessitates a reduction in production costs and an increase in automation. Although standardised product specifications may constrain innovation in product design, there is significant scope for innovation in processes and business operations (Lamprecht, 2021). Enhancing automation and adopting innovative manufacturing processes are vital for reducing costs and improving the international competitiveness of South African automotive manufacturers (Lamprecht, 2021). In certain instances, leading global firms may assist local suppliers in developing and integrating new process innovations. Consequently, the automotive sector in South Africa presents considerable potential for the advancement of the 4IR technologies, especially in enhancing manufacturing processes (Lamprecht, 2021).

2.5 THE FOURTH INDUSTRIAL REVOLUTION

Industrial Revolutions (IR) are periods that bring about change and disruption in the socio-economic setup of a society and its economy (Bogner et al., 2016; Crnjac et al., 2017; Peters, 2017). At the root of IRs are the evolution of knowledge, ways of living, and values in society (Oztemel & Gursev, 2018; Xu et al., 2018). The world has gone through three distinct Industrial Revolutions, the 1IR, the 2IR and the 3IR, and we are currently in the 4IR age. The 1IR occurred between 1760 and 1840 and was characterised by the invention of the steam locomotive power that changed textile industries globally (Peters, 2017). The 1IR was a shift from heavy manual labour to more mechanical labour processes. This revolution marked the first dramatic change in how human labour was being used,

as it had traditionally been primarily used for agriculture and the creation of primary goods. It also heralded the emergence of new sorts of labour and new working circumstances, i.e. mechanised industries (Xu et al., 2018).

The end of the 19th century and the beginning of the 20th century signified the 2IR, which came with more advanced developments in technology. Improvements in steel production, the emergence of new chemicals and chemical production methods, the discovery and implementation of electricity, the creation and usage of the combustion engine, and production technological aspects such as large-scale production, easily replaceable parts and labour division all exemplified the 2IR (Uleanya et al., 2021).

The 3IR began in the early 1950s, building on the development of the first two (Appiah-Osei et al., 2020). In the early 1970s, the first microprocessor and programmable logical controller (PLC) were invented, kicking off the 3IR. The application of electronics and information technology meant that the mechanical and electrical systems of the first two Industrial Revolutions became more automated. Therefore, automation meant that a decrease in the amount of manual work was needed in the production process. The first three Industrial Revolutions highlight that at the foundation of technological innovations is the drive to increase productivity and efficiency.

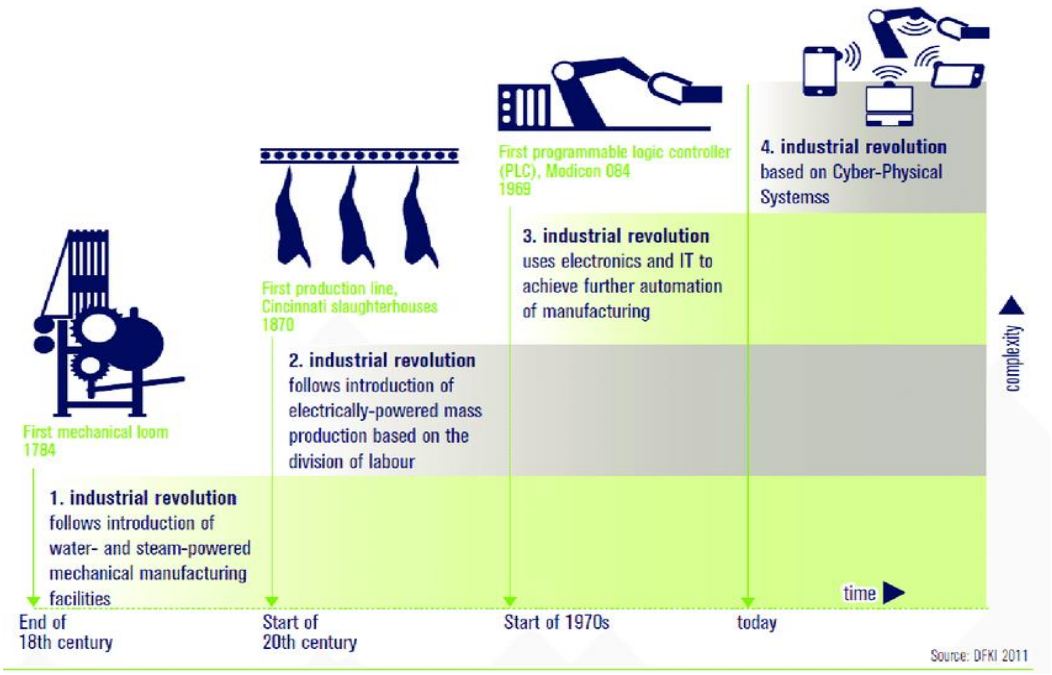


***Figure 2.3**: The evolution of the Industrial Revolutions*

Adapted from: DFKI (2011)

Figure 2.3 illustrates the evolution of the Industrial Revolutions over time. It also highlights that recent developments in the digital advances of the third Industrial Revolution have combined the digital and biological worlds. According to Schwab (2017), because of these developments, parts of the world are currently passing through the 4IR, which is signified by the integration of physical, digital, and biological worlds (Liao et al., 2017). The 4IR is considered a bigger step wherein humans, products and machines relate to one another (Appiah-Osei et al., 2020). As a result, the 4IR revolution is considered to have more powerfully embedded systems which can connect to one another wirelessly, enabling the convergence between the real and the virtual world through cyber-physical systems. As such, the innovative technologies that come with the 4IR enable the transformation of factories into smart environments because of the following key features:

- Virtualisation – electronic systems that monitor physical processes, invent virtual realities, and connect the physical and virtual systems and simulations (Schwab, 2017).
- Real-time capability – the collection and analysis of data to provide the derived insights immediately (Schwab, 2017).
- Decentralisation – using cyber-physical systems to make decisions and to manufacture local products using technologies like 3D printing (Schwab, 2017).
- Interoperability – the use of software systems that communicate with one another to generate information about the production processes (Schwab, 2017).
- Modularity – Smart factories can be easily applied to changing needs by replacing or broadening different components (Schwab, 2017).
- Service orientation – digital technologies connected with industrial products provide hybrid solutions which are neither good nor services exclusively (Schwab, 2017).

Schwab (2017) notes that the key characteristics of the 4IR allow companies and industries to do away with the normal barriers to trade as they bring changes in the products, processes and even business models. Moica, et al (2018) explains that industry 4.0 is considered the answer to the pressing challenges that businesses must address to remain competitive amidst globalisation, fluctuating market demands, reduced innovation and product lifespans, and the growing complexity of products and processes. Based on the latter assertion, the 4IR is then not only about technological advances but also about the adaption of new business models that incorporate both human and mechanical services. Personalisation of client needs, adaptability of production and transportation systems, improved decision-making, integration of ICT and Cyber-Physical Systems (CPS),

introduction of advanced manufacturing, intelligent automation concepts, and adapted business models are some of the main objectives of Industry 4.0 (Moica et al.,2018).

From the above discussion, it becomes clear that at the root of IRs is the creation of key inventions and innovations that help accelerate production processes and economic development through the creation of new industries. As such, for businesses to gain competitive advantage and move up in the value chain, they need to keep up with key innovations.

2.5.1 Industry 4.0

Industry 4.0 is the new paradigm of smart and autonomous manufacturing. It represents a transformative leap in manufacturing that is marked by the advanced fusion of operational systems with technologies in communication, information, and intelligence (Wang et al., 2016). This integration is identified as a significant shift towards smarter, self-sufficient manufacturing processes. Scholars and professionals alike have acknowledged the potential of Industry 4.0 to revolutionise manufacturing by offering lucrative business models, enhancing efficiency and product quality, and fostering better work environments (Liao et al., 2017; Hofmann & Rüsch, 2017). Despite the advantages, challenges such as a lack of understanding of the technology, high implementation costs, the need for changes in existing systems, and energy consumption concerns have posed obstacles to its widespread adoption (Saberi et al., 2019).

The technological landscape of Industry 4.0 comprises both physical and digital technologies. Physical technologies include developments like 3D printing and the use of sensors and drones in manufacturing processes (Gibson et al., 2014). On the digital technology side, it is comprised of advancements such as cloud computing, blockchain, big data analysis, and simulations (Liao et al., 2017). These technologies are still in the early stages of adoption in developing countries and among small to medium-sized enterprises. A deeper understanding and further development are crucial for their broader acceptance, especially for the underrepresented populations and their impact on sustainability (Müller et al., 2018).

2.5.2 Industry 4.0 technologies

1. **Artificial intelligence** encompasses computer systems designed to mimic human intelligence, performing tasks such as recognising patterns, making decisions, and solving problems (Bai et al., 2020). Machine learning, a subset of AI, involves algorithms that improve automatically through experience and use of data. In the automotive industry, these

technologies are employed for predictive maintenance, where algorithms analyse data from vehicle sensors to predict potential failures before they occur. Additionally, AI and ML are integral to the development of autonomous vehicles, optimising supply chain logistics and personalising the customer experience (Bai et al., 2020).

2. **Internet of Things** refers to the network of physical objects embedded with sensors, software, and other technologies that exchange data with other devices and systems over the Internet. In the automotive industry, IoT devices are used to monitor and improve manufacturing processes, manage supply chains in real time, and enhance vehicle connectivity for better user experiences, such as predictive maintenance and improved safety features (Jeschte et al., 2017).
3. **Additive manufacturing,** also known as 3D printing, involves making three-dimensional solid objects from a digital file, where the material is added layer by layer. In the automotive industry, 3D printing is used for prototyping, producing complex parts with reduced waste, and creating customised components more efficiently, enabling rapid prototyping and innovation (Bai et al., 2020).
4. **Robotics** involves the design, construction, operation, and use of robots for performing tasks with high precision and efficiency. Automation refers to the technology by which a process or procedure is performed without human assistance. Robotics and automation are used extensively in the automotive industry for tasks such as welding, painting, assembly, and inspection, enhancing precision, reducing production times, and lowering costs (Bai et al., 2020).
5. **Big Data Analytics** – data refers to the vast volumes of data generated from various sources, including IoT devices, while analytics involves the systematic computational analysis of data or statistics. In the automotive sector, big data analytics are used to analyse vast amounts of data from manufacturing processes, vehicle performance, and customer behaviour to improve decision-making, enhance product quality, and customise offerings (Richard et al., 2011).
6. **Cyber-physical systems (CPS)** are integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa (Wang et al., 2011). In automotive manufacturing, CPS enabled the creation of smart factories, where machinery and equipment can adjust operations autonomously in response to changing conditions or requirements, leading to more flexible and efficient production processes. (Monostori et al., 2016).

7. **Cloud computing** involves the delivery of computing services, including servers, storage, databases, networking, and software over the Internet, offering faster innovation, flexible resources, and economies of scale. On the other hand, edge computing involves processing data near the edge of the network where the data is generated instead of a centralised data processing warehouse. The automotive industry leverages cloud computing for data storage, analysis, and managing the vast amount of data generated from connected vehicles and manufacturing processes. Edge computing is used for real-time data processing in autonomous vehicles and in manufacturing settings where immediate data analysis is required for decision-making (Bai et al., 2020).
8. **Virtual Reality (VR) and Augmented Reality (AR)** are transformative technologies in the context of the 4IR, each playing a critical role in merging the physical with the digital (Bai et al., 2020). VR immerses users in a completely digital environment, offering an escape to entirely new worlds, which has profound implications for design, simulation, and training within the automotive industry (Bai et al., 2020). It enables engineers and designers to prototype new vehicle models in three-dimensional spaces without the need for physical models, provides immersive training environments for technicians, and allows customers to experience virtual test drives (Bai et al., 2020). AR, on the other hand, overlays digital information onto the real world to enhance the user's perception of their physical surroundings (Nagarajan, 2023). In the automotive sector, AR transforms the driving experience, maintenance procedures, and customer service by projecting navigation aids directly onto the windshield, providing mechanics with overlay instructions for repairs and maintenance, and enhancing the car buying experience with interactive information and features about vehicles (Nagarajan, 2023).

The above 4IR technologies, when integrated into the automotive industry's manufacturing and operational processes, not only streamline production but also pave the way for innovative products and services, transforming the industry's value chains and business models.

2.6 INDUSTRY 4.0 AND DEVELOPING ECONOMIES

Because of the demographics, dominance of the informal economy and the level of international trade, developing countries may experience Industry 4.0 differently from developed countries (Alqam & Saqib, 2020; Adegbite, 2021). The dominant argument within Industry 4.0 literature is that developing countries can transform their economies and enter new markets by adopting 4IR technologies and models. According to Lee (2019), embracing Fourth 4IR technologies presents a

chance for latecomer economies to fast-track their development by bypassing certain intermediary phases of industrialisation. For developing countries, 4IR provides an opportunity to catch up with more industrialised countries (Adendorff et al., 2018; Appiah-Osei et al., 2020). A dominant argument within the discourse on 4IR is that by adopting emerging technologies, developing countries could benefit from more competitive production processes (Xu et al., 2018). 4IR offers developing countries the chance to enter markets previously dominated by developed countries through "leapfrogging". For example, the fast adoption of mobile phones in countries that did not have large-scale landline coverage highlights how 4IR allows countries to skip certain stages of industrialisation (Lee, 2019). Similarly, Anderson (2012) argues that 4IR will result in the elimination of barriers between inventors and markets because of new technologies like 3D printing for prototyping. He further argues that automated systems allow companies to cut costs, thereby opening a market for new types of jobs. The replacement of certain manual tasks by machinery alters the concept of work and brings about a demand for new skills and talents within the workplace.

However, some researchers have highlighted that those developing countries may be ill-equipped to fully adapt to the changes needed to benefit from 4IR (Xu et al., 2018; Peters, 2017). Adegbite (2021) explains that for the benefits of 4IR to be fully harnessed, the following bottlenecks must be addressed: weak infrastructural assets, lack of people with specialised skills in the areas of 4IR, and weak collaboration between academia and industry. Peters (2017) and Xu et al. (2018) term the above pointers as viable resources developing countries need to ensure they unlock the benefits of 4IR. For example, research has shown that the key to unlocking 4IR for businesses is electricity (Searle & McWha-Hermann, 2020). However, African countries face challenges when it comes to generating electricity, with over 600 million people still without reliable electricity connections (Adegbite, 2021). As a result, African businesses may face difficulties in fully adopting 4IR technologies because such technologies require connectivity through electricity.

2.7 ECONOMIC CATCH-UP

The concept of catching up is a popular concept used in the literature to describe the position that organisations in developing countries need to reach to compete with other nations. It is the process through which a late-developing country narrows the gap in terms of technological capability and income compared to a leading country (Odagiri et al., 2010). The theory was first proposed by Alexander Gerschenkron in the 1950s, who outlined an approach to development based on capturing the "latecomer effect" (Mathews, 2006). The theory implies that latecomer countries or firms have the advantage of being able to learn from and imitate the best practices of more advanced economies

or firms, which can help them close the gap in terms of economic development (Mathews, 2006). The concept of catch-up in this study context emphasises the importance of adopting and implementing 4IR technologies to enhance the competitiveness and productivity of the automotive sector.

Lee and Lim (2001) identified three types of catchups that countries can follow, namely path-following catch-up, stage-skipping catch-up, and path-creation catch-up.

1. Path-following catch-up involves latecomers following the path taken by forerunners. An example of a path-following catch-up is the development of consumer electronics in Korea. In this case, Korean firms followed the path taken by Japanese firms in establishing the consumer electronics industry (Lee & Lim, 2001).

2. Stage skipping catch-up involves latecomers following the path but skipping some stages, thus saving time. An example of this strategy is the achievement of Samsung in memory chips called D-RAM. Samsung skipped some stages in the development of memory chips, which enabled it to catch up with the incumbent leader and become a market leader (Lee & Lim, 2001).

3. Path Creation Catch-up involves latecomer firms exploring their own path of technological development. An example of this strategy is the CMDA mobile and digital TV in Korea. In this case, Korean firms created their own path of technological development in the mobile and digital TV industry (Lee & Lim, 2001).

This theory emphasises that latecomer firms can exploit their late arrival to tap into advanced technologies rather than having to replicate the entire previous technological trajectory (Lee & Lim, 2001). They can accelerate their uptake and learning efforts by utilising various forms of collaborative processes and state agencies to assist with the process and bypassing some of the organisational inertia that holds back their more established competitors (Lee & Lim, 2001). They therefore strategise around the possibilities inherent in their latecomer status. The strategic goal of the latecomer is clear: it is to raise real incomes through catching up with the advanced firms and to move as quickly as possible from imitation to innovation (Lee & Lim, 2001). The theory of catch-up also highlights the importance of government intervention in promoting economic development (Lee & Lim, 2001). Governments can play a crucial role in fostering innovation and creating an

enabling environment for the adoption of new technologies. This can be achieved through policies such as investment in infrastructure, education, and research and development (Lee & Lim, 2001).

