Exploring the impact of the fourth industrial revolution on a ferrochrome production plant in South Africa

GJ Fouche

orcid.org/0000-0002-8991-8453

Mini-dissertation accepted in partial fulfilment of the requirements for the degree Master of Business Administration at the North-West University

Supervisor: Prof RA Lotriet

April 2024

DECLARATION

I hereby declare that the mini-dissertation submitted herewith to the North-West University in partial fulfilment of the requirements for the Master of Business Administration (MBA) degree is my own original work. It has been text-edited in accordance with professional communication standards and has not been previously submitted to any other institution for evaluation purposes.

Name: Gerrie Fouche

ACKNOWLEDGEMENTS AND RECOGNITIONS

I want to extend my heartfelt gratitude to the following individuals who have been instrumental in the completion of my Master's Degree in Business Administration:

- First and foremost, I thank Our Heavenly Father for giving me the opportunity and the strength to undertake this academic journey.
- My wife, Anrie Fouche, you are the cornerstone of my life. Your unwavering support and love have made every challenge manageable. As we close this chapter, I eagerly anticipate the many more we will write together.
- My Son, Gerhard Fouche, for understanding the time I could not spend with you. The weight of those missed moments drives my determination to complete my studies and devote the quality time you so richly deserve.
- Wayne Hill and Christof Bester, your pivotal roles in securing approval for this research, the required leave, and the necessary financial sponsorship have been invaluable.
- My manager, Vernon McManus, deserves special mention for his unwavering support and encouragement. Despite the demands of our work environment, you have consistently afforded me the time and space to focus on my studies.
- To my fellow MBA students, particularly the Innovengers syndicate group, your camaraderie has enriched this experience in ways I will always treasure.
- Prof. Ronnie Lotriet, your guidance has been indispensable. You set the bar high from the onset, and I hope my work has met your esteemed standards.
- Antoinette Bisschoff for elevating the academic rigour with her meticulous language and technical editing.

Your collective contributions have made this academic endeavour possible and profoundly enriching.

Thank you all.

ABSTRACT

The central research question of this study is, "How can the Fourth Industrial Revolution (4IR) impact a ferrochrome production plant in South Africa?" This question is particularly relevant given the increasing global focus on 4IR technologies and their potential to revolutionise industries. This is especially important for the South African ferrochrome industry, a sector crucial for the country's economy.

The study employs a mono-method, qualitative research approach, considered the most suitable due to its focus on non-numeric data collection and analysis. Semi-structured interviews were conducted with industry professionals to gain in-depth insights into their perspectives on 4IR. Eight participants from various management levels in one organisation were interviewed. The data was transcribed and analysed using coding techniques and Atlas.ti to identify key themes and patterns.

The research is structured into various sections, beginning with an introduction that outlines the problem statement, objectives, and the study's relevance in filling existing knowledge gaps. This is followed by a literature review that provides an industry overview and investigates the potential impact of 4IR on safety, profitability, and sustainability within the ferrochrome sector.

Key findings include a general familiarity with 4IR but a notable gap in practical understanding, the industry's emerging progress in 4IR adoption, and the potential for positive impacts on safety, profitability, and sustainability. The study underscores the necessity of 4IR implementation for the industry's competitiveness and sustainability, highlighting the importance of early technology adoption.

In conclusion, the study effectively addressed its primary objective by exploring the potential impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa. The industry's progress in 4IR is still in emerging stages. However, the potential for a positive impact on safety, profitability, and sustainability is evident. The importance of implementing 4IR technologies is emphasised by the ferrochrome sector's critical role in South Africa's economy. Given the industry's significance, adopting 4IR is beneficial and essential for its continued viability in South Africa.

As for the secondary objectives, the study successfully determined the industry's readiness for 4IR, explored its relevance for the future of ferrochrome production in South Africa, and drew actionable conclusions on its impact. The study also highlighted the importance of considering environmental, social, and political factors in strategic planning for 4IR. Recommendations for both practical industry applications and future research are provided, making this study a foundational piece for further investigations into the impact of 4IR on the ferrochrome industry in South Africa.

KEYWORDS

Ferrochrome, Fourth Industrial Revolution (4IR), Artificial Intelligence (AI), Machine Learning (ML), Robotics, Internet of Things (IoT), Challenges, Technology, Production

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
AR	Augmented Reality
DMRE	Department of Mineral Resources and Energy
ESKOM	Electricity Supply Commission
FeCr	Ferrochrome
GDP	Gross Domestic product
IoT	Internet of Things
IRR	Internal Rate of Return
MBA	Master of Business Administration
ML	Machine Learning
NPV	Net Present Value
PGE	Platinum-Group Elements
ROI	Return on Investment
SME	Small and Medium Enterprises
UNIDO	United Nations Industrial Development Organisation
VR	Virtual Reality

CHAPTER 1 – SCOPE AND NATURE OF THE STUDY

1.1. INTRODUCTION

Ferrochrome is a crucial ingredient in stainless steel production. Stainless steel consumption has increased over the past years, with incredibly high consumption reported in developing countries (Backeberg et al., 2021:7). Stainless steel is preferred above non-stainless types of steel due to the superior longevity that stainless steel has over non-stainless steel (Creamer, 2021b). The ferrochrome value chain is unpacked in a basic illustration in Figure 1 below:

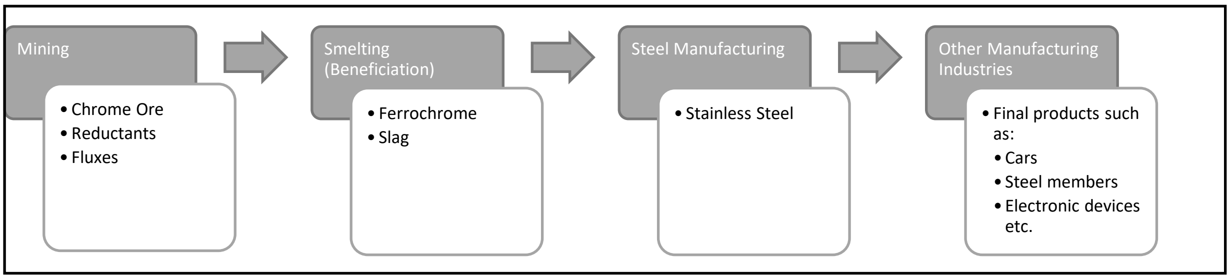

Figure 1: Ferrochrome Value Chain

(**Source:** Own compilation)

The ferrochrome value chain begins with the mining phase, where essential raw materials are sourced. The primary materials extracted during this stage are Chrome Ore, Reductants, and Fluxes. These materials are pivotal for the subsequent phase, which is Smelting (or Beneficiation). These raw materials are processed and refined during smelting, producing ferrochrome, a key ingredient in stainless steel manufacturing, and slag, a by-product.

After smelting, the value chain's next critical phase is Steel Manufacturing. Here, ferrochrome is utilised as a primary component to produce stainless steel, which possesses the combined strengths of steel and the corrosion resistance of chromium. This stainless steel then finds its way into various Other Manufacturing Industries. In this final phase of the value chain, stainless steel is transformed into multiple final products, including but not limited to cars, steel structural members, and a host of electronic devices. Each phase in this value chain adds economic value and emphasises ferrochrome's importance in modern manufacturing processes and end products.

South African government has a multi-dimensional approach to mineral beneficiation aimed at capitalising on the country's rich mineral resources for economic growth, job creation, and social development. During the 1990s this focus shifted South Africa from being a primary exporter of raw materials to a significant player in the global processed minerals market. Key legislation, such as the Mineral and Petroleum Resources Development Act of 2002 and the 2004 Mining Charter, provides the regulatory framework for this sector, empowering the Minister of Mineral Resources to set guidelines for beneficiation. Despite challenges like limited access to raw materials and high infrastructure costs, the government is committed to overcoming these through an integrated strategy. This commitment extends to regional collaboration, with South Africa leading a group of African nations to develop a continental framework for mineral beneficiation.

Historically, South Africa was well suited to produce ferrochrome mainly due to the abundance of raw materials (ores, fluxes, and reductants), cheap and reliable electricity and well-developed and maintained infrastructure (Dlamini & von Blottnitz, 2023:5). The ferrochrome industry has significant contributions toward tax income, job creation, local community development, world investment, and world trade, in South Africa (Creamer, 2021a).

Many factors influence the perception that South Africa is still well suited to produce ferrochrome. Some factors that negatively affect the perception and the future of ferrochrome smelting in South Africa include escalating electricity tariffs and the general deterioration of national infrastructure such as roads, railways, and harbours (Dlamini & von Blottnitz, 2023:5). Other factors positively influencing the industry's future include low ore input cost, established high capital investment plants, and well-developed business infrastructure.

Many factors make it increasingly difficult for South African ferrochrome producers to compete sustainably in an already highly competitive sector. Other nations besides South Africa produce ferrochrome. Intense competition from other countries, including

China and Kazakhstan, may limit the industry's ability to remain competitive globally. These factors should be identified through crucial management processes to allow the South African ferrochrome industry to develop mitigating plans to stay competitive in the foreseeable future (Creamer, 2021b). Determining the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa is vital for embracing the competitive levels of available technology. The 4IR can positively and negatively impact the future of ferrochrome producers in South Africa.