The Presidential 4IR Commission 2020 Report highlights the potential of 4IR technologies to transform the South African economy and society. The report identifies several priority areas for investment and development, including the automotive industry. The report notes that the industry is a key contributor to the South African economy, accounting for approximately 7% of GDP and 30% of manufacturing output. However, the industry faces several challenges such as low productivity, low levels of innovation, and limited access to global markets. The report recommends that the industry should leverage 4IR technologies to improve its competitiveness and sustainability. This includes investing in research and development, developing new business models, and improving the skills of the workforce (Commission on the Fourth Industrial Revolution, 2020).

Bringing the above to the context of 4IR and the SA automotive industry, it is evident that the adoption of 4IR technologies such as robotics, artificial intelligence, and the Internet of Things can play a critical role in facilitating catch-up in the South African automotive industry thus driving economic growth and development in the country. This can be achieved through the process of secondary innovation, which will be discussed in the next section.

2.8 THEORETICAL FRAMEWORK

This study adopts two key theoretical frameworks: Secondary Innovation and the Readiness for 4IR framework. Secondary Innovation serves as the primary theory, emphasising how enterprises can leverage existing technologies and processes to enhance their systems, capabilities and drive innovation. Complementing this, the Readiness for 4IR framework offers a structured approach to assessing the sector's preparedness for integrating advanced technologies associated with the Fourth Industrial Revolution. Together, these frameworks establish a conceptual foundation for evaluating and interpreting the automotive industry's level of readiness, addressing the core research questions, and guiding the overall analysis.

2.8.1 Secondary innovation

The Secondary Innovation Framework, an evolutionary model initially proposed by Wu Xiaobo in the 1990s, is a theoretical construct that highlights the role of enterprises in building systems capability and innovation. This model was proposed based on Chinese enterprises, and it aims to provide an in-depth understanding of the dynamic process of how enterprises achieve organisational

learning, knowledge accumulation, and capability building. The Secondary Innovation Framework is a valuable tool that will guide the study at hand, enabling a comprehensive exploration of the potential for Industry 4.0 to transform the automotive industry in SA (Wu et al., 2006).

Wu et al. (2006) explain that the process of secondary innovation involves five specific stages: acquisition, assimilation, improvement, crisis, and renewal. These stages are not independent and may sometimes overlap. Corresponding to this are five different modes of organisational learning that correspond to the stages of the cycle of innovation: Adaptive learning, maintenance learning, developmental learning, transitional learning, and creative learning (Wu et al., 2006; Wu et al., 2008).

Further, the process also involves four distinct and complementary dimensions of an organisation's technological capability: duplicative imitation, creative imitation, exploitative innovation, and explorative innovation.

1. The initial stage of secondary innovation is technology acquisition, which is when the latecomer imports foreign technologies (Wu et al., 2006; Wu et al., 2008). The advantage of this stage for latecomers is that there are reduced entry risks and R&D investments. At the acquisition stage, capabilities are developed through learning by using, and at this stage, R&D and internal organisational capabilities are very low (Wu et al., 2006; Wu et al., 2008).

2. The second stage is assimilation, where the latecomers' dominant focus is on the localisation of the acquired technologies and working towards forming production capability through learning by doing (Wu et al., 2006; Wu et al., 2008).

3. The third stage is the improvement stage. This stage is about combining the acquired technologies with existing ones and applying them to different fields. The crisis stage, which is the fourth stage, is where the latecomer faces the challenge of new technological paradigms, new user demands, or new rivals and substitutes. The fifth stage is renewal, where the latecomer initiates the next secondary innovation cycle by acquiring new technologies or achieving in-house R&D breakthroughs (Wu et al., 2006; Wu et al., 2008).

During these stages, the learning mode varies from adaptive learning to creative learning, depending on the stage they are in. For example, the dominant organisational learning mode in the first stage of secondary innovation is adaptive learning, where the main task is to adjust to the new technological paradigm. In contrast, the dominant organisational learning mode in the fifth stage of

secondary innovation is creative learning, where the main task is system restructuring and rebuilding (Wu et al., 2006; Wu et al., 2008).

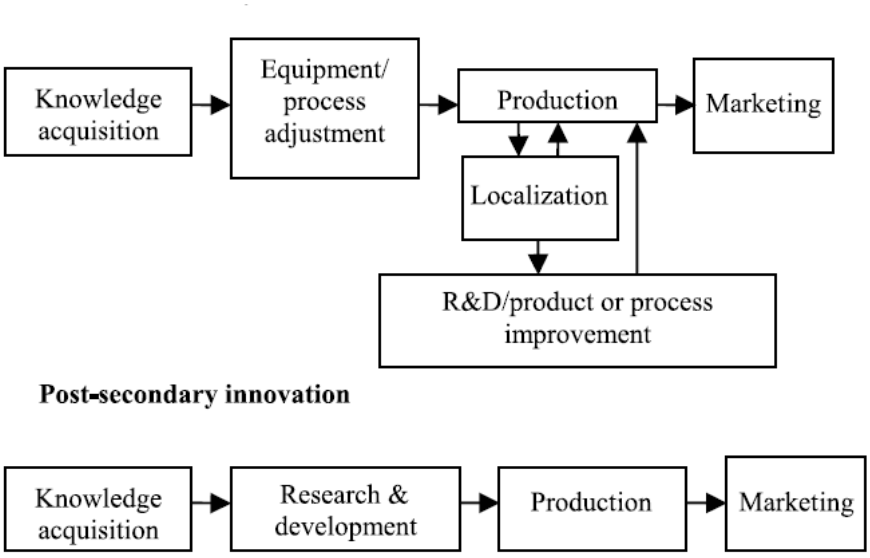


***Figure 2.4**: Secondary Innovation processes: the standard secondary innovation and post-secondary innovation*

Source: Wu et al. (2008)

Standard secondary innovation focuses on the acquisition of already mature technologies from developed countries (Wu et al., 2008). Although it reduces entry risks and R&D investments for latecomer firms, sometimes there is not sufficient time for latecomers to fully exploit the technologies before new emerging technologies render the acquired technologies obsolete, resulting in latecomers lagging (Wu et al., 2008). On the other hand, post-secondary innovation focuses on the acquisition of emerging technologies that are still in the transitional stage to evolve it to original technology.

Post-secondary innovation presents a window of opportunity for latecomers to leapfrog and not lag (an inherent risk in standard secondary innovation) (Wu et al., 2008). However, post-secondary innovation requires high levels of R&D capability and advanced production capability, an area where latecomers lack and does not necessarily lead to the development of a new technological paradigm (Wu et al., 2008).

According to Wu et al. (2006) and Wu et al. (2008), the process of secondary innovation has four distinct and complementary dimensions of an organisation's technological capability: duplicative

imitation, creative imitation, exploitative innovation, and explorative innovation. These dimensions are classified based on the pattern and orientation of problem-solving.

1. Duplicative imitation is the first dimension of an organisation's technological capability. In this mode, the latecomer imports foreign technologies and masters the operational technology through learning by doing. The dominant organisational learning mode in this stage is adaptive learning, where the main task is to adjust to the new technological paradigm (Wu et al., 2006; Wu et al., 2008).

2. Creative imitation is the second dimension of an organisation's technological capability and is characterised by the combination of foreign and existing technologies. In this mode, the latecomer localises the acquired technologies and forms production capability through structural understanding. The dominant organisational learning mode in this stage is maintenance learning, where the main object is to make the production systems more reliable and more efficient (Wu et al., 2006; Wu et al., 2008).

3. Exploitative innovation is the third dimension of an organisation's technological capability, and it is characterised by incremental innovation within established technological paradigms. In this mode, the latecomer combines the acquired technologies with existing ones and applies them to different fields. The dominant organisational learning mode in this stage is developmental learning, where the main task is product improvement, diversification, and innovation within established technological paradigms (Wu et al., 2006; Wu et al., 2008).

4. Explorative innovation is the fourth dimension of an organisation's technological capability and is characterised by radical innovation outside established technological paradigms. In this mode, the latecomer must address the challenge of new technological paradigms, new user demands, as well as new rivals or substitutes. The dominant organisational learning mode in this stage is creative learning, where the main task is system restructuring and rebuilding (Wu et al., 2006; Wu et al., 2008).

2.8.2 Factors affecting secondary innovation

Several factors can affect the success of secondary innovation, including the availability of technology, the degree of novelty, the market potential., and the level of competition (Wu et al., 2008). The availability of technology is crucial as it determines the range of options available for secondary innovation. Technologies that are widely available and well-understood are more likely to be successfully applied in new ways than technologies that are rare or poorly understood. The degree of novelty is also a critical factor in secondary innovation. Highly novel applications of existing technologies are more likely to be successful than applications that are only slightly different from existing products or services.

Market potential is another essential factor in the success of secondary innovation. Secondary innovation is more likely to be successful when there is a large and growing market for the product or service being developed. Finally, the level of competition is a crucial factor affecting secondary innovation. Secondary innovation is more likely to be successful when there is little competition or when the competition is weak.

2.8.3 Case studies of secondary innovation

Several case studies have been conducted to explore the dynamics of secondary innovation in different industries and countries. Hangzhou Hangyang Co., Ltd. (HHCL), a leading air separation plant manufacturer in China, is one such case study (Wu et al., 2008). The case study showed how HHCL was able to improve its existing technology by acquiring and adapting foreign technology to meet local needs, and the company's capability-building process of secondary innovation. The study highlights the importance of organisational learning, knowledge accumulation, and capability building in the success of secondary innovation.

Another case study is the Taiwanese semiconductor industry, which has successfully developed its technological capabilities through secondary innovation (Wu et al., 2008). The industry has developed a supportive institutional environment that promotes the development of technological capabilities. The study shows that the government's support in providing necessary infrastructure, research and development funding, and other incentives has played a crucial role in the semiconductor industry's success.

2.8.4 Secondary innovation framework

1. Duplicative Imitation (Foci: Operation) Basic assimilation: merely assimilation of imported technology	2. Creative Imitation (Foci: Localisation) Structural understanding: Interaction between foreign imported technology and endogenous technology capability
3. Explorative Innovation (Foci: differentiation) Functional understanding: Interaction between localised foreign technology and user requirements	4. Exploitative Innovation (Foci: value innovation) Interaction between emerging foreign technology and new product concept

Figure 2.5: *Primary theoretical Framework: Secondary innovation framework*
Source: Wu et al. (2006)

In essence, the secondary innovation frameworks emphasise that through its provisions, latecomer firms can acquire, assimilate foreign technologies, and improve upon them to become competitive players in the global market. It provides a guidance for latecomer firms on how to catch up with more advanced economies by leveraging absorptive capacity to assimilate and apply new knowledge.

What is important to note regarding this framework is the emphasis on the importance of problem-solving skills and learning capability in the capability-building process. This simply means that latecomer firms must be willing to adapt to changing environments, experiment with emerging ideas and concepts and innovate within established paradigms. Overall, this framework can be a very useful guiding tool for harnessing the potential of 4IR technologies to drive economic growth and development.

2.8.5 The readiness for 4IR framework

Olaitan et al. (2019) defined readiness as the "ability to capitalise to capitalise on future production opportunities, mitigate risks, and challenges and be resilient and agile in responding to unknown future shocks". Essentially, readiness is the ability to adapt and respond effectively to changing circumstances and capitalise on opportunities while mitigating potential risks and challenges.

Schumacher et al. (2016) proposed a nine-dimension readiness tool to measure manufacturing companies' readiness for Industry for 4.0:

1. Strategy – the measures under strategy include the availability of the roadmap for Industry 4.0, the available resources as well as the adoption of Industry 4.0 business models.
2. Leadership – measures the willing of leaders to adopt 4.0, their competencies as well as the existence of central coordination for Industry 4.0.
3. Technology – focuses on availability of ICT systems, mobile device use and machine-to-machine communication.
4. Operations – focuses on the decentralisation of processes, interdepartmental collaborations as well as modelling and simulations.
5. Products – focuses on digitalisation and integration of products into other systems.
6. People – focuses on the ICT competencies of the personnel and their openness to new technology.
7. Governance – looks at Industry 4.0 regulations, protection of intellectual property and suitability of technological standards.
8. Culture – looks at knowledge sharing, innovation, and cross-collaboration.
9. Customers – Focuses on the digitalisation of services, utilisation of customer data and media competence.

The 4IR readiness framework is important in the context of the South African automotive industry as it can help in understanding the level of adoption of new technologies within the industry (Schumacher, 2016). With the integration of digital technologies such as robotics, artificial intelligence, and IoT automotive industry, the readiness model can be applied to identify the gaps in technology adoption and assess the level of readiness of the industry to embrace and exploit the opportunities presented by 4IR (Schumacher, 2016). By using this framework, companies can develop strategies to upskill their workforce, explore, establish partnerships, and engage with the government to facilitate the transition to 4IR technologies, ensuring that they remain competitive and relevant in the global market.

2.9 CONCEPTUAL FRAMEWORK

Based on the Secondary Innovation Framework and Industry 4.0 readiness assessment framework, the following conceptual framework will be used to guide the study:

The Secondary Innovation Framework, together with the Readiness for 4IR Framework "Industry 4.0 Readiness Assessment Framework", provides a comprehensive understanding of the level of readiness of the South African Automotive Industry for the 4IR. The readiness framework can be used to assess the industry's preparedness to adopt and integrate new technologies by evaluating factors such as Strategy, leadership, products, operations, culture, people, governance, technology and customers (Schumacher et al., 2016). The secondary innovation framework evaluates the industry's approach to innovation and capability building by analysing four key areas: Duplicative Imitation, Creative Imitation, Exploitative Innovation, and Explorative Innovation (Wu et al., 2006). By combining these two frameworks to assess the automotive industry's readiness, the study will be able to determine the level of readiness of the SA automotive industry, identify gaps, challenges, and opportunities in the adoption of 4IR technologies, and understand the industry's innovation capabilities.

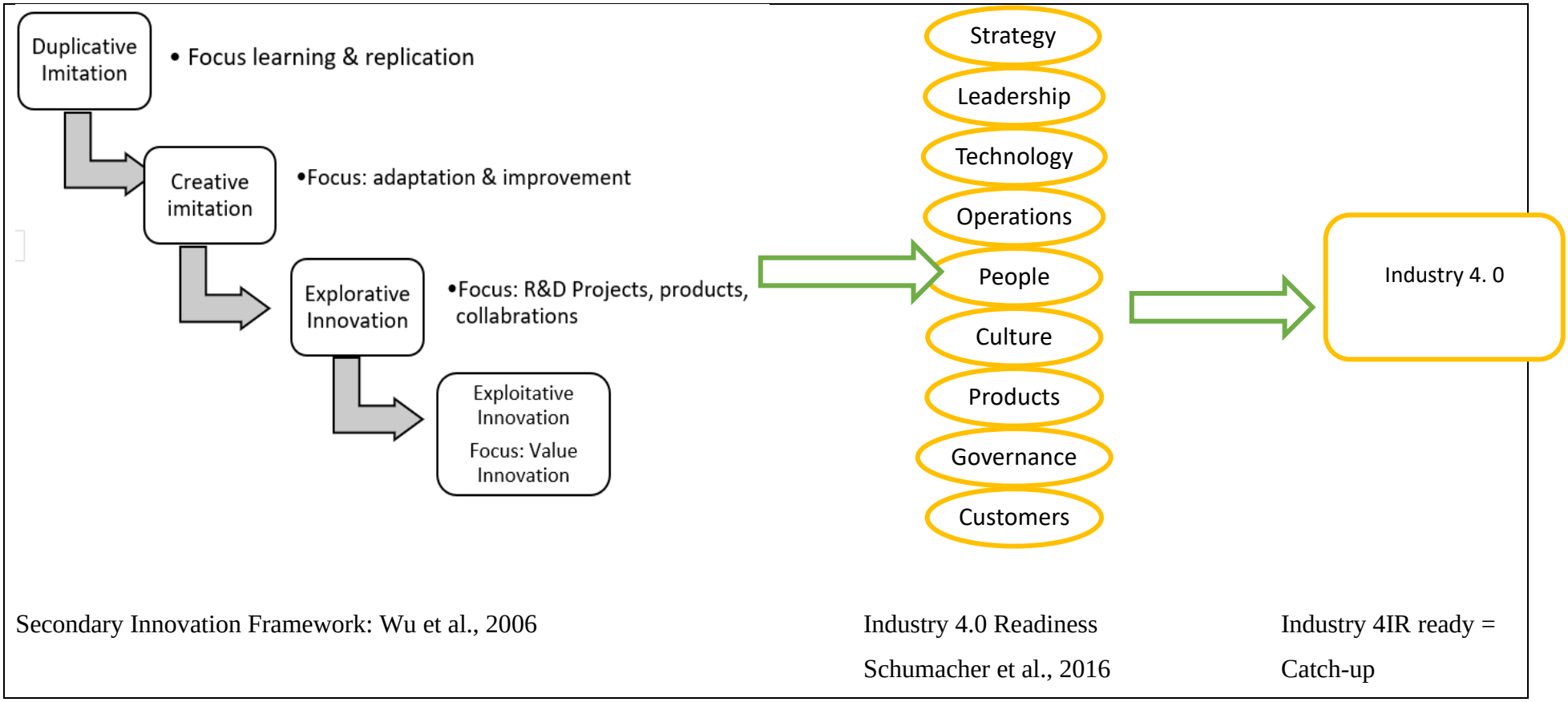


Figure 2.6: *Conceptual framework that will be used to assess the readiness of the automotive industry for the 4IR*

The proposed conceptual framework for this study aims to combine two established frameworks: the readiness framework and the secondary innovation framework. The readiness framework focuses on the capacity of organisations to adapt and respond to changes in their environment, while the secondary innovation framework provides a roadmap for latecomer economies to leverage foreign technologies and become competitive players in global markets. By merging these two frameworks, the aim is to develop a comprehensive conceptual framework that will guide the analysis of the adoption and implementation of Fourth Industrial Revolution (4IR) technologies in the automotive sector.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

The preceding chapter reviewed literature relevant to this study. This chapter focuses on the research methodology and the procedures applied in the study. It outlines the research paradigm, research design and the description of the approach taken. In addition, an in-depth explanation of data collection and analysis and ethical considerations are provided.

3.2 RESEARCH PARADIGM

There are three important components that are key in the research design: the philosophical worldview, the strategy of enquiry related to this worldview, and the methods of research that translate the approach into practice. Guba (1990) explains a research philosophy or worldview as a "basic set of beliefs that guides action". This research will be guided by the interpretivist worldview. According to Hammersley (2013), the interpretivist worldview is rooted in the belief that reality is socially constructed and is thus subjective. This worldview thus believes that multiple versions of reality exist that are dependent on the individual context of people or firms. Taking on an interpretivist worldview will allow the researcher to understand the different realities of firms in the automotive industry when it comes to 4IR readiness, without applying a blanket approach. Such a stance is important because since each firm has its own complexity that is specific to its context, it thus becomes important for the researcher to understand how these impact the readiness of firms. Hammersley (2013) adds that when adopting an interpretivist approach, one must understand "the diverse ways of seeing and experiencing the world through different contexts and cultures". Taking on an interpretivist approach will allow the researcher to understand the key issues related to 4IR readiness for the chosen firms without generalising the findings.

3.3 RESEARCH DESIGN

A research design is the set of strategy or approach that a researcher adopts in conducting a research study (Creswell, 2012). A research design thus allows researchers to collect the necessary data to answer research questions. A research design is crucial for any research project because it allows the researcher to answer questions about the kind of data needed, where the data will be collected, and the number of participants needed. The research design can be broadly classified into qualitative, quantitative and mixed methods research design (Asenahabi, 2019). Qualitative methods involve the collection and analysis of non-numerical data to make sense of opinions, experiences, and concepts. In contrast, quantitative research uses numerical data to analyse and understand

patterns, and test causal relationships (Asenahabi, 2019). Mixed method research design is an integration of qualitative and quantitative research (Asenahabi, 2019).

Quantitative research can be categorised into two main types: non-experimental research and experimental research designs. Non-experimental design refers to quantitative research that does not involve experiments during the data collection process (Asenahabi, 2019). This type of research can be further classified into three categories: survey design, causal-comparative design, and correlational design (Asenahabi, 2019). On the other hand, experimental research involves the manipulation of one or more dependent variables to measure their effects on one or more independent variables. This approach typically uses two groups: an experimental group, which receives the treatment, and a control group, which does not undergo any manipulation (Asenahabi,2019).

Qualitative research emphasises exploring and understanding the meanings that individuals or groups assign to social or human problems, as noted by Creswell (2014). Within qualitative research design, various approaches exist. A case study represents a design of inquiry in which a researcher conducts an in-depth analysis of a specific case, which could involve a process, an animal, a person, a household, an organisation, a group, an industry, a culture, or a nationality (Asenahabi, 2019). Other approaches include narrative research, phenomenological research, grounded theory, ethnography, and action research (Asenahabi, 2019).

Mixed methods research design integrates qualitative and quantitative research methods and data within a single study. This approach includes three primary types: convergent parallel mixed methods, explanatory sequential mixed methods, and exploratory sequential mixed (Asenahabi, 2019).

The current study seeks to analyse the readiness of domestic firms in the automotive industry for 4IR, as such, a qualitative approach will be more advantageous. A qualitative research approach is explained as one that depends on utilising text, audio, or video to gather and interpret the experiences, attitudes, or perceptions individuals attribute to social phenomena (Creswell, 2014). A qualitative research approach is more suitable for this study because it will allow the researcher to collect the unique experiences of each firm and make sense of their readiness within the context of each firm (Denzin & Lincoln, 2005). Furthermore, the study also seeks to understand each firm's experience in adapting to 4IR. A qualitative research approach will allow the researcher to understand the unique characteristics of each firm in trying to make sense of their ability to adapt to

4IR. A qualitative research approach is beneficial for research studies that seek to make sense of experiences that cannot be quantified.

3.4 POPULATION AND SAMPLING

Population refers to the object of examination that is comprised of people, gatherings, associations, human items, and occasions in a condition under which they are uncovered (Michel, 2010). The population that this study focuses on comprises manufacturing companies in the automotive sector in South Africa.

According to Acharya et al. (2013), a sample is a subset of the population selected to be representative of the larger population. Sampling is important in that, by taking a representative sample of the population, one can reduce the costs and time taken to conduct the research as well as the manpower required. Acharya et al. (2013) state that the representativeness of a sample rests on three factors: the sampling methodology, the size of the sample and the response rate.

The researcher used a purposive sampling method to gain detailed information about the readiness experiences of the selected automotive firms. Purposive sampling is a method that involves selecting participants that have in-depth knowledge of the research topic being investigated (Asenahabi, 2019). In this study, the focus was on domestic firms within the automotive industry in South Africa. The selection of participating firms was guided by specific criteria and factors, which are:

- Firms must be in the automotive sector and involved in the manufacturing of components or vehicles.
- The participating firms needed to have a physical presence in South Africa to ensure the findings reflected the local context.
- The selection included a range of firms, from small to large enterprises, to capture a broad spectrum of experiences and insights.
- Firms must be willing to engage with the research process and share information about their practices and readiness for 4IR.

The companies chosen range from multinational companies and OEMs with extensive local manufacturing facilities to small and medium-sized companies that specialise in automotive parts and innovation. These companies are located across major industrial hubs in South Africa: Gqeberha (formerly Port Elizabeth), Pretoria, East London, and Durban.

This sampling technique ensures that the participants meet the qualifying criteria for participation in the study. Another technique that the researcher has used is snowballing. Snowball sampling is also considered a convenience sampling method that is commonly used when it is challenging to find participants (Naderifar, 2017). This technique involves recruiting potential participants for the study through the person interviewee/existing study subject (Naderifar, 2017). Snowballing is known to be a cost-effective and efficient method for accessing individuals who are hard to reach or find (Naderifar, 2017). This method is said to have been mostly used to find participants who are unwilling to disclose their identities (Naderifar, 2017).

3.4.1 Selection of sample

Table 3.1 provides information about the participants involved in the research study.

Table 3.1: *Participant Information*

Participant code	**Position/role**
RP01	Senior Manager: Sustainability
RP02	Education & Training Manager
RP03	Executive Innovations Director
RP04	Executive Research
RP05	Final Area Manager
RP06	Innovation Engineer
RP07	Internal Relations & Numsa Representative
RP08	Production Manager
RP09	Managing Director
RP10	Executive Manager
RP11	Managing Director: automotive aftermarket
RP12	Manufacturing & technical director

3.4.2 Data collection and instrument

The goal of data collection is to collect quality information evidence that makes it possible to formulate convincing and credible answers to the posed research questions. A qualitative research approach favours collection methods that encourage capturing participants' perceptions and accounts. For this study, interviews were used as the primary data collection instrument.

Interviews are mostly used to capture participants' accounts, perceptions, stories and responses to certain situations or phenomena. Interviews can either be structured, semi-structured or unstructured (Paradis et al., 2016). The research makes use of semi-structured interviews to allow room for the participants to share information the researcher might not have thought of. The interviews were conducted through various modes: face-to-face, telephonic, and virtual sessions via MS Teams. In total, 12 participants took part in the study. The interview questions were guided by the research questions as well as research objectives. The researcher also made use of document analysis as a

secondary data collection method, utilising automotive industry reports and publications from automotive associations. The researcher also referred to similar studies done on the topic to make sense of some of the research findings.

3.4.2.1 Primary data: Semi-structured interviews

Semi-structured interviews are a type of qualitative research method that allows for flexibility in the questioning process while maintaining some structure in the interview process (Fontana & Frey, 2005). In a semi-structured interview, the interviewer has a list of pre-determined questions and topics to cover. However, they are also free to ask follow-up questions and explore the participant's responses more deeply (Fontana & Frey, 2005). This type of interview method is useful when the researcher wants to collect rich and detailed data while allowing for the participants' perspectives to be shared fully (Fontana & Frey, 2005). Semi-structured interviews are used in various research studies, including healthcare, education, and social sciences (Fontana & Frey, 2005). Researchers have found that semi-structured interviews provide an opportunity to gather detailed information from participants while maintaining some control over the interview process (Fontana & Frey, 2005).

The study utilised primary data in the form of semi-structured interviews as it allowed for in-depth exploration of the research topic from the perspective of the participants, providing valuable insights into their experiences and perceptions. This approach also facilitated the collection of rich and detailed data that could not have been obtained through secondary sources. The study's participants comprised company employees and several experts in the South African automotive industry. This included esteemed academics with a focus on automotive engineering, retired industry experts with decades of experience in vehicle manufacturing, and active union members.

Twelve (12) interviews were conducted, with 10 interviews conducted via Microsoft Teams. The interviews were semi-structured and lasted for about 45 to 60 minutes. The interviews were recorded and transcribed using MS Teams' integrated features, as well as manually, ensuring a high level of accuracy in data capture and ease in analysis.

For one participant, face-to-face interviews were conducted. These were held in controlled environments. The in-person approach was particularly beneficial for engaging with participants who preferred a more direct interaction over MS teams.

Because of connectivity issues, one participant opted to provide their insights through a written submission. Follow-up questions were then asked through a telephone conversation. Throughout

the study, strict ethical guidelines were adhered to. All participants participated voluntarily, with informed consent obtained before each interview. Confidentiality was maintained, with data anonymised during transcription using codes to protect individual and company privacy.

The study encountered several challenges in the process of gathering data from participants. One of the primary issues was the difficulty in coordinating interviews. Instances were noted where participants initially agreed to interviews but subsequently did not respond to follow-up communications for scheduling. This lack of response led to delays in data collection and necessitated repeated attempts to establish contact. There were also instances where participants agreed to a scheduled meeting but did not show up, and others would cancel at the last minute, citing urgent work matters.

Email communication also proved to be less effective than anticipated. Several participants who had agreed to participate did not respond to emails regarding the confirmation of interview details. This led to a lack of clarity of whether they were still available to participate and further scheduling challenges.

Connectivity issues presented another challenge, particularly for participants in areas with unstable internet connections. This affected the quality and continuity of both MS Teams and phone interviews, leading to incomplete data capture in some cases. Yet, these challenges were navigated with flexibility in scheduling, follow-ups, and adapting interview methods as needed.

3.4.2.2 Secondary data: Document review

Secondary data, also known as pre-existing data, is a valuable resource for researchers looking to answer research questions or supplement primary data (Bowen, 2009). Document review is a type of secondary data collection method that involves analysing existing documents, such as reports, policies, and medical records, to gather information relevant to the research study (Bowen, 2009). Document review is a cost-effective and efficient way to collect data, and it sometimes eliminates the need for primary data collection. Document review can supplement primary data collection methods, providing additional context and depth to the research study.

The study used secondary data to complement the primary data collected through interviews and surveys, providing a more comprehensive understanding of the research topic.

3.5 DATA ANALYSIS

Data analysis explains the methods that the researcher will use to analyse the data. In qualitative studies, the data tends to be narrative in nature and thus requires categorising through coding. As such, for this research, the data collected is categorised into key themes that are derived from the research questions.

3.5.1 Analysis of interview data: Thematic analysis

According to Braun and Clarke (2006), thematic analysis is a flexible and accessible method that can be used in various research fields. It involves six stages: data, generating codes, finding themes, reviewing the themes, defining & and naming themes, and reporting. By using the thematic method of analysis, the researcher can identify and report on the key themes that emerged from the data, providing valuable insights into the research question.

The study employed a thematic method of analysis because it enabled the researcher to identify, analyse, and report on themes within the data gathered. This method allowed for deeper exploration and understanding of the meanings and experiences of participants in a systematic and rigorous way.

3.5.2 Document analysis

According to Krippendorff (2013), document analysis is a systematic and interpretive approach used to make sense of textual data. It involves identifying, coding, and interpreting patterns or themes in documents, which can include texts, images, videos, and other forms of media. By using document analysis, the researcher can analyse and interpret various documents related to the research question, including policy documents, reports, and other written materials.

This study also employed the document analysis method utilising automotive industry reports and publications from automotive associations, to gain a rich and more nuanced understanding of the phenomenon under investigation, and the researcher was also able to draw meaningful conclusions based on the findings. The researcher also referred to similar studies done on the topic to make sense of some of the research findings.

3.6 LIMITATIONS OF THE STUDY

The limitations of this study are as follows:

- Unavailability of people for interviews: Some participants were not able to commit to the scheduled interview time due to their busy schedules. This limited the number of participants

who could be interviewed, and it also made it difficult to schedule interviews in a timely manner.

- Unwillingness of participants to disclose some information: Some participants were reluctant to disclose certain information due to its confidential or proprietary nature.
- People not showing up for interviews even though they had agreed: Some people who had agreed to participate in the study did not show up for the interviews. This reduced the sample size and therefore affected the representativeness of the study.
- Company policies not allowing people to participate in research: Some companies had policies that did not allow their employees to participate in research studies and this limited the pool of potential participants.
- Could not interview academia and policymakers to add to depth: Unfortunately, due to time constraints, representatives from academia and the policy space could not be interviewed. This would have added to the depth of the research findings and more valuable insights about the topic.
- Limited time for data collection due to the December shutdown period: The limited time available for data collection due to the December shutdown period resulted in fewer interviews being conducted. This may have affected the quality and depth of the data collected.
- Delays in the ethical approval process: The delay in the ethical approval process added to the overall delay in data collection. This further reduced the sample size and may have affected the study's representativeness.

3.7 ETHICAL CONSIDERATIONS

The ethical considerations relating to this study are the following:

- Participant Consent

All participants were provided informed consent, acknowledging their understanding of the research objectives, methods, potential risks, and benefits. Consent forms were designed to be clear and accessible, ensuring participants were fully informed before their participation.

- Anonymity and Confidentiality

To protect the privacy and personal data of participants, measures were put in place to ensure anonymity and confidentiality. This included the use of codes in reporting results. Only the researcher had access to the raw data, and all identifying information was removed before analysis.

- Integrity and Transparency

This research was conducted with the utmost integrity and transparency. The research objectives, methods, and outcomes were clearly communicated to all participants.

- Ethical Approval

This study received ethical approval from the Wits Business School ethics committee.

3.8 RELIABILITY AND VALIDITY

Reliability and validity are important for evaluating the quality of research designs and ascertaining whether the research design indeed represents a set of logical arguments (Yin, 2018). The trustworthiness of qualitative research is proven by maintaining four indicators: credibility, transferability, dependability, and confirmability (Yin, 2018). Validity in qualitative research refers to the appropriateness of the tools, procedures, and data that the researcher used, the validity of the research question for the intended result, the appropriateness of the methodology for addressing the research question, the appropriateness of the design for the methodology, the appropriateness of the sampling and data analysis, and lastly the appropriateness of the findings and conclusions for the sample and context (Yin, 2018).

To ensure the consistency of the interview process, a detailed interview protocol was developed, which included a set of core questions to guide the semi-structured interviews. This protocol ensured that while allowing for the natural flow of conversation, each interview addressed the same key themes, facilitating comparability across interviews.

3.8.1 Triangulation

Triangulation is a research technique that involves the use of multiple methods or sources to validate research findings. It is used to increase the reliability and validity of research results by cross-verifying data obtained from different sources. Triangulation can be used in qualitative and quantitative research studies, and it involves the use of different data collection methods such as interviews, observations, and surveys (Creswell, 2013; Yin, 2013).

Data from semi-structured interviews (with participants from companies and industry experts) were analysed alongside document analysis, allowing for the cross-verification of information and themes.