The 4IR is here and is identified by online and physical system integration (Xu *et al*., 2018:90). The 4IR can lead to benefits such as increased profitability, higher reliability and better predictive maintenance measures, better processing, and analysis due to machine-to-machine communication and higher levels of productivity thanks to human-machine interaction (Bloem *et al*., 2014:4). The shift from the existing manual systems to automated systems requires significant capital and a paradigm shift in the normal way of operating.

The industry must reflect a positive perspective regarding investors and capitalise on all available opportunities, including the 4IR, to have a future for the South African ferrochrome industry. If this study can determine the impact of the 4IR on a ferrochrome production plant in South Africa, processes and technology can be aligned to ensure a future for ferrochrome smelting in South Africa.

1.2. PROBLEM STATEMENT

Ferrochrome is a crucial ingredient in stainless steel production. Stainless steel consumption has increased over the past years, with incredibly high consumption reported in developing countries (Backeberg *et al.*, 2021:7). Stainless steel is preferred above non-stainless types of steel due to the superior longevity that stainless steel has over non-stainless steel (Creamer, 2021b). The ferrochrome value chain is unpacked in a basic illustration in Figure 1 below:

The South African ferrochrome industry used to be the world leader in ferrochrome production; however, over the past 15 years, it has become less competitive despite having the richest chromium ore deposits globally (Dlamini & von Blottnitz, 2023:5). The ferrochrome industry's challenges can be mitigated by emphasising alternative electricity supply, particularly renewable energy, possibly by implementing a national economic revival plan with aggressive infrastructure maintenance and development and, most importantly, implementing new technologies associated with the 4IR.

Although the industry faces many challenges, key considerations place the South African ferrochrome industry strategically advantaged. South Africa is well suited to produce ferrochrome mainly due to the abundance of raw materials (ores, fluxes, and reductants). More than 70% of the world's exploitable chromite reserves are in South Africa's Bushveld Igneous Complex (Dlamini & von Blottnitz, 2023:5), and well-developed and maintained infrastructure such as smelting facilities. Why are smelting companies in South Africa struggling to stay competitive, not attracting investors, and ultimately closing?

The competitive world is embracing the 4IR opportunities. The 4IR poses threats and opportunities in mining countries. The most prominent threats are job losses due to technology. At the same time, some of the possibilities include safety, profitability, and sustainability (Mutanga *et al*., 2021:3). Many industries are increasingly mechanising and automating in workplaces. Some technologies introduced in businesses raise new challenges (Hooker *et al*., 2019:35). Industry-leading technology such as artificial intelligence, robots, self-driving vehicles, and the internet (Internet of Things) are introduced to build a world where individuals and businesses can manage their affairs through digital domains and reality (Xu *et al*., 2018:90).

The downfall of firms like Nokia and Kodak, contrasted with the triumphs of Amazon, Google, and Apple, can be ascribed solely to the presence or absence of strategic technological foresight. Utilising technology could assist the South African ferrochrome sector predict the pertinent technologies that will shape its future production (Letaba & Zulu, 2021:101). The ferrochrome sector is not an exception to the global technological revolution that the 4IR is exhibiting in several industries. Due to the highly competitive nature of the ferrochrome industry, South Africa cannot afford to be late adaptors of technology.

Given the industry's urgent challenges, the primary problem that this study focuses on is how the 4IR affects a ferrochrome production plant in South Africa, explicitly considering the numerous difficulties the sector is currently experiencing. Exploring the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa could identify potential benefits and potential hazards of 4IR technologies in ferrochrome production. Although the 4IR promises improved safety, greater profitability, and sustainability, it also has risks, including the possible loss of jobs and the requirement for significant funding for implementation.

It is crucial to understand the dynamics impacting the ferrochrome industry and the impact that available technology has on the industry to re-energise the ferrochrome business, attract investment, and assure its sustainability in a highly competitive global market. This study is essential to help the industry develop a strategic response that can balance the advantages and potential dangers of the 4IR in this industry, assuring its sustained relevance and competitiveness in the global ferrochrome production sector.

1.3. RESEARCH OBJECTIVES

1.3.1. Primary objective

The primary objective of this study is to explore the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.

1.3.2. Secondary objectives

The following secondary objectives achieve the primary objective:

- To determine the readiness of a ferrochrome production plant to implement the fundamentals of the Fourth Industrial Revolution (4IR) into the production processes.
- To explore the relevance of the Fourth Industrial Revolution (4IR) on the future of a ferrochrome production plant in South Africa.

- To use the study's outcome to conclude the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.
- Make recommendations on the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.

1.4. CONTRIBUTION OF THE STUDY

The study aims to contribute in the following ways:

- Theoretical contribution:
    - Through this study, we aim to fill the knowledge gaps discovered in our preliminary database searches. Given the scarcity of scientific literature in this area, this will augment the theoretical understanding of this subject.
- Practical contribution:
    - The study intends to identify whether South Africa could leverage the 4IR's technologies for sustained mineral beneficiation, using ferrochrome as a case study.
- Industry contribution:
    - This research seeks to provide valuable insights that can enhance the operations of a ferrochrome production plant in South Africa, notably in areas such as:
        - Training and awareness
        - Safety
        - Profitability
        - Sustainability
        - Identifying and navigating potential challenges when implementing technology associated with the 4IR
        - Strategy
        - Vision

Defining and comprehending key terms and concepts that will repeatedly appear throughout the study before moving on to the primary research is crucial. This study is built on the evaluation of prior research in the field, which will also reveal areas that need more investigation. The data collection and analysis methodologies significantly shape the study's outcomes and insights. Assurance of the study's credibility, transferability, and dependability is also crucial in the research process.

1.5. LIMITATIONS OF THE STUDY

This study has potential limitations. Discussions on the limitations and the proposed direction for future studies are listed.

- Lack of previous research on the topic:
    - Previous research studies should be cited and referenced for the literature review. A database search has revealed limited literature on the topic. With limited studies available, there might be a gap in the study's theoretical foundation.
        - Future studies could include a larger geographical area and more smelters, companies, and countries, increasing the scientific information available.
- Insufficient sample size
    - Many ferrochrome smelters in South Africa have closed. Few smelters are still in production (50%) (Van der Lingen & Paton, 2018:1087). The sample size might be restricted and biased because respondents were selected from one ferrochrome production plant in Rustenburg. Therefore, generalisation for the referred industry cannot be inferred.
        - Future studies could include a larger geographical area and more smelters, companies, and countries and, therefore, a larger sample size.
- Limited access to data
    - Only two predominate companies operate ferrochrome smelters in South Africa, and respondents could be selected from one ferrochrome

production plant. This means a limited number of senior managers could be considered for questioning.

- Future studies could include a wider sector in beneficiation and include different beneficiation sectors, increasing access to data.

Even though this study aims to significantly advance the knowledge of how the 4IR affects a South African ferrochrome production facility, it is crucial to recognise its inherent limits. The limited sample size due to the small number of functioning ferrochrome smelters, the restricted access to data, and the limited number of previous research on the subject could impact the study's thoroughness. However, these restrictions also point to potential directions for further research. Expanding the study's geographic scope, including more organisations and industry sectors, and using a larger sample size could all lead to a broader and more thorough understanding of the relationship between 4IR and the ferrochrome market. This study should be viewed as exploratory by nature, opening the door to future, larger-scale investigations into the effects and promises of the 4IR within and outside South Africa's ferrochrome industry.

1.6. RESEARCH QUESTION

How can the Fourth Industrial Revolution (4IR) impact a ferrochrome production plant in South Africa?

1.7. RESEARCH METHODOLOGY

1.7.1. Literature review

This study was conducted in two phases to achieve the primary and secondary research objectives. Firstly, a comprehensive literature review explored the impact of the 4IR on a ferrochrome production plant in South Africa. The secondary data used for the literature review was obtained by using the following sources of information:

- Dissertations and papers on the subject
- Journals
- News and Internet articles

- Academic sources
- Published citations
- Database searches
- Websites and internet sources

The covered primary constructs are:

- Ferrochrome
- Ferrochrome market and uses
- The Fourth Industrial Revolution and its benefits
- The Fourth Industrial Revolution and its threats
- The Fourth Industrial Revolution and associated technologies
- Sustainability and technology

An empirical study using primary data identified the factors determining how the 4IR can impact the ferrochrome business in South Africa. It also identified possible limitations to ferrochrome plants when implementing technologies associated with the 4IR. The data collected from the semi-structured interview protocol was analysed employing thematic analysis and word clouds. The results were used to answer the research question.

1.7.2. Empirical investigation

1.7.2.1. Research paradigm

A research paradigm can be seen as the foundation of the study and outlines the methods on which the study is based. Four primary management and business research paradigms exist: positivism, interpretive, advocacy and pragmatism (Rahi, 2017:1). Positivism (associated with quantitative research) and interpretivism (related to qualitative research) paradigms are discussed below. The positivist paradigm assumes that research can be obtained through observation and experiment. The interpretive paradigm develops subjective meanings of their experiences towards the research topic to get a deep understanding. (Rahi, 2017:1). This study adopted an interpretivism research paradigm associated with qualitative research.

1.7.2.2. Research approach

Deductive research falls under the positivistic research paradigm. This type of research builds research hypotheses through existing literature as a foundation, and the hypotheses are tested using deductive reasoning (Saunders *et al*., 2016:74). Alternatively, inductive research occurs in the interpretivist research paradigm. This involves building a new theory through observation and collecting primary data without considering existing theories (Saunders *et al*., 2016:74). This study will start with a solid theoretical investigation and aim to build conclusions through data collection; therefore, it will follow an inductive approach.

1.7.2.3. Methodological choice

The methodological choice explains how the research project was conducted. The methods are quantitative, qualitative, and mixed. Quantitative research is associated with numeric data collection and analysis, while qualitative research is associated with non-numeric data collection and analysis. (Saunders *et al*., 2016:165). For this study, mono-method, qualitative research was considered the best methodological choice due to the nature of non-numeric data collection and analysis (Saunders *et al*., 2016:165).

1.7.2.4. Research strategy

In research terms, the strategy is a plan of how a researcher aims to answer the research question (Saunders *et al*., 2016:177). Experiments and surveys are used for quantitative research (Saunders *et al*., 2016:178). Four qualitative methods commonly used are semi-structured interviews, in-depth interviews, observations, and focus groups. (Babbie, 2016:268). This study collected primary data by conducting semi-structured interviews. Semi-structured interviews offered a balanced approach, allowing for flexibility and structure, thereby facilitating the exploration of complex topics and capturing rich, qualitative insights.

1.7.2.5. Data collection

The researcher identified respondents within his organisation based on the inclusion and exclusion criteria and explain the terms and conditions which would be agreed upon.

For this study, the inclusion criteria were:

- Managers working at a ferrochrome smelting company in the Western limb of South Africa.
- Male and female respondents were included.
- Different management levels were included if they work for a ferrochrome smelting plant in the western limb of South Africa.
- Managers of all ages were included.

The exclusion criteria for this study were:

- Non-management employees working at a ferrochrome plant.
- Management employees in the beneficiation sector do not work at a ferrochrome smelter.
- Management employees working at a ferrochrome smelter in the eastern limb of South Africa.

The researcher contacted respondents via email. In the email, the researcher asked the respondents for their participation, present the purpose of the study, including ethical considerations, consent letters (see Appendix C), and indicate that an interview should not take more than 40 minutes. The consent letter was attached to the email to be signed by the respondent. The interview was facilitated through an online platform (such as Teams) or in person, depending on the respondents' preference.

1.7.2.6. Sample size

The sample size was limited by the number of managers in the company, the willingness to participate, and non-responsive participants also influenced the sample size. The sample size was eight participants. The sample size was guided by (Vasileiou *et al.*, 2018:2):

- Data saturation: Adding more respondents did not add new information. Data saturation was achieved after seven interviews, and using the “n+1 method”, the final confirming interview was number 8.
- Data richness: Samples with rich data and information could require fewer samples.

1.7.2.7. Time horizon

The time horizon is research done over a snapshot (cross-sectional studies) or a more extended period (longitudinal studies). Cross-sectional studies are often used with survey strategies. Longitudinal studies have the advantage of valuable secondary data collected over time. (Saunders *et al*., 2016:200). The research in this study was conducted over a single period, exploring the impact of the 4IR on a ferrochrome production plant in South Africa.

1.7.2.8. Reliability and validity (trustworthiness)

Reliability and validity are strong considerations related to the quality of the research. Reliability refers to the consistency of the research related to similar previous research. Reliability can be divided into internal and external reliability. Conversely, validity refers to the accuracy of the results and findings (Saunders *et al*., 2016:202).

The trustworthiness of a qualitative research study has four different criteria (Bryman *et al*., 2014:45):

- Confirmability
    - Confirmability ensures that the research findings result from the experiences and perspectives of the participants rather than the biases or beliefs of the researcher. It aims to maintain objectivity in interpreting the data (Stahl & King, 2020:28). Objectivity was maintained by focusing on the participants' experiences and perspectives. This was achieved through a structured interview process, where responses were directly related to the research questions, minimizing researcher bias.

- Transferability
  - Transferability is concerned with the applicability of research findings to other contexts. Unlike quantitative research, qualitative research does not seek replicability but aims to provide enough context for the reader to determine if the findings can be transferred to other settings (Stahl & King, 2020:27). Detailed descriptions of the research context and participants were provided, allowing readers to assess the applicability of the findings to other settings. The inclusion of direct quotes from participants added depth to the findings, enhancing their transferability.
- Credibility
  - Credibility refers to the confidence readers can have in the research findings. It is the qualitative counterpart to the quantitative concept of validity, aiming to ensure that the research accurately represents the phenomena it is intended to describe (Stahl & King, 2020:26). To ensure credibility, the research findings were cross-checked with existing literature on the subject. This triangulation method helped validate the findings by comparing them with established knowledge in the field.
- Dependability
  - Dependability focuses on the stability and consistency of the research findings over time. It is similar to the concept of reliability in quantitative research but accommodates the fluid nature of qualitative data (Stahl & King, 2020:27). The research process was thoroughly documented, including the development of the interview protocol and data analysis methods. This transparency allows for the research process to be audited, ensuring dependability.

Trustworthiness ensures that others have confidence in the quality of the investigation. Trustworthiness in qualitative research is important in validating the study's findings and enhancing its credibility. It can be ensured by regularly consulting the supervisor.

1.8. SCOPE OF THE STUDY

1.8.1. Field of the study

This study investigated the general and technology management fields of study. The 4IR is driven by technology. The researcher investigated both fields to complete this study.

1.8.2. Sector/industry/business under investigation

This study investigated the ferrochrome industry. The sector under investigation is mining beneficiation (with ferrochrome as a case study) and the general impact due to technologies related to the Fourth Industrial Revolution.

1.8.3. Geographic demarcation

The geographic demarcation of this study was the western limb of the bushveld complex in South Africa. The researcher focused on managers working for a ferrochrome plant in Rustenburg.

1.9. ETHICAL CONSIDERATIONS

Information was obtained from various corporate entities or persons; therefore, ethical considerations were involved in this research design. The ethical considerations are described below:

- The researcher ensured that participants were not exposed to undue harm.
- The researcher ensured that appropriate permissions were obtained from individuals and companies to utilise the data obtained during the study.
- The researcher ensured that the data was presented suitably to ensure that no person or company can be associated with the data.
- The researcher ensured full acknowledgement is given to the work by referencing and citing all work used during the study.

- The researcher obtained ethical clearance from the Economic and Management Sciences Research Ethics Committee (EMS-REC) on, 23/05/2023. The ethics approval letter with ethics number NWU-00595-23-A4 is attached in Appendix D.
- The informed consent form (Appendix C) describes:
  - How long should an interview take on average (40 min)
  - The researcher followed the regulations of POPIA
  - Confidentiality agreement
  - No incentives for participants

1.10. LAYOUT OF THE STUDY

Figure 2 shows the proposed layout of the study.