3.8.2 Transferability

Transferability, on the other hand, refers to the ability to generalise research findings from one context to another. It is concerned with the extent to which the findings of a study can be applied to other situations or populations. Transferability is an important consideration in research because it helps to determine the relevance and applicability of research findings to real-world situations (Maxwell, 2012).

While the study's focus was on the automotive industry, the findings may be transferable to other industries that are facing similar technological integration challenges.

3.9 SUMMARY

This chapter has largely outlined how the empirical research processes unfolded from the conceptualisation of the study to the conclusions of the study to achieve the main aim of the study. Further, this chapter highlighted the research approach, research design, research paradigm, and sampling methodologies of the study, which were not limited to data analysis.

The chapter that follows will consider the results and analysis of the study.

CHAPTER FOUR: RESULTS AND ANALYSIS

4.1 INTRODUCTION

The previous chapter discussed the research methodology employed in this study. This chapter presents the outcomes of the qualitative research undertaken to examine the readiness of the South African automotive industry for 4IR. The research methodology encompasses a qualitative approach through in-depth semi-structured interviews to understand the industry's current state of readiness for 4IR. The interviews aimed to answer specifically the following questions:

- What is the level of readiness of the South African Automotive Industry to adopt 4IR?
- What are the challenges and opportunities associated with the adoption of 4IR in the South African Automotive Industry?
- How can the South African automotive industry prepare for Industry 4.0 implementation to fully exploit the opportunities of 4IR?

4.2 BACKGROUND OF THE COMPANIES

This study focused on a selection of key players in South Africa's automotive industry. The automotive sector in South Africa is known for its significant contribution to the national economy and for being a major player in the global automotive market. The companies chosen range from multinational companies or OEMs with extensive local manufacturing facilities to small and medium-sized companies that specialise in automotive parts and innovation. These companies are located across major industrial hubs in South Africa: Gqeberha (formerly Port Elizabeth), Pretoria, East London, and Durban.

4.3 BACKGROUND OF THE PARTICIPANTS AND PROCESS FOLLOWED

The study's participants comprised company employees and several experts in the South African automotive industry. This included esteemed academics with a focus on automotive engineering, retired industry experts with decades of experience in vehicle manufacturing, and active union members.

Twelve (12) interviews were conducted, with 10 interviews conducted via Microsoft Teams. The interviews were semi-structured and lasted for about 45 to 60 minutes. The interviews were recorded

and transcribed using MS Teams' integrated features, as well as manually, ensuring a high level of accuracy in data capture and ease in analysis.

4.4 PRESENTATION OF FINDINGS

This section details the findings from interviews conducted with personnel from selected companies and industry experts.

4.4.1 Duplicative imitation

4.4.1.1 Meaning and understanding of 4IR

In terms of meaning and understanding of what 4IR is, the participants' responses highlighted a multifaceted view of 4IR, with some placing emphasis on its role in enhancing operational efficiency, the transition towards New Energy Vehicles (NEVs), and leveraging digital technologies to improve production outputs.

One participant responded that 4IR is:

"The Migration towards technology-based use of applications… as the term dictates itself, Fourth Industrial Revolution which is driven by Information Technology. We are talking about systems that are going to enable ease of existence particularly around mobility" RP10.

RP08's perspective underscores the essence of 4IR to achieve higher organisational efficiency—

"*Doing more with less."*

This notion points towards the optimisation of resources and processes across the spectrum of automotive manufacturing and management, suggesting a strategic shift towards leaner, more agile operations.

Two participants, RP04 and RP07, understand 4IR as the transition from petrol cars to NEVs, which represents a significant move towards alternative, green energy within the automotive sector, driven by 4IR technologies.

RP03's insights emphasise the distinction between automation and digitisation, suggesting that 4IR's impact extends beyond mere productivity enhancements.

"It's around using digital technologies to enhance and improve the output of production facilities at the end of the day… It is not related to automation; it does improve productivity or output, but digital and digitisation is a different opportunity to achieve against the common goal."

Another observation from participant RP05 was that South African companies are mirroring global 4IR practices, which underscores the international nature of these technological shifts. This replication indicates a recognition of the successful strategies implemented by leading automotive industries worldwide, adapting them to local contexts to stay competitive.

RP02's comments shed light on the role of technology in expediting the production process, especially for exports. The emphasis on quick delivery and the nature of 4IR technologies in achieving this speed illustrate the critical role of technological advancements in meeting the demands of the global market.

"For industry, 4IR means the introduction of technology to produce goods and services at a very fast pace, to ensure quick delivery of services, more especially the export orders to the export markets. A quick way of producing goods, and without 4IR, this might not be possible."

RP01 understands 4IR as a different way of manufacturing using the 4IR technologies.

"A different way of manufacturing products using advanced technologies applicable in the world today."

The 4IR has significantly transformed manufacturing processes, particularly in the automotive industry, by promoting sustainability, efficiency, and interconnectedness, as highlighted by Vicente and Dias-Trindade (2021). This transformation is driven by advanced technologies, such as AI and smart manufacturing frameworks, which enable smarter decision-making and increased productivity (Kapp, 2018; Gianolli, 2020).

The other participants, RP05, RP06, RP11, and RP12, understood 4IR as just the automation of processes.

4.4.1.2 Adoption of 4IR within companies

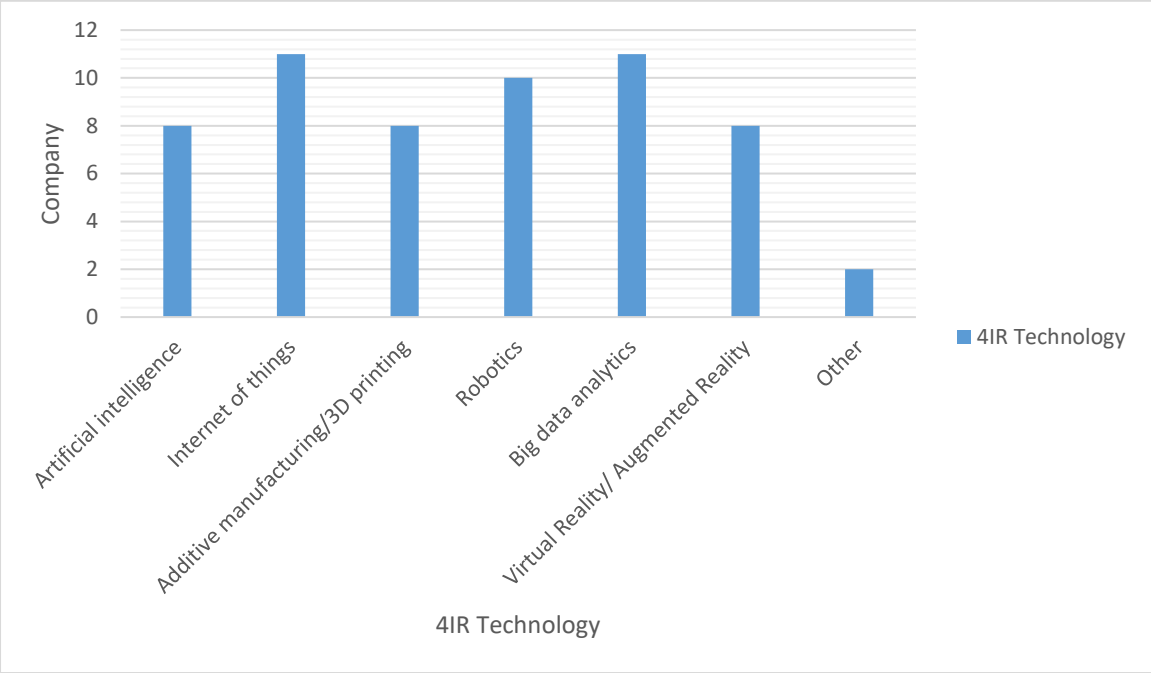


***Figure 4.1**: 4.0 technology adoption*

Figure 4.1 illustrates the number of companies that have adopted each of the following technologies: Artificial Intelligence (AI), Internet of Things (IoT), 3D Printing, Robotics, Big Data Analytics, Virtual Reality (VR), and others. IoT and Big Data Analytics are leading, with 11 companies each adopting these technologies. This indicates a strong trend towards leveraging data for decision-making and employing IoT to enhance business processes. Robotics follows with 10 companies, suggesting a significant investment in automation and efficiency improvement in operations. VR and 3D printing have been adopted by 10 and eight companies respectively. This reflects an investment in innovative and immersive technologies for training or customer interaction. AI is slightly less adopted by seven companies. Two companies have adopted other technologies, including cyber-physical systems.

The findings above suggest that the adoption of 4IR technologies in the automotive industry is on the rise. This is shown by an increasing trend in the usage of robotics, artificial intelligence, and the Internet of Things. These findings indicate that the industry is moving towards digital transformation and is investing in 4IR technologies to improve productivity and efficiency. Additionally, the graph also shows that the automotive industry is lagging behind in the adoption of blockchain technology, as not a single participant mentioned the use of blockchain. This means that there is an opportunity to explore the benefits of blockchain technology and leverage it for their operations.

4.4.1.3 Training programmes for employees to be able to work with the 4IR technologies

The responses to the data collected reveal a diverse landscape of training initiatives aimed at preparing employees to work with the 4IR technologies mentioned above.

Four participants, RP02, RP06, RP07, and RP08, revealed that their organisations have learning or training centres that offer a range of courses to keep the employees up to date with training requirements, particularly those related to 4IR. The skills or training offered in these centres range from technical skills which focus on production to training that is targeted at new technologies that are brought into the organisation.

"The organisation has a learning academy, that is there to understand the gaps within the organisation and for bridging them. The academy is responsible for identifying individuals to be trained in the latest technology such as Robotics, 3d printing, etc." RP08.

RP03 highlighted that his organisation uses an adaptive training model, ensuring employees are up to date with the technologies developed or created by their company, highlighting continual learning to keep pace with technological evolution.

> *"So, we take an active role in involving all of our employees and including them and keeping them up to date with the technologies we are developing for our customers and by way of keeping them up to date with regular update sessions... it is essentially training on the future training on 4IR technology".*

Two other participants shared that most training programmes are done through exchange programmes with the parent organisations – in the case of multinational companies. This is an effective method for skills transfer and providing employees with exposure to advanced technologies and a global perspective.

> *"Training is done through sending employees to Japan where the mother company is located, so when a new product comes, they get sent to Japan for skills transfer. People from the parent company in Japan also comes down to South Africa to train the people".*

Another training programme mentioned by RP10 was a training programme on NEVs, which focuses more on the maintenance and servicing of NEV cars.

What was also uncovered from the responses is an often-overlooked aspect of 4IR readiness – the importance of soft skills such as communication, teamwork, and adaptability. These skills are crucial for fostering an innovative, collaborative, and flexible workforce capable of navigating the fast-paced changes in the industry. Despite the training initiatives available in the organisations, the participants share the same sentiments that there should be a multidisciplinary approach to training due to the complex and interconnectedness of 4IR and that companies should fund training initiatives tailored to developing both technical and soft skills, ensuring that employees are well equipped to leverage the 4IR technologies.

4.4.1.4 Skills gaps that hinder assimilation.

Under this question, the participants highlighted several skills gaps that would hinder the assimilation of the 4IR technologies.

One significant skills gap that has been identified revolves around big data analytics. It was pointed out that there is an internal lack of expertise for analysing and interpreting the enormous datasets received. They further stated that the verification and accuracy of this data would become a challenge.

"There is a lack of expertise internally to be able to analyse the huge amounts of data received and interpret what exactly the data means. Verification of the data received also is a huge problem."RP01

Another gap identified pertains to the lack of planning due to insufficient information from senior management regarding the new skills requirements for 4IR technologies. This gap leads to the training department being unable to adequately prepare for the skills needed in advance, often resulting in the industry having to source the skills from overseas when it comes to the implementation of technology strategies, particularly in the maintenance department.

"*There exists a skills gap due to lack of information from senior management in terms of new skills required, therefore the training department isn't able to plan the skills required in advance*." RP02

It is evident from the study findings that implementing Industry 4.0 requires a strong relationship between technological readiness and design principles, with a focus on process-related objectives as highlighted by Adebanjo et al. (2021).

The other participants felt that the adoption and effective utilisation of AI technologies are hindered by isolated skills and a lack of awareness about the potential applications of AI.

"The adoption of AI is lacking as these skills are isolated, and the lack of awareness of the possibilities that come with AI." RP03

"The adoption of I think AI in particular has been lacking. Umm, because the skills are not spread, the skills are isolated".

RP10 raised that:

"If we get somebody that is qualified in the auto industry, it's somebody that would have gone through some curriculum that is outdated as a starting point".

This points out that some qualified individuals in the auto industry may have gone through an old curriculum that did not cover some aspects of modern technology or 4IR technologies. Therefore, individuals who have not updated their training may not possess the current skills necessary to work with 4IR technologies.

The widespread acceptance and optimal use of AI technologies face obstacles due to limited expertise and insufficient awareness of potential applications (Płonka, Rosiek & Jedynak, 2022). Additionally, there is a notable gap in AI research, raising concerns about its future consequences (Kapp, 2018). Despite these hurdles, the communication industry is actively investigating the integration of AI into networks and services to enhance efficiency and user satisfaction (Nyagadza, 2021).

RP07 stated that there is currently no skills gap in his organisation that he could think of as employees are trained before any technology is implemented.

One participant was unable to provide an informed answer as his organisation is currently conducting internal skills audits to identify and address gaps in 4IR technologies.

The Minister of Higher Education, Science & Innovation once highlighted that there is a huge skills mismatch in the country, referring to the types of graduates produced by universities and colleges versus the skills required by the labour market. He further emphasised that there is a need for more stem graduates and artisans, particularly in the areas related to the 4IR (merSETA sector skills plan, 2021). This is synonymous with sentiments shared by the majority of the participants on the issue of the outdated curriculum in institutions of higher learning.

4.4.1.5 Challenges faced by companies in implementing 4IR technologies.

The findings highlight several key challenges faced by companies in implementing 4IR technologies with communication and information sharing emerging as the foremost issue:

"The *biggest problem is around communication and information sharing because the Industry 4.0 is not isolated from the company strategy... in most cases, information is not shared, and there is not proper communication."* RP02

"Training departments aren't able to plan skills required in advance due to lack of information from higher ups. Employees also taking up careers and skills not based on what is going to be required due to lack of information. Which results in shortage of skills when it

comes to the implementation of these strategies. Which results in the industry sourcing the skills from oversees".

Another challenge is the dependency on external expertise for the introduction and effective training on new technologies. RP08 emphasised the importance of immersive training experiences, suggesting that sending groups to the mother plant for extensive participation in the process could bridge the knowledge gap, ensuring a deeper understanding of the technology upon their return.

"The company should take groups of individuals to the mother plant for training, leave them for months to be part of the process so that when they come back, they fully understand the technology."

RP08 also highlighted a critical issue of underutilisation of skills, pointing out a disconnect between the training provided and its practical application. This suggests that while employees may be trained, the effectiveness of this training in equipping them to work with 4IR technologies is questionable, indicating a broader issue of training adequacy.

"Skills are there, however, they are not adequately utilised due to inadequate training there is a huge disconnect in the delivery method of the method."

Other participants highlighted that the readiness of staff to adapt to 4IR technologies as the most significant skill gap. Despite receiving training, there's an underlying concern regarding whether the training is comprehensive enough for employees to be effective in a 4IR-driven environment.

Another challenge that came up mostly from the small domestic firm was financial. The high costs associated with adopting new technologies require substantial investments, often beyond the budget of SMEs, impacting their ability to fully compete in the market – RP09. In addition to the high cost, there is also a challenge of access and connectivity issues.

"Some of the challenges relate to access. I mean, if you look at the geographic outlook of the Eastern Cape, we still have such an area as that one of proper network and proper network connectivity. So that's you know your broadband related issues. Number 2 it is actual possession of the actual tools that are necessary to enable your technology based, you know, operation of your business".

Alexander (2022) highlights that connectivity services in South Africa are underdeveloped. This is a result of the deteriorating quality of the South African infrastructure (World Bank, 2018). Deloitte also identified this issue in its 2016 report titled "Industry 4.0: Is Africa ready for digital transformation?" by stating that one of the challenges related to 4IR adoption in South Africa is connectivity and accessibility.

The implementation of 4IR technologies in various industries is hindered by a range of challenges. Communication and information sharing are identified as the primary issues, with a lack of relevant skills, training capacities, and negative perceptions, which also pose significant obstacles (Malomane, 2022).

Employee resistance to change was also raised as a challenge, which is caused by a lack of clear leadership vision and inadequate change management strategies.

> *"I think there's always some human resistance to try new things, especially very skilled artisans are used to doing things a certain way".*

A range of studies have highlighted the challenges of employee resistance to change in the context of technological and organisational shifts. Rehman (2022) emphasises the importance of employee participation in decision-making and the need for effective change management strategies to mitigate this resistance. Miller (2019) further underscores the potential for technological advancements to reduce employee resistance. Integration with existing systems was also cited as a challenge, with participants noting technical difficulties in ensuring compatibility between old and new systems.

RP07 and RP04 shared that the transition to NEVs demands significant investment in research and development (R&D), new manufacturing equipment, and technology infrastructure. This requirement has a huge impact and could put a strain on financial resources.

4.4.2 Creative imitation

4.4.2.1 Creative adaptation or improvement of existing technologies to better suit the South African market?

The integration and adaptation of automotive technologies for South African roads illustrate an innovative process aimed at enhancing road safety and vehicle performance in response to local challenges. RP02 gave an example of how the built-in sensors in vehicles were adapted to detect potholes, potentially mitigating road damage. A similar example was given by RP11, RP07, and RP05, highlighting the modification to technologies for optimal performance in local terrain, e.g. the car being able to detect mud, rural roads, and ditches and switching the driving mode accordingly. All these modifications were done to ensure that vehicles are equipped to navigate the unique challenges presented by the South African landscape.

An interesting finding from three participants highlighted that there is a process for the replication and creative adaptation of imported technologies and mechanical parts:

> *"The company receives products and prototypes from the parent organisation. A rigorous methodology is employed, involving a comprehensive database of all imported components and technologies. These items undergo detailed analysis and testing to ascertain their compatibility with South African conditions. The objective is to localise production while ensuring these adaptations meet the region's specific requirements"* RP01.

RP04 also alluded to the acquisition of blueprints from the parent company, which were then modified to align with local conditions.

> *"This process includes the design and development of products specifically engineered for the South African environment. And local service providers are brought on board to replicate and*

improve on the technology and then it gets taken through a homologation process to ensure compliance with South African Standards and market requirements".

What has also been noted within the companies were the adaptations of AI and Virtual Reality simulations to support plant operators in maintenance and training. These show the willingness and application of technology for the improvement of internal manufacturing processes. Another example of the creative adaptation of AI was the use of AI-powered vision systems for the assessment and improvement of product quality inspection. This system enhances the effectiveness of the evaluation, reducing the errors that are sometimes found during manual inspections.

> *"We're using AI computer vision to help guide operations on how to assemble a product using digital work instructions that dynamically change based on the operators' tasks, collecting the data in the cloud, giving them that streamlining of... We also create VR simulations to train the operators"*

The use of AI and Virtual Reality (VR) in manufacturing processes has been noted as a significant trend, with applications in plant operation support, maintenance, and training (Bai et al,2020). According to Bai et al. (2020), these technologies have been found to have various applications in plant operation support, maintenance, and training. One significant application of AI and VR in manufacturing processes is in enhancing the effectiveness of evaluation and reducing errors in product quality inspection. Bai et al. (2020) found that AI-powered systems can detect defects and anomalies in products with greater accuracy and precision than human inspectors. This can help reduce costs, improve production efficiency, and enhance product quality. In addition to quality inspection, VR has also been applied in the training of process plant operations (Alexander, 2021). By creating a virtual environment that simulates the actual manufacturing process, trainees can gain hands-on experience in a safe and controlled environment, this can help reduce the risk of accidents and errors during actual plant operations (Alexander, 2021).

RP12 and RP10 have highlighted that the 4IR technologies serve as enablers to help companies produce goods that meet the required specifications for the entire value chain.

"Those are the enablers. Those are the techniques we used to solve the problem."

"4IR is an enabler as well to make sure that we produce as much as we can. To meet the right specifications that are required in the entire chain, yeah."

4.4.2.2 Percentage of local content used

Results from the companies are presented in *Table 4.1*.

Table 4.1: *Percentage of local content used (locally produced parts, components, and materials in the manufacturing of vehicles such as technology for automation, and 3D printing components and prototypes)*

% local material utilisation/content	# of companies
0–9	0
10–19	0
20–29	0
30–39	1
40–49	5
50–59	0
60+	4
Not sure/confidential – can't disclose	2

Table 4.1 summarises the data on local material utilisation in the automotive industry. It outlines the current utilisation percentages. This data suggests a concerted effort by the companies towards increasing the percentage of locally sourced material. The data shows that the South African companies are moving towards localisation.

Half of the participants were satisfied with the percentage of local content used and the strides made by the companies towards achieving the targets set in the policy document by the Department of Trade and Industry.

Concerning local content, a reference was made by RP04 that according to the Automotive Industry Masterplan, the industry-wide target for local vehicles is 60%, with a specific goal for local content per vehicle at 40%. One participant stated that there has been notable improvement over the years and that this incremental progress suggests a positive trend, albeit slow, towards higher local content in automotive production. In contrast, two other participants shared that South Africa is behind in reaching the target.

"This is the target for each year and the country is not close in achieving the target and the country is sitting at around 40–45 % target on localisation and we have been around the same mark for the past 5 years" RP02

"So, we are a bit behind in terms of ensuring localisation."

While the figures above are positive, some concerns were expressed regarding the feasibility of achieving these targets, especially in the context of transitioning towards NEVs.

"The adaptation to NEVs poses a significant challenge, as the localisation of parts may be delayed by the slow development of the required supply chain" RP04.

There has also been a concern from RP02 that the figures above have remained relatively stable over the past 5 years. This highlights the need for government programmes that will support the companies and ultimately expedite the actions towards meeting the localisation rates in alignment with industry goals and national policy objectives.

The South African Automotive Industry Masterplans 2035 paints a different picture of the results. According to this plan, the national target is to increase the use of local content to up to 60% by 2035. In terms of performance against this target, the average local content in vehicles is currently below 40%, with approximately 30% for high-technology vehicles.

While there is a clear intent and policy direction towards increasing the percentage of locally sourced materials, actual achievement varies widely across the industry.

4.4.2.3 Collaborative ventures with foreign companies

The insights gathered from the participants provide a nuanced view of these collaborative efforts. The companies agree that they do have collaborations with foreign companies. The multinational companies in SA specified collaborations with parent organisations. The collaborations with multinational organisations are strategic and are aimed at manufacturing activities or launching products in South Africa. RP04 states that:

"This approach signifies a strategic effort to integrate into the global supply chain while contributing to the local automotive industry's growth and development".

"Multinational companies also provide huge investments in infrastructure" RP10.

RP01, RP07 and RP12 mentioned that they are currently not in partnership with any other company except the parent organisation, highlighting a cautious approach to external collaborations. This outlook is primarily driven by the desire to maintain proprietary information and secure a competitive edge, leading to a cautious approach to collaborations.

The other forms of partnership mentioned were collaborations with research organisations for 4IR and with the service partners. The companies have mentioned that with some of the technologies being imported, they need partnerships to assist with servicing and training.

"It's difficult to collaborate with local companies because our competition laws are very, very tight, very strict. But we do collaborate a lot overseas. We are members of several research organisations and industry organisations internationally. We actively participate in research projects with these organisations. We have overseas suppliers that we normally compete with, but we actually collaborate with them." RP12

RP06 further added that:

"Involvement with foreign companies is in the form of a supplier relationship, seeking external expertise when local solutions are insufficient."

The importance of partnerships in the form of collaborations with service partners is underscored by several studies. Nyagadza (2021) highlights the benefits of collaborative relationships, emphasising the positive outcomes, while Crouse discusses the strategic advantages. Rampersad (2014) further supports this, showing that international collaborations can enhance a firm's decision to enter the export market.

There was also a perspective that contrasts the above, noting:

"OEMs in SA are multinationals, so instead of collaborating with other companies they view other companies as competitors and even when they engage in industry forums, they don't want to give too much information for the competition."

Despite this competitive stance, RP02 acknowledged a partnership with another OEM on the development of a local product, indicating selective collaboration when it aligns with mutual interests. The companies are also affiliated with certain professional bodies to leverage the resources and networks offered by these bodies.

4.4.2.4 Types of technologies and knowledge exchanged collaborative ventures with foreign companies

The type of knowledge exchanged in these partnerships varies. The participants revealed the following information regarding the type of knowledge exchanged.

For multinational companies, knowledge exchange encompasses the production of parts or products on their behalf, along with technology transfer. This exchange is vital for local companies to integrate global technologies and production methodologies, enhancing their capabilities and competitiveness. The findings also show that the knowledge exchanged includes engineering designs and infrastructure, along with the deployment of engineers and a highly skilled workforce.

> *"Engineering designs, engineers, and the highly skilled workforce."RP02*

> *"Incubators which are part of the infrastructure of ensuring that we create this environment to ensure that you develop and produce products or components that would meet the standards in a controlled environment."RP12*

RP01 elaborated on the knowledge exchange, noting it extends to product knowledge on new or imported products, investment insights for plant development, blueprints of the plant and products, skills transfer, and benchmarking of South African products against global standards.

There was also an emphasis on the transfer of advanced manufacturing technologies, including manufacturing processes, automation, vehicle technology, software technology, and digitisation.

4.4.2.5 Impact of collaborations on production output

Some of the participants highlighted that it enhances employee efficiency and confidence in handling and using the 4IR technologies. This contributes to a more skilled and capable workforce.

Another key impact mentioned in the collaboration has been the reduction of competition from fully built imports. By producing the products locally, the collaboration contributes to the local economy, particularly in terms of job creation. This approach not only fortifies the market position of the companies involved but also supports the broader economic landscape of SA.

"The collaborations have led to increase in the sales of … and it also boosts the market share... Also helps in reducing the competition from foreign direct imports when cars come in fully built in country where they are not contribution to jobs… In terms of marketing strategy is working very well." RP02

RP04 added that the creation of value addition through localisation efforts led to lower vehicle prices and a wider variety of products. This approach not only benefits consumers but also strengthens the local industry's competitive edge.

Research has consistently shown that collaboration leads to a range of benefits, including reduced costs, increased sales, improved customer service, and a competitive edge (Rampersad, 2014). This is particularly true when there is a high level of collaboration, which can lead to improvements in operational and relational outcomes, ultimately enhancing asset utilisation, competitive position, organisational performance, and profitability (Gianolli, 2020). Furthermore, collaboration can significantly impact innovation performance, with the collaboration process, learning capability, and operation capability all playing a key role. Yet, the success of collaboration in supply chains is also influenced by factors such as collaborative planning, decision-making, and execution, which can lead to future collaborations (Ramanathan, 2014).

RP01 stressed that:

"The collaborations enable the production of products that meet global standards and governmental requirements."

4.4.3 Exploitative Innovation

4.4.3.1 Investments in R&D

Some participants revealed that they do not have a unit that focuses on R&D. However, when it comes to the allocation of budget, there is very limited allocation, which means that as much as the organisations understand the importance and impact of R&D, it is not a priority.

Three other participants mentioned that there's no active R&D in their organisations and that R&D is mainly done at the parent organisations. RP04 alluded to this by saying:

"Product development done overseas. We are responsible for the assembling."

Another participant revealed that R&D is core to their business; therefore, investments in the budget are made.

"A huge percentage of our of our budget is dedicated to R&D because that's the nature of our business... a big portion…20% towards developing new digital products".

Two other participants said the budget is limited. However, they were unsure of what the percentage allocation was. RP04 shared that:

"There are low levels of R&D because product design is done overseas, and South Africa focuses on process design."

One participant was not comfortable sharing that as it is strategic information.

RP10s response regarding R&D investments was:

> *"The parent companies have invested significantly into research and development. I mean, if you look at the likes of BYD and what I'm going to say is in the public domain, there was an article that indicates that they've employed 90,000 researchers which form part of their employees' compliment which is an excess of 7000. And see from that scenario that there is a significant investment into R&D and obviously given the fact that OEMs are current companies including the component manufacturers, they also are addressing themselves to the future needs. So, there is a significant investment that has been made for from that point of view. I mean, if you look at the likes of the Council for Scientific and Industrial Research which is part of the South African investment into research and development, and, by the way, the first model of an EV of an electric vehicle was produced in the early 70s in South Africa and that intellectual property in is held by the by the CSIR."*

In comparison to global standards, South Africa is lagging when it comes to investing in R&D (Alexander,2021). This phenomenon could be attributed to several factors. Firstly, R&D is mostly viewed as an activity of multinational corporations (MNCs) or parent organisations, whereas South African companies are primarily involved in process R&D (Alexander, 2021). This limits their level of involvement in developing innovative products or services. Furthermore, the end products in the supply chain are often restricted by the original equipment manufacturers (OEMs) standards, which are set at a global level (Alexander,2021). This limits the scope of innovation for local companies to the manufacturing processes only, and thus they may struggle to keep up with global competitors.

Lorenz et al. (2019) reveal that SA firms (OEMs) are marginalised in R&D by multinational companies as their core competencies s are limited mainly to integrating the operating system and coordinating large networks of suppliers that provide components and subassemblies. Barnes et al. (2018) alludes to this, highlighting that this leaves little room for the development of local technology, and South African firms have been marginalised in R&D activities since the mid-1990s, despite their integration into GVCs since the advent of the Motor Industry Development Programme

(MDP) in 1995. This highlights the need for a shift towards a more inclusive and collaborative approach to innovation.

4.4.3.2 Unique project leveraging 4IR

The companies interviewed showed some initiatives about the exploration of the 4IR technologies to improve manufacturing processes, vehicle performance, and customer services.

RP04 response was:

"We are using advanced technologies to

help unskilled people".

Two participants disclosed their engagement with 4IR technologies using 3D printing. While they acknowledged that their projects might not be entirely unique in the global context, they have effectively capitalised on the opportunities presented by 3D printing technology. 3D printing is primarily applied to the production of parts – ranging from the replacement of faulty or frequently breaking components to the development of parts that offer significant performance improvements. This practice not only enhances the efficiency of their manufacturing processes (as they do not have to wait weeks for replacement parts to be imported).

RP06 responded that:

"Currently I'm working on a software bot to automate some of the processes that our manufacturing process engineers
do repeatedly, some of the work that they do repeatedly."

Another participant highlighted that their designs are crafted in-house, suggesting a high level of customisation and innovation within their production processes. Conversely, the other company pointed out their method of working from an existing blueprint, which they then modified or improved upon to achieve the desired outcomes.

One participant mentioned that the company is working on many projects, mostly AI-based projects. However, he could not disclose any information about the projects.

However, not all participants reported engaging in distinctly unique projects that leverage 4IR technologies. Some companies indicated that their focus lies in incremental innovation rather than groundbreaking projects.

One participant mentioned that there are innovative projects that he is working on with a university, and they have already developed some prototypes that are aimed at addressing some of the challenges within the automotive space.

The above responses highlight the varied pace at which different companies are embracing the opportunities presented by 4IR technologies.

4.4.3.3 Collaborations with academic institutions

The majority of the participants highlighted that there is some partnership with the neighbouring institutions of higher learning, such as universities and TVET colleges, which plays a crucial role in the ecosystem of innovation and skills development within the automotive industry.

RP02 specifically mentioned collaboration through university automotive chairs, highlighting the formal structures in place that facilitate interaction between academia and industry.

"OEMs in each province are working very closely with universities in that province and they mostly form part of engineering chairs in the universities. That's an example of collaboration between industry and academia. The value derived from the collaborations relates to the improvement of products and technology as some of the technologies such as the robots are manufactured locally. So, they benefit because they obtain the knowledge in terms of what kind of technology should be used and which one is cheaper than the other."

This is supported by RP04s' allusion to similar partnerships, suggesting that these relationships are instrumental in bridging the gap between theoretical knowledge and practical application in the automotive field. The company collaborates on advisory boards, as chairs at the institutions, and consults on curricula on automotive perspective, research work, and innovations in terms of manufacturing processes.

Other participants mentioned having a partnership with university-based programmes to assist in research on innovation and technology-driven solutions for the company. They also mentioned using the partnership for design and prototyping-related activities, as well as for testing and validation of products.

Another participant mentioned a partnership with public sector agents:

> *"I'm sure you are aware that there is what you call the XYZ one of the areas of focus are solid technology driven solutions that are aimed at supporting the automotive industry".*

One participant, however, provided a different perspective, indicating that their partnerships with universities are primarily focused on sourcing students and providing bursaries. This suggests that while there is engagement with academic institutions, it is mainly oriented towards talent acquisition and financial support for students rather than direct collaboration on research and development projects.

One participant mentioned that they are in partnership with a university but not for research purposes due to his history with IP ownership-related claims. This participant also mentioned that the turnaround times for universities are very slow. However, he did mention that they use universities for other things:

> *"So, we don't use them for R&D, but we use them to augment our R&D. So, all of our testing that we require and validation and things like that, they get involved in that regard".*

These findings revealed a noticeable gap in terms of working closely with the intention of innovating. This indicates that while there are interactions between companies and universities, there may be untapped potential for deeper, more collaborative efforts focused on driving innovation within the industry. Furthermore, there was no mention of working with other research institutes, such as the CSIR, which is noteworthy for its contributions to scientific research, including in the automotive space.