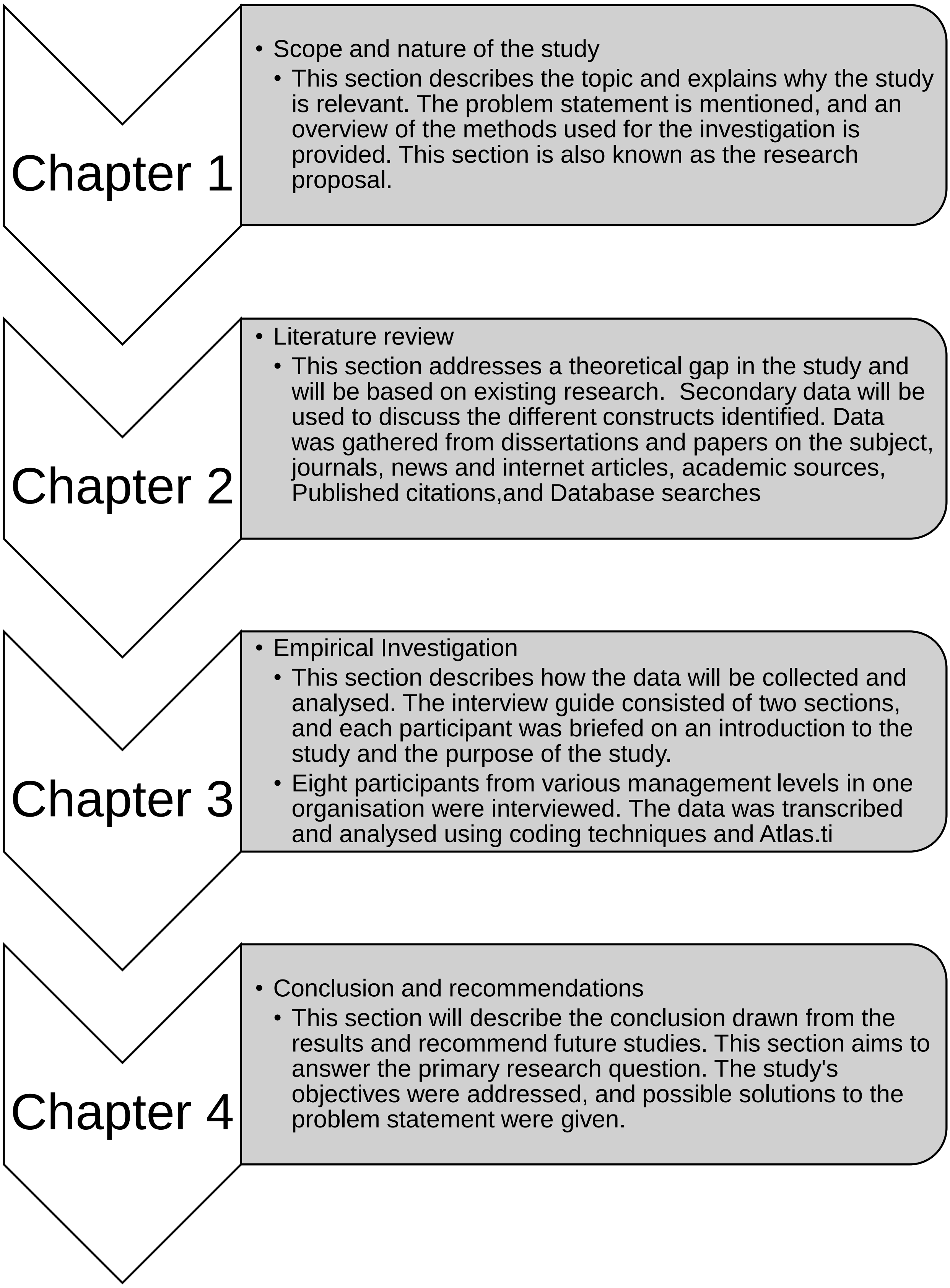

Figure 2: Layout of the Study

(**Source:** Own compilation)

1.11. CHAPTER SUMMARY

This chapter identified and described the purpose and significance of the study. It offers an introduction and an overview of the research. Also included in this chapter is a summary of the research. In this chapter, the research question and the primary and secondary objectives of the study were laid out. This chapter talked about the study's potential shortcomings.

In Chapter 2, a literature review of the effects of the 4IR on a South African ferrochrome manufacturing facility was done. This was done to gauge the influence of the 4IR on a South African ferrochrome manufacturing facility.

The results of the empirical investigation described in Chapter 3 are crucial for determining whether the chapter's primary and secondary objectives have been met. The research is concluded in Chapter 4 with a discussion of the results and recommendations.

CHAPTER 2 - LITERATURE STUDY

2.1. INTRODUCTION

The ferrochrome industry in South Africa has a broad range of challenges that directly affect its viability and competitiveness. The rising cost of electricity is one of the biggest challenges, as smelters are energy-intensive and immediately affect production costs and overall profitability. The suppressed selling prices, driven mainly by the Chinese market, make this rise in operational costs even worse. The industry has noticed a considerable reduction in beneficiation inside South Africa in addition to these economic difficulties, which reduces the value-added advantages of ore processing. Additionally, the industry is struggling with increased labour costs, which add to the financial stress on producers. Increasing ore exports to China is also a serious concern (Letaba, 2021:101).

Worldwide businesses and economies are transformed by the 4IR, defined by a combination of technologies that blur the boundaries between the physical, digital, and biological domains (Jegede, 2021). There is no exception in South Africa, where the ferrochrome industry plays a significant role in the GDP and employment of the nation (Creamer, 2021a). This literature review aims to investigate the effects that the 4IR might have on a ferrochrome manufacturing facility in South Africa and to analyse the opportunities and problems it could pose.

South Africa's ferrochrome sector is going through a critical period. For the sector to survive, new methods of ferrochrome production are required. The techniques used by South African producers now might not be effective in 30 years. This is due to the rising labour prices, raw materials, and power. In addition, China is increasing its influence on the ferrochrome market as a producer and importer of chromium ore, driving down ferrochrome prices. South African businesses find it more difficult to compete as a result.

Additionally, ferrochrome processing has decreased in South Africa, which is bad for the economy. The industry must consider new competitive technology and approaches to continue strong in the face of all these obstacles (Letaba, 2021:101). This decrease lowers the profitability of ferrochrome processing and has wider economic ramifications for South Africa. These considerations highlighted the necessity for the sector to adopt new manufacturing technologies and methods.

This literature review aims to present an overview of the current academic literature, business reports, and case studies about the effects that the 4IR might have on the South African ferrochrome sector. The review will review the leading technologies driving the 4IR, their possible uses in ferrochrome manufacturing, and the opportunities and problems they pose for the sector.

2.2. FERROCHROME PRODUCTION IN SOUTH AFRICA

2.2.1. Overview of the Ferrochrome industry

An essential component in the creation of stainless steel is ferrochrome, an alloy of chromium and iron (Lind, Fällman & Larsson, 2001). With large chromite ore reserves and a solid infrastructure for processing and exporting the alloy, South Africa is a prominent producer of ferrochrome globally (Parliamentary Monitoring Group, 2020).

Mining in South Africa shaped the socio-economic development of the country. Mining is seen as a significant economic driver and resulted in the development and investments of infrastructure and manufacturing (Dlamini & von Blottnitz, 2023:6). South Africa is rich in resources. Different ores and minerals are mined in various geographical locations in South Africa. One ore, Chromite ore (Chromium), is extensively used in ferrochrome production. It is estimated that 90% of all processed chromite is used in ferrochrome production (Dlamini & von Blottnitz, 2023:5).

In the Bushveld Complex of South Africa, the Merensky Reef is a significant reserve for platinum-group elements (PGE). Chromite, the ore from which Chromium is extracted, is commonly found as a stratiform layer within this geological formation. The Critical Zone is known for its rich platinum-group elements and chromite deposits. Within this zone, chromite layers are often stratified and can be found in multiple seams, but they are especially abundant in the lower sections (Smith *et al*., 2021). Discovered by Hans Merensky in 1924, the reef has been a focal point for mining activities for close to a century. Figure 3 below shows a typical geographic map of the Bushveld complex.

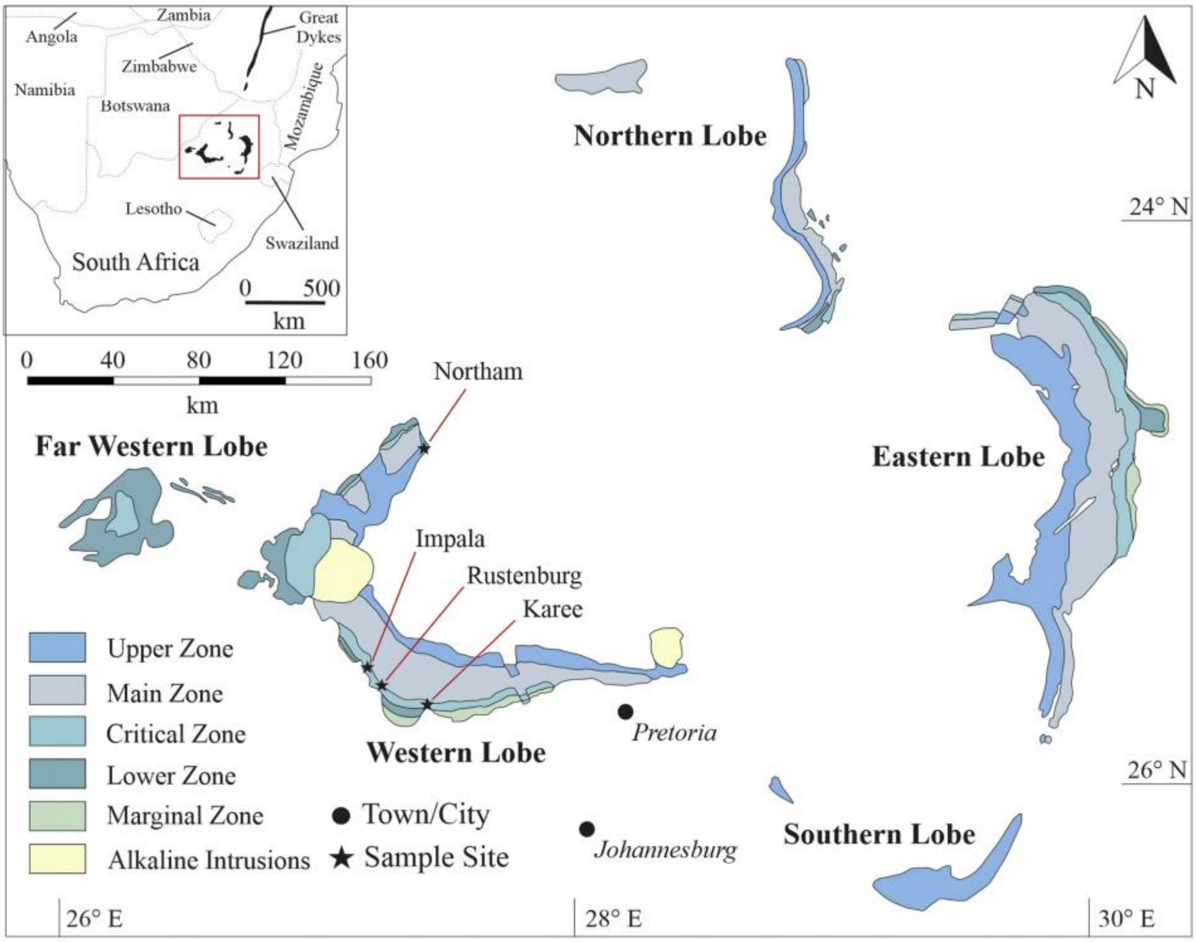

Figure 3: Geographic Map of the Bushveld Complex

(**Source:** Smith *et al.*, 2021)

Depending on the region, Chromite can be mined underground or in open pit mining. The run-of-mine is treated through comminution and classified according to different sizes. This process is achieved through crushing, screening, and gravity separation. The resulting product is either a fine or a lumpy material (Dlamini & von Blottnitz, 2023:5). Lumpy can be refined in pyrometallurgical carbothermic reduction of chromite, while fines require a sintering process. Ferrochrome production requires mainly fluxes, reductants, and chromite as raw materials. Figure 4 provides an overview of ferrochrome production.

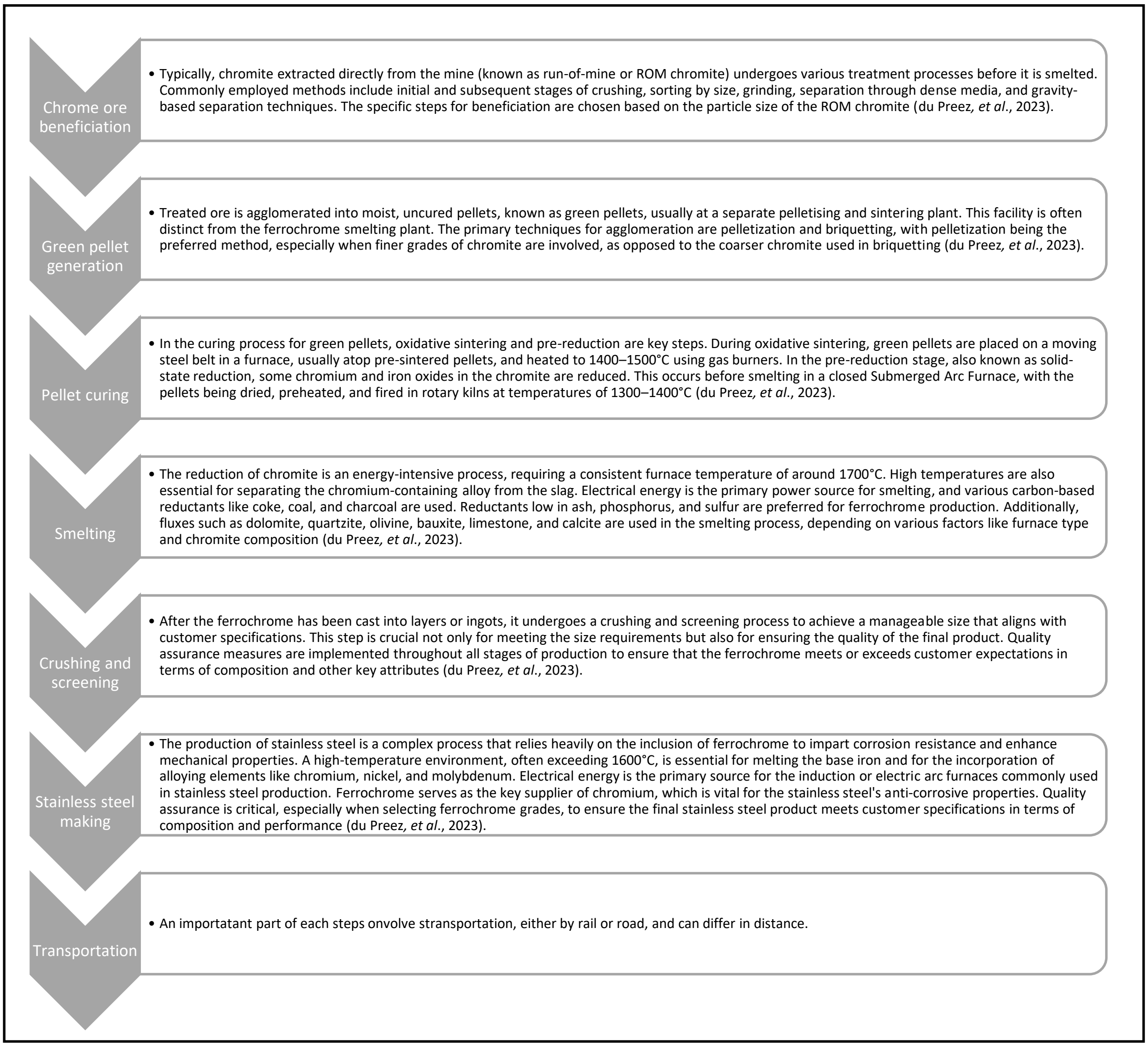

Figure 4: Overview of the Ferrochrome Production Process

(**Source:** Own Compilation)

Ferrochrome is an iron-chromium alloy and contains between 50% and 70% chromium by weight. Chromium improves the longevity of steel due to its remarkable corrosion resistance properties (Van der Lingen & Paton, 2018:1087). Chromium is essential to produce stainless steel and other superalloys, which has strategic importance. Therefore, chromium and ferrochrome can be considered a commodity of strategic importance.

South Africa has abundant raw materials required to produce ferrochrome and used to be the leading producer of ferrochrome. Other factors contributing to South Africa being the top ferrochrome producer at one stage included reliable and reasonably priced electricity and well-established and maintained infrastructure (Dlamini & von Blottnitz, 2023:5). China triumphed the South African ferrochrome market by becoming the leading producer of ferrochrome in 2010 (Van der Lingen & Paton, 2018:1087). The shift in ferrochrome production leadership from South Africa to China can be attributed to a combination of factors. South Africa exported the industry to China by supplying them with inexpensive chromite ore, a key cost component. Meanwhile, China leveraged its advantages, such as subsidised electricity for smelting and lower labour costs. This blend of China's benefits and South Africa's challenges effectively relocated the ferrochrome industry to China (Lotriet *et al*., 2022).

Demand and price forecast expect the steel alloy market value to increase by 40% from 2023 to 2030. The main value drivers in this increase are nickel and chromium (Backeberg *et al*., 2021:7). The South African ferrochrome industry remains well-positioned to be one of the leading producers of ferrochrome when considering low ore input cost and well-developed ferrochrome production infrastructure. The local ferrochrome organisations have high competency levels and use some of the best available technology in the industry (Van der Lingen & Paton, 2018:1093).

2.2.2. The role of ferrochrome in South Africa's economy

In South Africa's economic landscape, the government adopts a detailed and strategic approach towards mineral beneficiation to leverage the nation's abundant mineralogical assets for economic development, employment creation, and social upliftment. As described by the Department of Mineral Resources and Energy (DMRE), the term 'beneficiation' encompasses transforming rudimentary materials procured through mining activities into value-added finished or semi-finished goods (Department of Mineral Resources, 2023). This transformational process can manifest in various forms, from capital-intensive operations such as smelting to labour-intensive activities like artisanal jewellery crafting.

The emphasis on beneficiation underwent a significant paradigm shift in the 1990s, repositioning South Africa from a primary exporter of raw commodities to a noteworthy contributor in the global market for processed minerals. In 2004, South Africa was responsible for approximately 45% of global ferrochrome production (Department of

Mineral Resources, 2023). Legislative frameworks, notably the Mineral and Petroleum Resources Development Act of 2002 and the Mining Charter of 2004 are pivotal regulatory mechanisms facilitating local beneficiation. These legal instruments empower the Minister of Mineral Resources with the discretion to promulgate guidelines for beneficiation, thereby transmuting South Africa's inherent comparative advantages in mineral resources into a competitive advantage at the national level.

Despite the considerable advancements in this sector, the DMRE acknowledges the persistence of challenges, including but not limited to restricted access to raw materials, elevated costs associated with infrastructure, and innovation deficits. Nevertheless, the government remains resolute in its commitment to surmount these challenges through an integrated, multi-faceted strategy (Department of Mineral Resources, 2023). Significantly, this strategy extends beyond national boundaries to encompass regional initiatives, exemplified by South Africa's leadership role in a consortium of 12 African nations to formulate a pan-African framework for mineral beneficiation (Department of Mineral Resources, 2023).

The ferrochrome sector significantly contributes to the South African economy by creating jobs and exporting goods that earn foreign currency. Additionally, the sector fosters the growth of downstream industries like the manufacturing of stainless steel, which has additional beneficial effects on the GDP and employment of the nation (Creamer, 2021a). Mineral beneficiation such as ferrochrome production is a significant instrument adopted by the South African government in their development strategy (Dlamini & von Blottnitz, 2023:5). Further beneficiation of chromium ore has a significant socio-economic impact on the regions where the ferrochrome smelter is situated. The ferrochrome industry significantly contributes to employment, electricity payments, tax contributions and the overall Gross Domestic Product of the South African economy (Mutanga *et al*., 2021:3). Figure 5 shows the South African ferrochrome industry’s contribution to the South African economy.