The automotive industry faces significant challenges, including the need for more efficient and alternative fuel vehicles. However, there is a noticeable gap in collaborative efforts between companies and universities, which could drive innovation. The importance of industry-academia collaboration for sustainable development and productivity improvement is highlighted by Freitas et al., (2013). Industry-academia collaborations are vital for technological innovation, by incorporating the industry sector into the university curricula, academic institutions are fostering a culture of innovative thinking that is driving progress in automotive industry (Freitas et al., 2013). Additionally, companies that collaborate with universities often provide funding for gifted students to conduct industry-relevant research, which not only benefits the companies but also provides students with valuable real-world experience (Macpherson,2023). These collaborations are mutually beneficial, as they allow industry to stay on the forefront of technological advancements while providing universities and students with the resources and knowledge necessary to drive innovation forward.

On a positive note, collaboration with the merSETA was highlighted. This partnership is focused on developing the skills and research capacity within the automotive industry. merSETA's involvement is crucial for ensuring that the workforce is equipped with the necessary skills and knowledge to meet the industry's evolving demands, thereby supporting growth and innovation.

4.4.3.4 Measurement of success

The participants responded that the success and impact of their R&D initiatives can be measured through several key indicators.

The successful launch of a product was highlighted as a primary measure of success for R&D initiatives. Interviewees indicated that bringing a product from the conceptualisation phase through to market introduction serves as a tangible indicator of the initiative's effectiveness and its ability to meet targeted needs within the marketplace.

Revenue generation was also emphasised as a critical metric for evaluating the impact of R&D projects. Participants pointed out that the ability of a newly developed product or service to generate revenue is a direct reflection of its market acceptance and the value it brings to customers. This financial metric is crucial for assessing the return on investment in R&D activities.

"*Revenue, are we able to make money out of it*." RP04

Improvements in efficiency within systems and production lines were identified as another important measure of success for R&D efforts. Participants noted that R&D initiatives aimed at enhancing operational efficiencies can significantly reduce costs, improve productivity, and increase overall business competitiveness. These improvements are often quantifiable and contribute directly to the organisation's bottom line.

Research shows the positive impact of optimising operational efficiencies on the financial returns of R&D investments, as indicated by studies like that of Ikome and Kanakana (2018). This correlation is particularly pronounced in complex operational environments characterised by high labour intensity and geographical diversity. The adoption of lean principles within R&D activities is recognised as a strategic approach to enhance efficiency and effectiveness (Ikome and Kanakana, 2018). The importance of organisational effectiveness also emerges as an important factor influencing R&D productivity, this show that the organisational structure and processes play a critical role in determining the success and efficiency of R&D endeavours.

4.4.3.5 Perspective on managing risk?

Some organisations highlighted a similar process when it comes to risk-taking. The process is initiated by involving all responsible individuals and parties that could be impacted by the technology (or new project) to ensure that a variety of perspectives are considered from the planning phase, making the risk assessment more comprehensive. Then, key stakeholders are identified, including members from the innovation or planning department, product engineers responsible for the specific body or component, process engineers overseeing the manufacturing process being modified, maintenance personnel, and production staff. After that, a thorough risk assessment is performed with contributions from all stakeholders.

"This stage is critical for identifying potential concerns and risks from each stakeholder's viewpoint, aiming to compile a complete picture of possible challenges the project might face" RP06.

Following the identification of potential risks, strategies to address and mitigate these risks are developed. After each phase of the project, there are some iterative reviews to assess the progress and re-evaluate the risk, and stakeholders reconvene at each critical milestone to review progress and reassess risks. The project's status is continually evaluated against predefined benchmarks to decide whether it is safe to proceed.

A different approach to risk-taking was also highlighted, and this involved the process that follows. Decisions to explore new technologies are made by the team. Upon identifying a potential technological advancement, a general assessment is quickly conducted. This initial evaluation aims to ascertain the technology's relevance and potential benefits to the organisation and its customers. If the general assessment yields promising insights, the organisation promptly puts together a dedicated team to investigate the technology further.

"This team is tasked with exploring the technology's applications and implications over a fixed period, such as the next 12 months, to thoroughly understand its potential impact." RP04.

Once a decision is made to pursue a new technology, the organisation acts immediately. There is no lag between decision-making and the initiation of the project, ensuring that innovative solutions are rapidly developed and deployed. There are risk management policies in place for the management of risk.

A range of perspectives on managing risk have been explored in the literature. Kapp (2018) emphasises the importance of considering the life cycle and stakeholder perspectives in construction projects, while Gianolli (2020) highlights the significance of risk management in supply chains. Kapp (2018) discusses the limitations of quantitative risk assessment and the need for stakeholder involvement in decision-making processes. Gianolli (2020) proposes a risk management framework for product development processes, focusing on the structure and architecture for defending against various risks. These perspectives collectively underscore the need for a comprehensive and inclusive approach to risk management, considering the various stages of a project, the involvement of key stakeholders, and the specific risks associated with different processes.

4.4.4. Explorative Innovation

4.4.4.1 Novel technological innovation introduced to enhance the global competitiveness

A few participants highlighted that they are active in this dimension:

> *"There's numerous different ones.*
> *Obviously the XYZ one is a big one in that we realise the opportunity with digitisation and so umm, we've invested heavily in that".*

> *"There's about four active capital projects of AI projects that are underway and some of the other projects. Also, I can't talk about because that's a strategic advantage, but I can tell you right now as we stand there are four active projects that will terminate or will reach conclusion by the end of the month".*

South African companies have made progress in adapting, integrating, and significantly enhancing existing technologies to boost efficiency and global competitiveness. However, the findings from the interviews paint a somewhat contrasting picture regarding the extent of explorative innovation. Most of the companies reported a lack of significant innovations that differentiate them from competitors. Furthermore, some companies felt that this section did not apply to them. These responses suggest that the focus among many companies is on incremental and exploitative innovations (to an extent) that are about refining existing technologies rather than pioneering new ones.

4.4.4.2 Intellectual property or patents held by companies differentiate it in the global market

Only one company distinguished itself by developing a new technological platform that is competing globally.

> *"To compete better globally, we have our own ERP system that we developed, which is essentially software technology allowing us to streamline our processes".*

This company also disclosed having three pending patent applications, showing a commitment to innovation as a core business strategy. However, sometimes the filing of patents is not prioritised due to the process's complexity and financial implications, which highlights systemic barriers to innovation.

> *"Yeah, we have a few patents pending. There's been a few over a couple of years…For example, a few of them, they cost a lot of money, especially to do a global one. So, the majority of the ones we're technically we could have, uh, we decided not to because it's not worth the money… there's 2 of them are related to software and one of them is a mechanical one."*

An interesting view also came from RP12, who stated that his organisation has some of the best innovative products in the world. However, they are sceptical of patenting as it exposes their innovation to competitors who might steal through reverse engineering. He further highlighted that once a company decides to patent, it must be on top of its game with continual innovation, which puts some pressure on the company.

> *"The thing is, as soon as you patent, by the time you patent something, you have to be on the next development, right? So, if you haven't, then you fall behind. So personally, I don't believe in patents. …The thing about a patent is as soon as you patent it, everybody sees it and regardless of how rock solid you make your patents. [A] clever engineer will be able to get an idea and adapt an idea based on your patents, so you can't. Once it's patented you can't keep it secret, right? So, I don't. Personally, I don't believe that's part of our strategy. My strategy, I don't patent anything."*

4.4.4.3 Strategy for bringing new innovations to market.

Majority of the companies do not have a go-to-market strategy for explorative innovation.

"This is something that we're going through at the moment, and we are figuring that out as we go along. And the problem, the problem we have with new technologies is that I think a big part of the go to market strategy has to be education. Uh, informing people why this makes sense independent of your product and we were figuring that out now."

A few participants pointed out that the lack of investment in explorative innovation stems from a skills gap. For SA to emerge as a leader and compete globally, particularly in NEVs and other cutting-edge technologies, the government should intervene by creating a conducive environment through supportive policies. This is essential for fostering explorative innovation among South African companies.

The next chapter will be a discussion.

CHAPTER FIVE: DISCUSSION

5.1 INTRODUCTION

The preceding chapter was on results and analysis. This chapter provides a discussion of the results of the study using the Secondary Innovation Framework as a theoretical lens. The analysis focuses on the South African automotive industry's performance in each phase of innovation as outlined in the framework. The discussion aims to provide insights into the automotive industry's approach to innovation and its preparedness to adopt and integrate the 4IR technologies.

5.2 THEMES

5.2.1 Duplicative imitation

The theory of secondary innovation provides a useful framework for understanding the development process that latecomers can follow to acquire and assimilate new technologies and innovations (Wu et al., 2008).

Duplicative imitation is the first dimension of an organisation's technological capability and refers to the process of a latecomer importing foreign technologies and mastering the operational technology through learning by doing (Wu et al., 2006; Wu et al., 2008). This includes importing manuals, technicians, blueprints, and technological know-how. In this stage, the dominant organisational learning mode is "adaptive learning", which involves adjusting to the new technological paradigm. This means that the organisation focuses on understanding and mastering the imported technology. This stage is an important foundation for the organisation's future technological capability development.

The present study indicates that the automotive industry in South Africa is dominated by multinational corporations. These entities bring a wealth of resources, including foreign direct investment, cutting-edge technologies, specialised training programmes, and comprehensive support systems (Lorenz et al., 2019). This influx of resources has been instrumental in enabling South Africa to develop the necessary capabilities for manufacturing vehicles and related components. However, domestic firms, especially those not backed by multinational partnerships, face considerable challenges in acquiring and applying 4IR technologies.

At present, domestic companies import foreign technology through parent organisations or collaborative partners in developed countries. This includes infrastructure, blueprints, technology know-how, prototypes, and skills. The findings suggest that South African companies in the industry have gained proficiency in these technologies through years of manufacturing and competition in the market. They are also exporting companies to other countries, including developed nations, indicating their mastery of the technology at this stage.

The study further highlights the increasing trend of the application and adoption of Fourth Industrial Revolution (4IR) technologies in the automotive industry, with robotics, artificial intelligence, and the Internet of Things being the most commonly used technologies. The industry is investing in 4IR technologies to improve productivity and efficiency. However, smaller companies are facing challenges in implementing or fully adopting these technologies due to financial constraints, lack of proper infrastructure, and access issues. This was also highlighted by Moos and Sambo (2018) in their study findings, which showed that SMEs within the automotive industry face challenges related to lack of funding, poor management skills, and little infrastructure. Muyengwa et al. (2013) also alluded to this, citing that infrastructure and funding were the most significant barriers to implementation and adoption.

A prevalent theme in the literature is the importance of developing skills in the era of the Fourth Industrial Revolution. Olaitan et al. (2021) point out that there is a gap between the skills taught in existing STEM curricula and the skills needed in the 4IR economy.

The study reveals several skills gaps that are hindering the assimilation of 4IR technologies. Moreover, some of these gaps are linked to weaknesses in skills at the intermediate technical level, with a big gap between the knowledge acquired through technical training in TVET institutions and the capabilities and problem-solving skills needed to be operational in the firm. This gap calls for a re-evaluation of the skills training curriculum to ensure that it meets the demands of the changing technological environment. Noqayi (2021) also realised this gap and thus proposed a conceptual framework that focuses on early exposure and skill development to foster 4IR skills.

Lorenz et al. (2019) also found that employees from TVET colleges lack the problem-solving skills required in the work environment, alluding to the aforementioned point. Therefore, there is a need for the vocational education system to better integrate work activity and experience in the firm into the curriculum so that employees can apply knowledge effectively in their work environment

(Lorenz et al., 2019). What was also found was that there is a low level of capability in the industry for programming for programmable logic controllers (PLCs) and automation solutions.

The study found that the qualified individuals working in these companies attended institutions of higher learning in the country, which have outdated curricula that are not producing personnel that are 4IR ready. Based on the above findings, it is evident that there is a lack of a proactive approach when it comes to skills planning in response to the evolving skills requirements of the 4IR. Regarding training the organisations to provide in-house training to equip the employees to be able to work with the technologies, Lorenz et al. (2019) maintain that while companies in South Africa do provide such training for their employees, the available technologies, specialised training such as laser welding is not readily available within the country. Such training is usually provided by parent companies, which creates a disadvantage for local firms that do not have links to international organisations. Organisations such as merSETA are at the forefront of providing industry-specific training and support to ensure that the sector is 4IR-ready and ready to compete with other countries. Furthermore, some companies are not prioritising 4IR training, and qualified personnel in these technologies are being poached by international companies, leaving behind those who are not as proficient.

Challenges faced by companies in implementing 4IR technologies include communication and information sharing, dependency on external expertise, underutilisation of skills, employee resistance due to lack of awareness and fear of the technologies, and not understanding the possibilities that come with these technologies. SMEs face additional challenges related to access and financial constraints. Despite these challenges, the automotive industry remains the largest contributor to the South African economy, with 351,785 vehicle units exported in 2022 with an export value of R18.7 billion (NAAMSA, 2022).

The above signifies that South Africa was successful in developing basic production and technical capabilities through mastering manufacturing know-how by learning by doing.

5.2.2 Creative imitation

Creative imitation is the second dimension of an organisation’s technological capability and involves the combination of foreign and existing technologies (Wu et al., 2006; Wu et al., 2008). In this stage, the latecomer localises the acquired technologies and forms production capability through structural understanding (Wu et al., 2006; Wu et al., 2008). This means that the organisation adapts

the imported technology to fit its specific context and combines it with existing technologies to create a unique production system. The dominant organisational learning mode in this stage is "maintenance learning", which focuses on making the production systems more reliable and efficient (Wu et al., 2006; Wu et al., 2008). This includes activities such as improving maintenance procedures, optimising production processes, and reducing waste. The organisation is still relying on imported technology but is now able to customise it to its specific needs, combining it with its existing technological capabilities to enhance its overall competitiveness. This stage requires a higher level of technological capability than duplicative imitation and is an important step towards developing the organisation's own innovative capacity (Wu et al., 2006).

The findings show that SA companies are performing well in this area, where most companies have adopted the technologies and incorporated them into their work, production, and processes. This integration shows a shift from just using the material (duplicative) to customising the technology to meet the local conditions. Several examples were included, all of which signified the effort towards process improvements and product improvement. Further, companies in this sector have also been localising imported technologies to suit the South African market and applying them to different fields. For instance, AI and Virtual Reality simulations have been adapted to support operators in maintenance and for training purposes. The study also highlights the use of AI-powered vision systems for the assessment and improvement of product quality inspection.

The data further reveals that the South African automotive industry is intentional when it comes to localisation, as reflected in legislation, such as the SA Automotive Masterplan. Local content is another key area of focus for the automotive sector. The study findings suggest that the industry has made progress towards achieving the target of 60% local content set out in the Automotive Industry Masterplan. Further, the companies have been able to improve productivity and reduce manufacturing costs while producing production systems and products that meet world standards. However, much still needs to be done to reach and maintain targets. Also, the transition to NEVs means that SA would have to work even harder towards higher local content, and that means the government would have to intervene to support players in the NEV space.

Collaboration is another critical aspect of creative imitation. The study found that multinational companies in South Africa collaborate with parent organisations for manufacturing activities or launching products in South Africa. These collaborations involve the exchange of knowledge, engineering designs, and the deployment of engineers and a highly skilled workforce. The impact

of these collaborations has been the enhancement of employee efficiency and confidence in technology, contributing to a more skilled and capable workforce. The collaborations have also led to the reduction of competition from fully built imports, contributing to the local economy, particularly in terms of job creation.

However, the study findings suggest that there is still a significant gap when it comes to collaborations, as some companies mentioned that they only collaborate with foreign companies as their service partners. This highlights the need for further exploration and incorporation of collaborations as a critical component of secondary Innovation.

5.2.3 Exploitative innovation

Exploitative innovation is the third dimension of an organisation's technological capability, and it is characterised by incremental innovation within established technological paradigms. In this mode, the latecomer combines the acquired technologies with existing ones and applies them to different fields. The dominant organisational learning mode in this stage is developmental learning, where the main task is product improvement, diversification, and innovation within established technological paradigms (Wu et al., 2008).

The findings of the study suggest that South African companies in the automotive industry have started to explore the potential of Fourth Industrial Revolution (4IR) technologies to improve various aspects of their operations, from manufacturing processes and vehicle performance to customer service. However, it is evident that the pace at which different companies are embracing these technologies varies significantly.

Investments in R&D play a crucial role in driving innovation and growth. The study reveals that while some companies in South Africa invest in R&D, others do not have active R&D units, and their budgets for R&D are limited, suggesting that R&D is not a priority for some companies. This contrasts with the global automotive industry, where substantial investments in R&D are commonplace, driving innovation and technological advancement. The study also found that SA is only involved in process innovation, while product innovation is done by the parent companies. The South African automotive industry heavily relies on the strategic decision-making of multinational corporations that dominate the global value chains (GVCs) in which they operate. This classic, producer-driven GVC structure leaves South African firms dependent on the standards set by the MNCs and limits the development of local indigenous technology (Lorenz et al., 2019). As Barnes

et al. (2018) suggest, component suppliers must produce to the international standards set by OEMs, which further constrains the development of local technology. Sikhakhane et al. (2023) also share the same sentiments in that product innovation opportunities are limited due to standardised product specifications. That is why companies focus on process innovations, which leads to reductions in manufacturing costs and enhances the competitiveness of South African businesses globally.