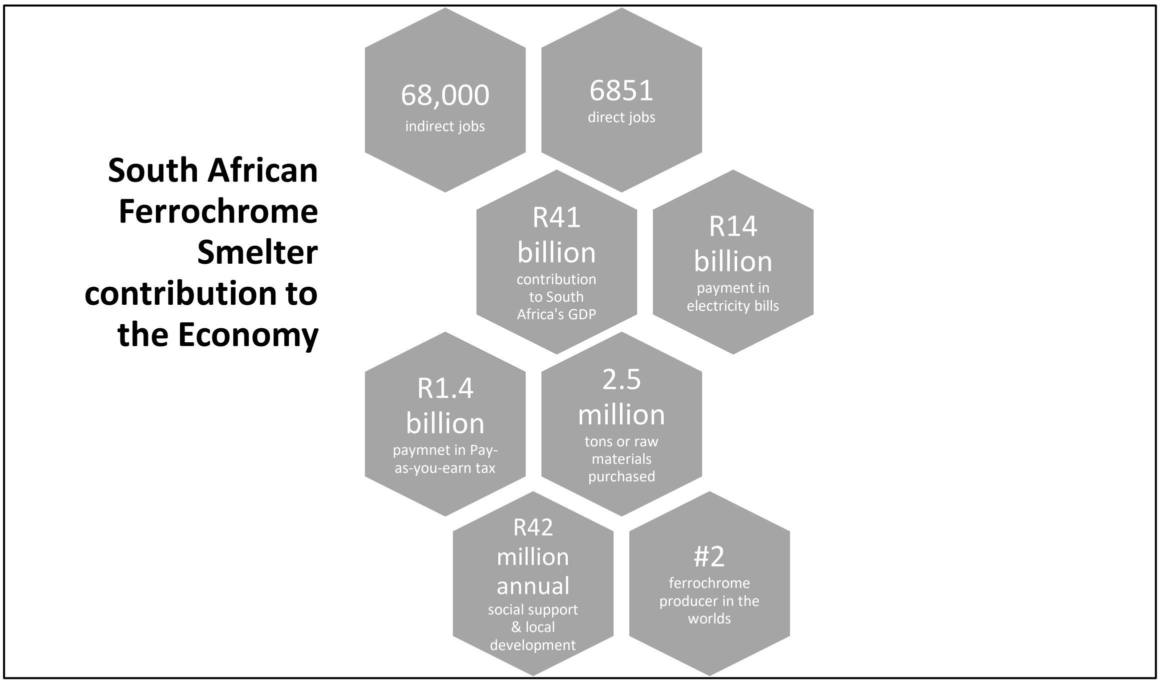

Figure 5: Economic Contribution of Ferrochrome Smelters

(**Source:** Authors own illustration based on Creamer, 2021a)

Although becoming increasingly less competitive, the South African ferrochrome industry contributes significantly to the economy. The smelters are responsible for more job creation than the mines per ton of ferrochrome exported (Letaba & Zulu, 2021:102). The South African ferrochrome industry employs 6 851 workers, indirectly supports 68,000 jobs, and contributes R41 billion to South Africa's gross domestic product. The industry also pays R14 billion a year in electricity bills to ESKOM, has pay-as-you-earn tax payments of R1.4 billion, purchases 2.5 million tons of raw materials from South African mines per year, and pays R42 million a year in social support and local enterprise development (Creamer, 2021a).

In Table 1, a summary is provided that outlines the key ferrochrome producers in South Africa along with their respective production capacities. This visual representation serves as a comprehensive guide to understanding the landscape of the ferrochrome industry within the country. It offers insights into which companies are the major players in the market and how much ferrochrome they can produce.

Table 1: South African Ferrochrome Producers Summarised

Company Name	Capacity in 2006 (kt/year)	Capacity in 2020 (kt/year)
Glencore	1620	2340
Samancor	1200	2300
Tata KZN	150	150
Afarak (Including Mogale alloys)	110	110
Hernic Ferrochrome	420	Acquired by Samancor
International Ferro Metals (IFM)	267	Acquired by Samancor
ASA Metals (Newco)	410	Acquired by Samancor
Assmang Chrome	300	Non-operational since 2012
Total South African Capacity	4175	4895

(**Source:** Dlamini & von Blottnitz, 2023)

2.2.3. Key challenges faced by the South African ferrochrome industry

Numerous obstacles, such as fluctuating worldwide demand and pricing, high electricity costs, and escalating environmental requirements, beset the South African ferrochrome industry (Liedtke, 2021). A decrease in production capacity and profitability because of these issues has forced industry stakeholders to look for novel solutions, such as adopting 4IR technologies, to stay competitive (Letaba & Zulu, 2021).

- The ferrochrome industry in South Africa has faced various challenges over the past few years. These challenges include: (Van der Lingen & Paton, 2018:1087)
- Influence from the market
- Labour
- The control that China has over both ferrochrome and chrome ore from South Africa
- Electricity supply constraints

- Output pressure to remain globally competitive

China's South African chrome ore supply increased from 36% in 2010 to 70% in 2016. In 2021, the South African ferrochrome producers had favourable prices and market share due to production challenges in China. The local ferrochrome market has been uncompetitive (Van der Lingen & Paton, 2018:1087). This resulted in four of the eight producers closing operations in 2016, as shown in Table 1.

Ferrochrome production is energy-intensive, and ferrochrome producers in South Africa have faced alarming electricity fee increases and electricity supply complications over the past few years (Van der Lingen & Paton, 2018:1087). Ferrochrome producers in South Africa have seen more than 500% electricity tariff increases over the past ten years (Creamer, 2021a).

Increasing reports of supposed difficulties related to South Africa’s electricity supply have caused investment hesitations from key players in the ferrochrome industry. These reports created the impression that South Africa will not be able to support the anticipated growth of the ferroalloys industry and caused investors to seek attractive alternatives globally (Basson *et al*., 2007:17). The South African ferrochrome industry is predominantly inland near the mines, producing the required raw materials. This means any ferrochrome that is to be exported must be transported to the coastal harbours. The transportation of ferrochrome includes train transportation employing national railways and truck transportation by national roads. The South African freight infrastructure has been acceptable in previous years. However, economic growth and insufficient upgrades and maintenance have caused the infrastructure to result in significant shortfalls in the existing economic climate (Basson *et al*., 2007:18).

National infrastructure is required for the growth of the South African economy, including the South African ferrochrome market. The following aspects of national infrastructure are critical components of human life and the South African economy: transportation, energy, health, housing, and educational facilities (Stungwa & Daw, 2021:1). The South African ferrochrome industry relies on a recovery strategy that includes priority interventions such as infrastructure investments, energy security, and green economy interventions.

2.3. THE FOURTH INDUSTRIAL REVOLUTION (4IR)

Today, the world is in the Fourth Industrial Revolution. Throughout history, the world went through the first, second and third industrial revolutions (Mhlanga, 2022:6).

- The first industrial revolution occurred during the end of the 18th century and used fossil fuels as alternative energy (Mhlanga, 2022:7).
- The second industrial revolution occurred during the end of the 19th century and is known for breakthroughs in electricity distribution and wireless communication (Mhlanga, 2022:7).
- The third industrial revolution occurred in the 1950s and had great advances in computing power and information sharing (Mhlanga, 2022:7).
- It is believed that the Fourth Industrial Revolution started in the early 21st century and is driven by various technological improvements (Mhlanga, 2022:7).

2.3.1. Definition and key characteristics

The 4IR is the ongoing transformation of industries, economies, and communities brought about by the convergence of digital, physical, and biological technology (Serumaga-Zake & van der Poll, 2021). According to Bughin *et al*. (2018), the 4IR is characterised by the rapid rate of technological change, the fusion of technologies from several disciplines, and the growing interconnectedness of systems and the world previously underwent radical changes in the economic and social structures when new technologies and novel ideas came about. These changes are also known as industrial revolutions.

As mentioned, the present-day industrial revolution is called the Fourth Industrial Revolution, also known as the 4IR or Industry 4.0, characterised by cyber-physical systems. Many businesses are swiftly mechanising and automating workplaces. New technologies introduced may raise many questions for business and society (Hooker *et al*., 2019:35). State-of-the-art technology such as artificial intelligence, robots, self-driving vehicles, and the internet (Internet of Things) are introduced to build a world where individuals and businesses can manage their affairs through digital domains and reality (Xu *et al*., 2018:90).

2.3.2. Technologies driving the 4IR

The 4IR is driven by several core technologies, each potentially impacting the ferrochrome industry significantly. These technologies are listed below:

- Internet of Things (IoT)
- Artificial Intelligence (AI) and Machine Learning (ML)
- Robotics and Automation
- Advanced Analytics and Big Data
- Additive Manufacturing (3D Printing)
- Virtual and Augmented reality (VR and AR)

These core technologies are discussed in more detail in the section below.

2.3.2.1. Internet of Things (IoT)

The Internet of Things (IoT) has great potential. IoT links everyday objects and machinery, turning them into smart devices to gather and share data. Because of this capability, decisions can be made with better knowledge, improving productivity (Particle, 2023).

An intriguing possibility for improving safety measures is provided by wearable sensor technology, which is included in the IoT's more extensive definition. These wearable gadgets can monitor environmental factors and identify potential dangers in real time, thereby averting accidents. An increasing body of research shows that safety management systems and wearable sensor technology have a substantial impact. These organised frameworks systematically manage and enhance safety procedures, improving overall safety performance in diverse contexts (Okpala *et al.*, 2020). It is possible to track real-time health parameters like heart rate, sleep patterns, stress levels, and more using wearable sensors.

The uses of IoT become very intriguing when considering the ferrochrome sector. It could be necessary for inventory management. IoT can deliver real-time insights into stock levels and demand estimates in place of human checks and potential inaccuracies. The industry can also better understand its processes by incorporating IoT into production lines, enabling quicker interventions and less waste (Pratt, 2023). Through ongoing tracking, it can simplify operations for delivery and transportation. In addition, employing IoT for continuous equipment and site condition monitoring can considerably improve safety, a crucial concern in sectors like the ferrochrome industry.

2.3.2.2. Artificial Intelligence (AI) and Machine Learning (ML)

Robotic capabilities have changed dramatically because of the development of cutting-edge technologies like artificial intelligence (AI) and machine learning (ML). Robots can now process enormous volumes of data, learn from it, and make intelligent choices independently rather than merely depending on predefined programming. Due to this progress, robots are no longer just machines performing routine duties. Based on the information they come across, they can adjust, optimise their operations, and even forecast potential future scenarios or demands (Soori *et al*., 2023). A new era in which robots may function with a level of independence and intelligence previously thought unachievable by integrating AI and ML with robotics.

Since there is a rapid increase in the amount of data produced by different human activities, the term "big data" has gained popularity. This exponential expansion is frequently emphasised, particularly considering the IoT's growing significance. Big data, however, is about more than just the sheer amount of data. Even though it has become a buzzword, some people can mistake it for nothing more than a trendy phrase with big promises. Various cutting-edge software tools and analytical techniques are also a part of big data (Rodrigues *et al*., 2021). These methods and technologies can uncover significant value by identifying and highlighting patterns in data sets that, at first glance, may appear dispersed or unrelated.

Algorithms are written in programming languages in traditional computer science to instruct computers on specific activities. Using algorithms, ML enables computers to "learn" from data examples and underlying concepts. These ML-driven systems can carry out tasks not expressly described in the code (Rodrigues *et al*., 2021). In ML, learning is a protracted human process involving triumphs and mistakes. The confluence of ML with big data is crucial because it makes previously impractical ML approaches feasible, thanks to more examples and improved processing capacity.

Predictive AI and ML maintenance can predict equipment failures in the ferrochrome business, enabling prompt interventions. These technologies improve quality assurance by spotting discrepancies and ensuring product excellence (Pellegrini *et al*., 2019). Processes can be optimised by streamlining operations, increasing production, and eliminating waste. Additionally, safety precautions are strengthened, identifying potential risks early and encouraging a safer working environment in the ferrochrome industry.

2.3.2.3. Robotics and automation

Robotics and automation are important pillars of contemporary technological breakthroughs. It entails using specialised equipment and sophisticated computer systems specially designed to carry out challenging jobs, frequently with little to no human participation (Karaś, 2020).

Implementing such technology is quickly developing as a disruptive strategy in the dynamic ferrochrome industry. Due to automated systems' ability to operate constantly without being hindered by human fatigue, there is a noticeable increase in operational productivity. There is also a significant economic benefit because these technologies can significantly reduce costs by lowering labour costs and related overheads. Safety is a different but no less considerable advantage. Automation greatly lowers the likelihood of accidents at work, making employees safer (Mining Technology, 2022). Robotics and automation open the door for a more sustainable, effective, and forward-thinking future in the ferrochrome industry by incorporating these numerous benefits.

2.3.2.4. Advanced analytics and big data

Big data and advanced analytics have emerged as crucial elements in today's rapidly digitising world, denoting a disruptive method for how firms manage massive amounts of data. These ideas are fundamentally concerned with the gathering, handling, and sophisticated analysis of enormous data sets to derive insightful knowledge that may guide well-informed decision-making processes (Chen *et al*., 2014). In particular, the incorporation of advanced analytics is proven to be crucial in industries. It is a lighthouse for streamlining procedures like demand forecasting, enabling market participants to foresee demands more precisely. It could also prove useful in removing waste in complex processes.

Additionally, it is essential for streamlining numerous procedures and guaranteeing resource efficiency across all manufacturing stages. Supply chain management has significantly improved because of this data-driven strategy. In addition to ensuring the uninterrupted flow of supplies and goods, it helps identify and resolve issues before they become serious (Miller, 2023). Tools like sophisticated analytics are proving to be useful resources for companies as they attempt to be more responsive and agile in a competitive market, propelling the ferrochrome sector towards a future of increased efficiency and sustainability.

2.3.2.5. Additive manufacturing (3d printing)

The additive manufacturing process, 3D printing, is revolutionising the industrial industry. Materials are deposited layer by layer onto a digital model using this novel approach to create three-dimensional items with exact detailing (Gibson *et al*., 2021).

Beyond its generic applications, this technology has various implications for various industries. It gives the clear benefit of rapid prototyping. This process can quickly and effectively transform conceptual designs into prototypes, speed up design iterations, and decrease time-to-market. In addition, additive manufacturing is beneficial for creating unique parts customised to needs, enabling enhanced customisation without significant retooling. This approach can dramatically reduce material waste, which makes it advantageous across industries. There is a noticeable conservation of resources when adding material just where necessary, which positively affects the environment and the economy. Additive manufacturing, which offers unique solutions and opportunities for growth in various sectors, emerges as a leader as industries continue to look for sustainable and effective production solutions (The Steel Printers, 2023).

2.3.2.6. Virtual and Augmented reality (VR and AR)

Virtual reality (VR) and augmented reality (AR) are immersive technologies representing the cutting edge of digital interaction and experience. VR submerges viewers in a digitally created setting, providing an artificial experience that frequently feels intensely real. AR adds digitally improved information to the user's immediate surroundings by superimposing virtual features over their real-world view (Hall and Takahashi, 2017).

These technologies have a wide range of possible applications across numerous sectors. VR can considerably improve safety, a key concern in many industrial environments. Workers can be trained to respond effectively to potential dangers by simulating hazardous scenarios in a safe virtual environment without putting them in danger. This not only guarantees that the staff is well-prepared, but it also considerably lowers on-site incidents.

AR can also be used to streamline the maintenance of complicated systems and machinery, which is sometimes an uphill task in many industries. To facilitate quicker and more effective interventions, technicians can obtain real-time visual instructions overlaid on the equipment they are repairing. Additionally, VR and AR can be used to revolutionise training sessions, which often rely on theoretical manuals and periodic hands-on practice. Before they even set foot on the factory floor, new employees can immerse themselves in realistic simulations to obtain practical expertise and confidence (Cai *et al*., 2021). Immersive technologies offer efficiency and improved safety and competency as industries develop.

Having explored the core technologies that serve as the backbone of the 4IR, it is crucial to extend the discussion to a broader context. The following section delve into the implications of 4IR on the global economy and various industries. Understanding this wider impact contextualises the role of 4IR technologies and provides valuable insights into how they could reshape the ferrochrome industry in South Africa.

2.4. IMPLICATIONS OF THE 4IR

The 4IR has many implications across different aspects of society and industries. It is important to understand the global ramifications, particularly how 4IR impacts the world economy and various industries. This is a foundation for a more targeted examination of its effects on the South African economy and industrial landscape. Lastly, it should focus on the ferrochrome production sector, exploring how 4IR technologies fundamentally reshape this critical industry. These focus areas offer a comprehensive overview, ranging from global trends to localised impacts, especially within South Africa's ferrochrome production.

2.4.1. Implications of 4IR on the global economy and industries

The 4IR has acquired notoriety recently as a significant force behind change in the world economy and several industries (Schwab, 2017). Scholars and practitioners alike are very interested in the implications of the 4IR, and numerous studies have investigated its possible effects on employment, productivity, and global competitiveness.

The transition to automation and digitisation, which can boost productivity and efficiency in many industries, including ferrochrome manufacturing, is one key result of the 4IR (Chui *et al*., 2018). As certain occupations become obsolete and the need for highly skilled workers rises, the rise of technology could potentially lead to job displacement and greater income inequality (Acemoglu & Restrepo, 2020). As a result, decision-makers in the public and private sectors must weigh the advantages of technological development against any potential social and financial consequences.

However, companies that do not use technologies such as AI will soon be obsolete (McAfee & Brynjolfsson, 2017).

In addition to these effects on the labour market, the 4IR promotes the creation of new value chains and business models (Kagermann and Wahlster, 2022). For instance, the rise of digital platforms and the Internet of Things (IoT) has changed conventional industry structures and made it possible for supply chains to be more connected and share data more efficiently (Lasi *et al*., 2014). This change

significantly impact the competitiveness of businesses and countries, with those who can innovate and adapt more likely to prosper in the new economic environment (Mokyr *et al*., 2015).

Furthermore, given that the 4IR brings both opportunities and difficulties for sustainable development, the environment is a crucial concern (de Andres Gonzalez *et al.*, 2021). On the one hand, innovations in resource efficiency and greenhouse gas reduction, such as smart manufacturing and renewable energy, are possible (Fuso Nerini *et al*., 2019). Conversely, severe environmental problems may be associated with the quick development of digital infrastructure and the generation of electronic trash (Forti *et al*., 2020).