The absence of dedicated R&D units in some companies and the reliance on parent organisations for product development further highlights the challenges local firms face in engaging deeply with R&D activities. It is essential to develop tailored policies to support R&D in specific industries and small and medium-sized enterprises, considering that R&D is not a priority for small companies whose focus is on survival.

The study also highlights the importance of collaborations between academic institutions and the industry in driving innovation and skills development. While companies in the South African automotive industry collaborate with universities, the interactions are mainly oriented towards talent acquisition and financial support for students rather than direct collaboration on research and development projects. There may be untapped potential for deeper, more collaborative efforts focused on driving innovation within the industry.

However, there is also some resistance to collaborations, with multinationals being less proactive in product development as it is mainly done by parent companies. South African companies mostly focus on process innovation and improving internal processes, manufacturing capability, and output in plants. Risk aversion is also observed among South African companies.

The study concludes that South Africa still has a long way to go in developing its capabilities in 4IR technologies, and it starts with internal policies and support programmes to foster a culture of innovation and incentivise innovations. The lack of intensive R&D and fierce international competition in innovating 4IR technologies suggests the need for a more concerted effort to develop these capabilities and enhance the ability of small and medium-sized companies to become more innovative.

5.2.4 Explorative innovation

Explorative innovation is the fourth dimension of an organisation’s technological capability and is characterised by radical innovation outside established technological paradigms. In this mode, the

latecomer must address the challenge of new technological paradigms, new user demands, or new rivals or substitutes. The dominant organisational learning mode in this stage is creative learning, where the main task is system restructuring and rebuilding (Wu et al., 2008).

There is evidence of adaptation, integration, and enhancement of existing technologies to improve efficiency and global competitiveness in the South African automotive industry. However, the extent of novel technological innovation appears limited, as most companies focus on refining and improving existing technologies rather than pioneering new ones. This cautious approach prioritises operational improvements over the risks associated with groundbreaking innovation. The lack of intensive R&D and innovation-oriented approach may hinder the industry's ability to keep up with the rapid pace of technological advancement.

The study indicates a very limited number of companies that have new innovations that differentiate them from the market. One of the reasons for the limited number of patents held by South African companies is the lengthy and costly process of obtaining them. Additionally, some companies that innovate prefer not to go through the process of obtaining a patent as it exposes their innovation or technology to potential copying by competitors. This risk aversion may slow down the pace of innovation in the industry.

To overcome these challenges, South African companies in the automotive industry may need to adopt a more collaborative approach to innovation, such as partnering with academic institutions and research organisations to access the latest research and expertise. Incentivising R&D through targeted policies and support programmes could also encourage more companies to invest in innovation and build their research capabilities.

Globally, automotive companies, especially those in leading markets like China, heavily invest in R&D and explorative innovation. The lack of aggressive governmental support and policies to foster innovation, as well as challenges related to skills gaps and the complexity of innovation processes, are major hurdles for South African companies. Without a conducive environment for explorative innovation, South African automotive companies risk lagging behind global trends, especially in emerging technologies like NEVs.

5.3 SUMMARY

The analysis of Duplicative Imitation highlights the role of multinational corporations in introducing 4IR technologies to South Africa, leading to increased foreign direct investment, specialised training, and comprehensive support systems. However, domestic firms face challenges in acquiring and applying these technologies, such as budget constraints and inadequate infrastructure, indicating the need for upskilling and reskilling initiatives and innovative financing models.

The analysis of Creative Imitation reveals that South African companies are successfully adopting and integrating advanced technologies into their operations, customising technologies for local conditions, and achieving the Automotive Industry Masterplan's local content utilisation targets. However, challenges remain, particularly with the transition to NEVs, emphasising the need for government intervention and more robust partnerships to support growth and innovation.

The analysis of Exploitative Innovation highlights South African companies' limited R&D investment compared to global practices, leading to a focus on incremental innovation and underutilisation of academic partnerships for joint R&D projects. This suggests a need for more aggressive exploration of 4IR technologies and a stronger commitment to R&D.

The analysis of Explorative Innovation indicates that South African companies primarily focus on refining existing technologies rather than pioneering new ones, leading to a competitive disadvantage compared to global leaders like China, which heavily invests in explorative innovation and fosters an environment where innovation thrives. Without a conducive environment for explorative innovation, South African automotive companies risk lagging behind global trends, especially in emerging technologies like NEVs.

The next chapter will provide a conclusion and recommendations for the study.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

The penultimate chapter provided a discussion. This study assessed the readiness of the South African Automotive Industry for the Fourth Industrial Revolution. The purpose of this final chapter is to summarise the findings and conclusions that can be reached based on the literature and interviews on four main research themes: (1) Duplicative Imitation, (2) Creative Imitation, (3) Exploitative Innovation, and (4) Explorative Innovation.

6.1.1 Main research issue

Considering the research problem identified in Chapter 1, this study explored the following main research issue: What is the level of readiness of the South African Automotive Industry?

6.1.2 Research issues

- In exploring the main research issue, the following research issues were addressed:
- What is the level of readiness of South African Automotive Industry to adopting 4.0?
- What are the challenges and opportunities associated with the adoption of 4IR in the automotive Industry?
- How can the South African Automotive Industry prepare for Industry 4.0 implementation to fully exploit the opportunities of 4IR?

As discussed in Chapter 3, semi-structured interviews were conducted with 10 participants from the companies as well as experts in the field. The next section will summarise the findings of the study presented and provide the conclusion and recommendation for future research.

6.2 MAJOR FINDINGS AND CONCLUSION

The study findings suggest that the South African automotive industry is making significant efforts to adopt 4IR technologies, with multinational corporations leading the way in terms of resources and capabilities (Black, 2020). Alexander (2021) also agrees with this notion and sees that the adoption of 4IR technologies and its systems is growing in the South African Automotive industry. However, domestic firms, especially those without multinational partnerships, face significant challenges in acquiring and applying 4IR technologies, such as financial constraints, lack of proper infrastructure, and poor management skills (Moos & Sambo, 2018).

The study highlights the importance of secondary innovation in technology acquisition and assimilation, as well as the role of collaborations between academic institutions and the industry in driving innovation and skills development.

The study also highlights the skills gaps hindering the assimilation of 4IR technologies, particularly around artificial intelligence. This means that there is a need to invest in upskilling and reskilling the workforce to be able to work with these technologies. It also requires academic institutions to revise their curricula to align with the current 4IR skills.

In terms of technological capabilities, it is evident that South Africa still lags behind, and more efforts need to be made to build these skills (Black, 2020). To achieve this, it is essential to invest in research and development (R&D) and develop tailored policies and support programmes to incentivise investments in R&D, particularly for domestic firms or small or SMEs. It is also crucial to provide programmes tailored to capacitate SMEs with resources to participate actively in R&D as they are merely focusing on survival.

There is an opportunity with the New Energy Vehicles, and South Africa could take advantage of these new technologies to catch up. With the transition towards these vehicles, the South African industry could focus its efforts on building a domestic supply chain, particularly for critical components and materials for these vehicles.

Regarding collaborative ventures and technology transfer, there is a significant opportunity for South African companies to adopt a more collaborative approach to technology transfer, such as establishing partnerships with research institutions, academic institutions, and multinational corporations. This would enable them to access the latest research and expertise.

To overcome the challenges faced by the industry, such as the significant skill gap, the study recommends that the South African automotive industry continues to pursue strategic collaborations to enhance its capabilities and competitiveness. These collaborations could include partnering with multinational corporations, academic institutions, and research organisations to access the latest research and expertise and upskill the workforce.

In conclusion, to catch up with other countries in the automotive space, South Africa must invest in R&D, develop tailored policies and support programmes for SMEs, upskill the workforce, and

establish partnerships with research institutions, academic institutions, and multinational corporations. These efforts would drive innovation and skills development, strengthen the technological capabilities of domestic firms, build a strong domestic supply chain, and ensure that the industry remains competitive in the global market.

6.3 KEY RECOMMENDATIONS

Based on the study, the following recommendations can be made for the South African automotive industry to prepare for the adoption of 4IR technologies and improve its technological capabilities to compete with developed countries:

6.3.1 Recommendations for government

1. Pursue Strategic Collaborations: The South African government should ensure that multinational corporations continue to invest in the country by providing a conducive business environment and incentives. The government should also facilitate partnerships between these large corporations and domestic firms to help build local capabilities. These partnerships could be in the form of joint ventures, collaborative research and development, or technology transfer programmes. The government should also ensure that there is a clear and transparent regulatory environment to encourage investments and collaborations.

2. Enhance R&D: The government should establish a collaborative ecosystem that brings together universities, research institutions, and the private sector to foster innovation in the automotive industry. The government should also provide funding for R&D and innovation projects and develop policies that support R&D in the automotive industry. The government could collaborate with universities and research institutions to develop training programmes that focus on advanced technologies, such as artificial intelligence, to bridge the existing skills gaps.

3. Develop Skilled Workforce: The government should establish a comprehensive skills development programme that provides training in the use of advanced technologies, such as machine learning, robotics, and automation. The government should also support internships and apprenticeships in the automotive industry to promote the development of practical skills. To ensure the availability of a steady supply of skilled workers, the government should collaborate with the private sector to develop a pipeline of talent that can meet the industry's future needs.

4. Invest in Infrastructure: The government should invest in infrastructure development to support the adoption of 4IR technologies in the automotive industry. This could include upgrading the country's transportation, energy, and telecommunications infrastructure to support the development of electric vehicles and other advanced technologies. The government should also provide incentives for the development of charging stations and other infrastructure needed to support the growing demand for electric vehicles.

5. Learn from successful countries: The government should study successful countries that have adopted 4IR technologies, such as China and Korea, to learn from their experiences. The government should also collaborate with these countries to establish joint initiatives that promote knowledge exchange and technology transfer. By learning from successful countries, the South African government can develop policies and strategies that are tailored to the specific needs of the local automotive industry.

6. Building a Collaborative Ecosystem: The government should establish automotive innovation/incubation hubs that bring together automotive companies, technology firms, research institutions, and government agencies to promote collaboration and innovation. These hubs could be located in strategic locations around the country to ensure that all players in the automotive industry have access to the necessary resources. The government should also provide funding and incentives for the development of these hubs to ensure their long-term sustainability.

6.3.2 Recommendations for companies

1. Increase R&D Budgets: Companies should increase their R&D budgets to support the development of advanced technologies and innovation. Companies should also establish dedicated R&D units that focus on developing new products and services. To support R&D, companies should collaborate with universities and research institutions to access cutting-edge research and expertise. Companies should also explore funding opportunities from the government and other sources to support their R&D efforts.

2. Expand Training Programmes: Companies should expand their training programmes to ensure that their employees have the necessary skills to operate and maintain advanced technologies. Companies should collaborate with universities and research institutions to develop training programmes that focus on emerging technologies. Companies should also provide on-the-job

training and opportunities for employees to attend conferences, workshops, and other events that promote skills development.

3. Develop Structured Strategies for Market Entry: Companies should develop structured strategies for entering new markets with their products and services. This should include conducting market research to identify customer needs and preferences, developing competitive positioning strategies, and establishing partnerships and collaborations with local players in the market. Companies should also ensure that their products and services comply with local regulations and standards to ensure market acceptance.

Implementing these recommendations will require a concerted effort from all stakeholders in the automotive industry, including government bodies, companies, academic institutions, and research organisations. By adopting a holistic approach, the South African automotive sector can enhance its innovation capacity, develop a skilled workforce, and establish a competitive edge in the global market.

6.4 LIMITATIONS

This study faced several limitations that may have impacted the breadth and depth of the findings, as outlined below:

- Sample Size and Participant Allocation: The initial plan aimed to have a sample size of two participants per company to ensure a more comprehensive understanding of the companies' adaptation to 4IR technologies. However, companies opted to provide only one participant, citing that a second participant was unnecessary. This reduction in participant number may have limited the diversity of perspectives and insights collected.
- Timing of Data Collection: The data collection phase commenced in December, coinciding with the traditional shutdown period for many businesses. This timing proved to be less than ideal., as participants were generally unavailable until January, when companies resumed operations. The delayed start potentially affected the immediacy and relevance of the responses collected.
- Participant Commitment: A notable challenge encountered was the inconsistency in participant commitment. While many agreed to participate, follow-through was less reliable. This inconsistency may have introduced bias in the data collected, skewing the results towards the views of those more inclined or available to respond.

- Network and Infrastructure Challenges: External factors such as network issues, load shedding, and varying load scheduling times across different regions posed significant challenges in scheduling and conducting interviews. These disruptions likely affected the quality of communication and may have limited the amount of detailed information that could be gathered.
- Industry Sector Representation: Given the vastness of the automotive sector, covering everything from manufacturing to software development, there may have been limitations in adequately representing all relevant sub-sectors and their unique challenges and perspectives regarding 4IR.
- Confidentiality Concerns and Policy Restrictions: Some companies refused to participate due to fears of divulging confidential information or because of strict policy rules against participation in research studies. This limitation reduced the potential sample size.
- Saturation of Responses: As the interviews progressed, it became evident that the answers were becoming similar, with no new information being provided but rather repetitive information across the board. This saturation suggests that while a comprehensive understanding of certain aspects was achieved, the potential for uncovering novel insights was limited as the study advanced.

6.5 SUGGESTIONS FOR FUTURE RESEARCH

As such, for South Africa to fully unlock the economic benefits of Industry 4.0 within the automotive industry, more research is needed to highlight the position of SMEs within this sector.

Future research should focus on identifying the key success factors for the adoption of 4IR technologies in the South African automotive industry and developing a comprehensive framework for the industry to follow.

REFERENCES

Acharya, A., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it? *Indian Journal of Medical Specialities.* https://doi.org/10.7713/ijms.2013.0032

Adebanjo, D., Laosirihongthong, T., Samaranayake, P., & Teh, P. L. (2021). Key enablers of Industry 4.0 development at firm level: Findings from an emerging economy. *IEEE Transactions on Engineering Management.*

Adegbite, W. (2021). Emerging roles of small and medium enterprises in the Fourth Industrial Revolution in Africa. *Mediterranean Journal of Social Sciences, 5*(7), 151–166.

Adendorff, C., Lutshaba, U., & Shelver, A. (2018). Readiness of private and public sector South Africa for the 4IR. Port Elizabeth, South Africa: Nelson Mandela Business School.

Ahn, J. O., Jeung, H. S., Kim, J. S., & Choi, H.-G. (2008). A framework for managing risks on concurrent engineering basis. *In 2008 4th IEEE International Conference on Management of Innovation and Technology* (ICMIT) (pp. 378–382). IEEE. https://doi.org/10.1109/ICMIT.2008.4654379

Alexander, R. (2021). The Fourth Industrial Revolution in South African manufacturing and connectivity: Case studies of automotive and mining equipment manufacturing, along with transportation and ICT infrastructure and services. *SARChI Industrial Development Working Paper Series WP 2021–8c*. University of Johannesburg.

Alexander, R. (2022). *Key opportunities and challenges for 4IR in South Africa* (SARChI Industrial Development Working Paper Series No. WP 2021-8d). University of Johannesburg.

Alqam, H., & Saqib, M. (2020). An exploratory study and impact of Fourth Industrial Revolution (4IR) on SMEs in the Middle East. *International Journal of Integrated Engineering, 12*(7), 121–127.

Ambe, I. M., & Weiss, J. (2011). South African automotive industry: Trends and challenges in the supply chain. *Journal of Contemporary Management, 8,* 337–362.

Anderson, C. (2012). *Makers: The new industrial revolution.* New York, NY: Crown Publishing.

Appiah-Osei, B., Mensah, H., & Ragavan, N. (2020). Prospects of the Fourth Industrial Revolution for the hospitality industry: A literature review. *Journal of Hospitality and Tourism Technology*, *5*(2), 1–17.

Asenahabi, B. M. (2019). Basics of research design: A guide to selecting appropriate research design. *International Journal of Contemporary Applied Researches*, *6*(5), 76–90.

Automotive Industry Export Council. (2018). *South Africa Automotive Export Manual 2018.* https://doi.org/978-0-620-70287-4

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics, 229,* 107776. https://doi.org/10.1016/j.ijpe.2020.107776

Barnes, J., & Morris, M. (2008). Staying alive in global automotive industry: What can developing economies learn from South Africa about linking into global automotive value chains? *The European Journal of Development Research*, *20*(1), 31–55.

Barnes, J., Black, A., Comrie, D., & Hartogh, T. (2018). *Geared for growth: Report of the South African Automotive Masterplan Project*. Department of Trade and Industry, Government of the Republic of South Africa.

Black, A. (2020). Technology transfer and the development of the automobile industry in South Africa. In M. Lim (Ed.), *Studies in technology transfer: Selected cases from Argentina, China, South Africa and Taiwan Province of China* (pp. 44–67). Switzerland: UNCTAD.

Bogner, E., Voelklein, T., Schroedel, O., & Franke, J. (2016). Study-based analysis on the current digitalization degree in the manufacturing industry in Germany. *Procedia CIRP*, *11*(4), 4–19.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27–40.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Commission on the Fourth Industrial Revolution. (2020). *Summary report and recommendations.* Pretoria, South Africa: Department of Communications and Digital Technologies.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* Merrill.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches.* Sage Publications.

Crnjac, M., Veza, I., & Banduka, N. (2017). From concept to the introduction of Industry 4.0. *International Journal of Industrial Engineering and Management, 8*(1), 21–30.

Cunningham, S. (2018). *World Economic Forum and the Fourth Industrial Revolution in South Africa.* TIPS.

Deloitte. (2016). *Industry 4.0: Is Africa ready for digital transformation?* Deloitte.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2005). *The Sage handbook of qualitative research* (3rd ed.). Sage Publications Ltd.

Department of Trade and Industry. (2018). *IPAP 2018/19 – 2020/21: Economic sectors, employment and infrastructure development cluster.* Pretoria, South Africa: DTI.

Dolfsma, W., & van der Velde, G. (2014). Industry innovativeness, firm size, and entrepreneurship: Schumpeter Mark III? *Journal of Evolutionary Economics, 24*(4), 713–736. https://doi.org/10.1007/s00191-014-0352-x

Fontana, A., & Frey, J. H. (2005). The interview: From structured questions to negotiated text. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 645–672). Sage Publications.

Freitas, I. M. B., Marques, R. A., & de Paula e Silva, E. M. (2013). University–industry collaboration and innovation in emergent and mature industries in new industrialized countries. *Research Policy, 42*(2), 443–453. https://doi.org/10.1016/j.respol.2012.06.006

Gianolli, F. (2020). *The Fourth Industrial Revolution and the future developments in the automotive industry* (Doctoral thesis). Università Ca' Foscari Venezia. http://hdl.handle.net/10579/17510

Gibson, I., Rosen, D. W., & Stucker, B. (2014). *Additive manufacturing technologies* (Vol. 17). Springer. https://doi.org/10.1007/978-1-4939-2113-3

Guba, E. G. (Ed.). (1990). *The paradigm dialog.* Sage Publications, Inc.

Hammersley, M. (2013). *What is qualitative research?* Bloomsbury.

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry, 89*, 23–34.

Ikome, J. M., & Kanakana, G. M. (2018, August). A literature review of South African automotive industry global competitiveness. *In 2018 Portland International Conference on Management of Engineering and Technology (PICMET)* (pp. 1–8). IEEE. http://dx.doi.org/10.23919/PICMET.2018.8481934

Jeschke, S., Brecher, C., Meisen, T., Özdemir, D., & Eschert, T. (2017). Industrial Internet of Things and cyber manufacturing systems. In *Industrial Internet of Things* (pp. 3–19). Springer, Cham. https://doi.org/10.1007/978-3-319-42559-7_1

Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group.* Acatech.

Kapp, J. (2018). *The Fourth Industrial Revolution: Assessing the intelligences of engineers in the South African automotive industry* (Doctoral dissertation). Nelson Mandela University, South Africa.

Krippendorff, K. (2013). *Content analysis: An introduction to its methodology.* Sage Publications.

Lamprecht, N. (2020). *Automotive export manual 2020: Progress on wheels.* Pretoria, South Africa: AIEC.

Lamprecht, N. (2021). *Automotive export manual 2021.* Pretoria, South Africa: AIEC.

Layton, C., & Rustandie, J. (2017). *Automotive component value chain overview.* United States Agency for International Development (USAID).

Lee, K. (2019). *The art of economic catch-up: Barriers, detours, and leapfrogging in innovation systems.* Cambridge University Press.

Lee, K., & Lim, C. (2001). Technological regimes, catching up, and leapfrogging: Findings from the Korean industries. *Research Policy, 30*(3), 459–483. https://doi.org/10.1016/S0048-7333(00)00088-3

Lejarraga, I. A., Kouzul-Wright, A., Primi, M., & Wermelinger, M. (2016). Upgrading pathways in the automotive value chain. Background document for the 7th plenary meeting of the OECD Initiative for Policy Dialogue on GVC. Paris, France: OECD.

Liao, Y., Deschamps, F., Loures, E., & Ramos, L. (2017). Past, present, and future of Industry 4.0: A systematic literature review and research agenda proposal. *International Journal of Production Research, 55*(12), 3609–3629.

Lorenz, E., Tessarin, M., & Morceiro, P. (2019). *Report on the adoption of 4th Industrial Revolution technologies in South African industry.*

Macpherson, W. E., Werner, A., & Mey, M. R. (2023). Talent approaches for the South African automotive industry. *SA Journal of Human Resource Management, 21*(0), a2049. https://doi.org/10.4102/sajhrm.v21i0.2049

Malomane, R. (2022). *The impact of Fourth Industrial Revolution technologies in managing health and safety within the construction industry* (Doctoral dissertation). University of Johannesburg.

Mathews, J. A. (2006). Catch-up strategies and the latecomer effect in industrial development. *New Political Economy, 11*(3), 313–335. https://doi.org/10.1080/13563460600840142

Maxwell, J. A. (2012). *Qualitative research design: An interactive approach.* Sage Publications.

MERSETA. (2021). *Sector skills plan 2022/2023.* https://www.merseta.org.za/wp-content/uploads/2023/05/Sector-Skills-Plan_2023-24_.pdf

Meyer, R., & Wesson, J. (2020). The Fourth Industrial Revolution and the South African automotive sector: A qualitative study of readiness and potential. *South African Journal of Economic and Management Sciences, 23*(1), 1–13.

Miller, B. A. (2019). *Employee resistance to disruptive technological change in higher education* [Doctoral dissertation, Walden University]. ProQuest Dissertations Publishing.

Moica, S., Ferencz, P., & Dorleta Ibarra, J. (2018). Change made in shop floor management to transform a conventional production system into an "Industry 4.0." *Proceedings of the IEEE International Conference on Industrial Technology and Management*, 2018, 133–137. https://doi.org/10.1109/ICITM.2018.8333919

Moos, M., & Sambo, W. (2018). An exploratory study of challenges faced by small automotive businesses in townships: The case of Garankuwa, South Africa. *Journal of Contemporary Management, 8,* 467–494.

Moraru, G. M., & Popa, D. (2021). Potential resistance of employees to change in the transition to Industry 5.0. *MATEC Web of Conferences, 343*, 07005. https://doi.org/10.1051/matecconf/202134307005

Mukwawaya, G., Emwanu, B., & Mdakane, S. (2018). Assessing the readiness of South Africa for Industry 4.0: Analysis of government policy, skills, and education. *Proceedings of the 8th Annual International Conference on Industrial Engineering and Operations Management (IEOM)*, Pretoria, South Africa, 1587–1604.

Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change, 132*, 2–17. https://doi.org/10.1016/j.techfore.2017.12.019

Muyengwa, G., Mukhuba, K., Battle, K., & Mbohwa, C. (2013). Barriers to enterprise development: The case of SMMEs operating in the South African motor body repair sector. *Proceedings of the International Conference on Law, Entrepreneurship and Industrial Engineering*, Johannesburg, South Africa.

NAAMSA. (2022). Fueling the economy. *SA Economy*. https://www.naamsa.net

Naderifar, M., Goli, H., & Ghaljaie, F. (2017). Snowball sampling: A purposeful method of sampling in qualitative research. *Zabol University of Medical Sciences; Zahedan University of Medical Sciences.*

Nagarajan, G. (2023). The role of the metaverse in digital marketing. *CORE*. https://core.ac.uk/download/574722585.pdf

Naicker, N., & Singh, R. (2020). The evolution of the South African automotive industry in the context of the Fourth Industrial Revolution. *Journal of Economics and Behavioral Studies, 12*(2), 60–69.

Noqayi, A. (2021). *Digital platform skills requirements for SMMEs and start-ups: A South African perspective* (Masters Dissertation). University of the Witwatersrand.

Noqayi, A. (2021). *Digital platform skills requirements for SMMEs and start-ups: A South African perspective* [Master's thesis, University of the Witwatersrand]. Wits Institutional Repository.

Nyagadza, B. (2021). Fourth Industrial Revolution. *Management Education and Automation, 3*, 29.

Odagiri, H., Goto, A., Sunami, A., & Nelson, R. R. (2010). *Intellectual property rights, development, and catch-up: An international comparative study*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199574759.001.0001

Olaitan, O., Issah, M., & Wayi, N. (2021). A framework to test South Africa's readiness for the Fourth Industrial Revolution. *South African Journal of Information Management, 23*(1), 1–10.

Oztemel, E., & Gursev, S. (2018). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing, 13*(1), 1–56.

Paradis, E., O'Brien, B., Nimmon, L., Bandiera, G., & Martimianakis, M. A. (2016). *Journal of Graduate Medical Education, 8*(2), 263–265.

Pereira, A. C., & Romero, F. (2018). A review of the meanings and implications of the Industry 4.0 concept. *Procedia Manufacturing, 13*, 1206–1214. https://doi.org/10.1016/j.promfg.2017.09.032

Peters, M. A. (2017). Technological unemployment: Educating for the Fourth Industrial Revolution. *Journal of Self-Governance and Management Economics, 5*(1), 25–33.

Płonka, M., Rosiek, K., & Jedynak, T. (2022). The impact of the Fourth Industrial Revolution and contemporary megatrends on the production and distribution of public goods and services. In *Industrial Revolution 4.0: Economic foundations and practical implications* (pp. 40–60).

Presidential 4IR Commission. (2020). *Report on the Presidential Commission on the Fourth Industrial Revolution.*

Ramanathan, K., & Samaranayake, P. (2021). Assessing Industry 4.0 readiness in manufacturing: A self-diagnostic framework and an illustrative case study. *Journal of Manufacturing Technology Management.* Advance online publication. https://doi.org/10.1108/JMTM-09-2021-0339

Rampersad, D. (2014). *Analysis of global competitiveness in the light motor vehicle component industry of South Africa* (Doctoral dissertation). University of KwaZulu-Natal.

Rehman, H. M. (2022). *The readiness for Industry 4.0 of the Malaysian manufacturing sector: The roles of organization innovation and aging workforce* (Doctoral dissertation). Universiti Tunku Abdul Rahman (UTAR).

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research, 57*(7), 2117–2135.

Schumacher, A., Erol, S., & Sihn, W. (2016). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP, 52,* 161–166. https://doi.org/10.1016/j.procir.2016.07.040

Schwab, K. (2016). *The Fourth Industrial Revolution.* Geneva, Switzerland: World Economic Forum.

Schwab, K. (2017). The Fourth Industrial Revolution: What it means and how to respond. *World Economic Forum.* https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Searle, R. H., & McWha-Hermann, I. (2020). "Money's too tight (to mention)": A review and psychological synthesis of living wage research. *European Journal of Work and Organizational Psychology.* Advance online publication. https://doi.org/10.1080/1359432X.2020.1838604

Sikhakhane, F., David, O. O., & Stiglingh-Van Wyk, A. (2023). The 4th Industrial Revolution effects on industrial production of South Africa. *International Journal of Economics and Financial Issues, 13*(6), 53–62. https://doi.org/10.32479/ijefi.14625

Sima, V., Gheorghe, I., Subić, J., & Nancu, D. (2020). Influences of the Industry 4.0 revolution on human capital development and consumer behavior: A systematic review. *Sustainability, 12*(3), 1–28. https://doi.org/10.3390/su12031061

Sommer, L. (2015). Industrial revolution – Industry 4.0: Are German manufacturing SMEs the first victims of this revolution? *Journal of Industrial Engineering and Management*, *8*(5), 1512–1532. https://doi.org/10.3926/jiem.1470

Spena, P. R., Ciasullo, M. V., Palumbo, R., & Leone, D. (2016). Requirements for the design of flexible and changeable manufacturing and assembly systems: A SME-survey. *Procedia CIRP*, *41*, 207–212. https://doi.org/10.1016/j.procir.2016.01.001

Uleanya, C., Taiwo, S., & Uleanya, M. (2021). Review of the Fourth Industrial Revolution (4IR) nexus COVID-19 pandemic in the African education sector. *International Journal of Educational Excellence*, *7*(1), 61–77.

Vicente, P. N., & Dias-Trindade, S. (2021). Reframing sociotechnical imaginaries: The case of the Fourth Industrial Revolution. *Public Understanding of Science*, *30*(6), 708–723. https://doi.org/10.1177/09636625211007212

Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2016). Towards smart factory for Industry 4.0: A self-organized multi-agent system with big data-based feedback and coordination. *Computer Networks*, *101*, 158–168. https://doi.org/10.1016/j.comnet.2015.12.017

Wang, S., Zhang, G., Shen, B., & Xie, X. (2011). An integrated scheme for cyber-physical building energy management system. *Procedia Engineering*, *15*, 3616–3620. https://doi.org/10.1016/j.proeng.2011.08.677

World Bank. (2018). *Republic of South Africa systematic country diagnostic: An incomplete transition overcoming the legacy of exclusion in South Africa*. World Bank.

Wu, X., Ma, R., & Xu, G. (2006). Secondary innovation: The experience of Chinese enterprises in learning, innovation and capability building. *National Institute for Innovation Management, School of Management, Zhejiang University*.

Wu, X., Xu, G., Ma, R., & Du, J. (2008). The evolutionary process of secondary innovation in the context of globalization: A case study. *Industry and Higher Education*, *22*(5), 289–296. https://doi.org/10.5367/000000008786102053

Xu, M., David, J., & Kim, S. (2018). The Fourth Industrial Revolution: Opportunities and challenges. *International Journal of Financial Research*, *9*(2), 90–95. https://doi.org/10.5430/ijfr.v9n2p90

Yin, R. K. (2013). *Case study research: Design and methods* (5th ed.). Sage Publications.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (3rd ed.). Sage Publications.

ANNEXURES

ANNEXURE A: Research Tool

Dear Participant,

I would like to invite you participate in this research study that aims to investigate the readiness of the South African Automotive Industry for the Fourth Industrial Revolution (4IR). Specifically, the study focuses on the level of readiness of companies in the automotive industry to adopt 4IR technologies and fully exploit opportunities presented by 4IR.

Your participation in this study is entirely voluntary, and you may choose to withdraw at any point without penalty. The questionnaire consists open–ended questions and will take approximately 30 – 45 minutes to complete.

RESEARCH QUESTIONS:

1. **Background questions**

- What is your role in your organisation and what do you do in that role?
- For how long has your organisation been in operation and how many employees does it have?
- What is the core business of your organisation?

2. **Duplicative Imitation**

- What does the term 4IR mean to you, especially as it relates to the automotive industry?
- Which of these 4IR technologies has your company adopted?
    - Artificial intelligence
    - Internet of Things
    - Additive manufacturing/3D printing
    - Robotics

- Big data analytics
- Virtual and Augment reality (VR/AR)
- Other (Please specify)

- What training programmes are in place for employees to effectively understand and work with these technologies?
- What are the skills gaps that exist in relation to these technologies that hinder assimilation??
- What challenges does your company face in implementing these technologies.

3. Creative Imitation

- How has your organisation creatively adapted or improved upon existing technologies to better suit the South African market? (Provide specific examples of how these adaptations have been integrated into your existing processes)
- What is the current percentage of local materials/parts used in your production, and how has this figure changed over time?
- Is your company actively involved in collaborative ventures with foreign companies? If so, can you describe the nature and objectives of these collaborations?
- What are the types of technologies and knowledge exchanged in your collaborative ventures with foreign companies?
- What impact has this had on your production output?

4. Exploitative Innovation

- What percentage of your budget is allocated to R&D and how does this compare with global industry standard?
- What unique or groundbreaking projects that are leveraging 4ir technologies are you working on?

- Do you have collaborations with academic institutions, other companies or other industries?
- How do you measure success or the impact of your R&D initiatives?
- How do you approach risk in terms of experimenting with new technologies?

5. Explorative Innovation

- What novel technological innovation have you introduced to enhance the global competitiveness of your organisation?
- Does your company hold any Intellectual property or patents that differentiate it in the global market?
- What is your strategy for bringing new innovations to market?

Thank you very much for taking the time to speak with me today. Your insights and experiences have been extremely valuable and enlightening. As part of my ongoing research, I am looking to gather a range of viewpoints from other people or organisations in the industry. Could you recommend anyone else I should speak to, such as a colleague or industry contact? This would greatly assist in enriching the scope and depth of my research.