In conclusion, the Fourth Industrial Revolution will significantly impact the global economy and various industries. Both potential advantages and hazards will need to be adequately addressed. Therefore, it is crucial to continue study and collaboration between academics, businesses, and governments to ensure that the chances given by the 4IR are tapped for all benefits.

2.4.2. Implications of the 4IR on the South African economy and industries

For the economy and industries of South Africa, the 4IR offers both opportunities and challenges. As one of the top economies in Africa, South Africa is in an excellent position to take advantage of the transformative potential of 4IR technologies (Arntz *et al*., 2017). Still, it must also prepare for this change's potential risks and disruptions.

The potential for 4IR technologies to promote economic growth and development is a significant opportunity for South Africa. Various industries, including manufacturing, mining (including ferrochrome smelting), and agriculture, could experience greater productivity and innovation because of the adoption of cutting-edge technologies like AI, big data, and the IoT (Levin, 2018). These technologies can also aid in the growth of new markets and services, such as digital finance and renewable energy, which could contribute to the diversification of the South African economy and new job opportunities (Levin, 2018).

However, concerns about job displacement and escalating income inequality in South Africa are also raised by the country's shift to a 4IR-driven economy. The demand for low-skilled workers may decline as automation and digitisation spread, worsening the nation's current labour market issues (Bhorat *et al*., 2019). Policymakers and business executives must invest in education and training programs to equip the workforce for the challenges posed by a 4IR-driven economy to address this problem (Rasool & Botha, 2011).

The 4IR also poses possible concerns to South Africa's ecology and resource sustainability. The rapid growth of the digital infrastructure and the rise in consumption of electronic goods may lead to greater environmental challenges, even while emerging technologies like renewable energy might help manage resources more sustainably (Diale *et al*., 2022). The enormous amount of electricity required to operate smelters will likely impact environmental challenges related to renewable energy infrastructure. Looking at the triple bottom line principle of environment, people, and economy is important.

In conclusion, the Fourth Industrial Revolution will affect the South African economy and industry, posing enormous potential for growth and development and severe difficulties in job displacement, inequality, and environmental sustainability. To guarantee that the potential advantages of 4IR technologies are achieved while minimising their adverse effects, politicians, industry leaders, and researchers must work cooperatively to navigate this complicated environment.

2.4.3. Impact of 4IR technologies on ferrochrome production

The impact of the Fourth Industrial Revolution (4IR) technologies on ferrochrome production is a pivotal focus in understanding the future of this industry. This section delves into various technological advancements that are reshaping the sector. Overall, the discussion aims to understand how 4IR technologies are revolutionising ferrochrome production comprehensively.

Figure 6 maps the production process, indicating where 4IR technologies can be applied.

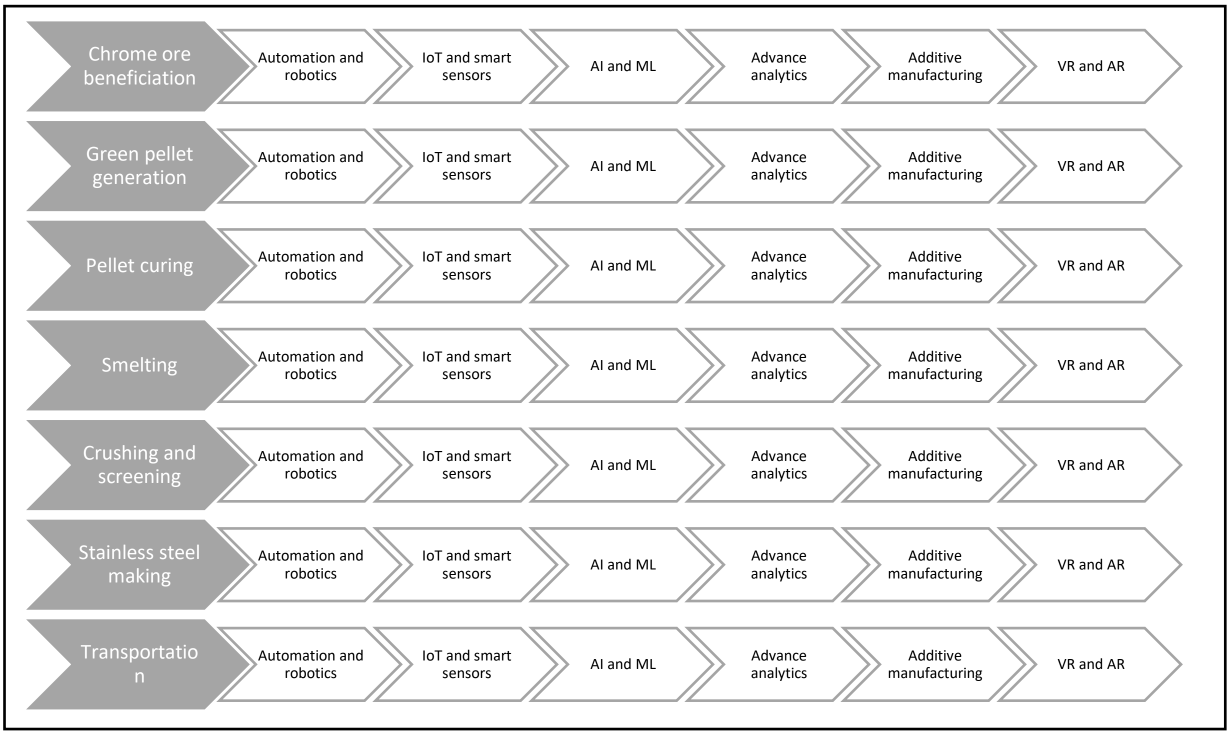

Figure 6: Ferrochrome Production Process Mapping and Possible 4IR Technology Application

Various technologies can be implemented across different stages of the ferrochrome and steel-making process:

Chrome Ore Beneficiation:

- Automation and Robotics can streamline the sorting and processing of chrome ore, enhancing efficiency and reducing human intervention.

- IoT and Smart Sensors can monitor ore quality in real time, ensuring optimal beneficiation processes are applied based on ore grade.
- With AI and ML, predictive models can be developed to forecast ore quality and adjust processes accordingly.
- Advanced Analytics allows for the deep analysis of ore data, identifying trends, and optimising beneficiation techniques.
- Additive Manufacturing provides tools to produce bespoke machinery components to enhance beneficiation.
- VR and AR can be used to train operators through the beneficiation process in a simulated environment.

Green pellet generation:

- Automation and Robotics ensure consistent and optimal pellet sizes and shapes.
- IoT and Smart Sensors detect real-time conditions during pellet generation, ensuring the proper moisture and ingredient mix.
- AI and ML can optimise the pellet creation process based on historical data.
- Advanced Analytics can monitor and adjust pellet composition in real time.
- Additive Manufacturing allows for rapid prototyping of tools or components that can improve pellet formation.
- VR and AR offer a visual guide for operators, highlighting any deviations in pellet quality.

Pellet Curing:

- Automation and Robotics provide consistent turning and movement of pellets, ensuring even curing.
- IoT and Smart Sensors monitor curing conditions, like temperature and humidity.
- Using AI and ML, predictive maintenance of curing ovens can be scheduled.
- Advanced Analytics ensures optimal curing times based on pellet composition.
- Additive Manufacturing can create parts or tools specific to unique curing needs.
- VR and AR can guide operators through the curing process and troubleshoot any issues.

Smelting:

- Automation and Robotics ensure consistent feeding of materials into smelters.
- IoT and Smart Sensors constantly monitor furnace conditions.
- AI and ML adjust smelting parameters in real time based on input material and desired output.
- Advanced Analytics can optimise smelting temperatures and times.
- Additive Manufacturing helps produce furnace components tailored to specific smelting needs.
- VR and AR can offer training and guidance during the smelting process.

Crushing and Screening:

- Automation and Robotics ensure uniformity in crushing operations.
- IoT and Smart Sensors monitor particle size and distribution.
- AI and ML adjust crushers based on the type and size of input material.
- Advanced Analytics helps in optimising the crushing and screening process.
- Additive Manufacturing can produce custom screens or crusher parts.
- VR and AR provide training and assist operators in managing the crushing equipment.

Stainless Steel-Making:

- Automation and Robotics streamline the pouring and moulding processes.
- IoT and Smart Sensors monitor steel composition and temperature.
- AI and ML adjust steel-making parameters in real time.
- Advanced Analytics ensures the desired steel grade and properties are achieved.
- Additive Manufacturing creates specific moulds or components for steel casting.
- VR and AR guide operators through the steel-making process.

Transportation:

- Automation and Robotics can be used for loading and unloading, reducing manual labour.
- IoT and Smart Sensors track product location and conditions during transit.
- With AI and ML, route optimisation and predictive maintenance of transport vehicles can be achieved.
- Advanced Analytics provides insights into logistics performance.
- Additive Manufacturing can produce parts for transportation equipment.

- VR and AR can train drivers and logistics personnel, offering real-time guidance during loading and transportation.

When integrated appropriately, these technologies can optimise each stage of the process, enhancing efficiency, quality, and overall productivity.

It's evident that 4IR technologies are versatile and can be integrated into every stage of the ferrochrome production process. While some steps may yield higher returns and others may have a more significant impact, the core principles of 4IR can be applied across the entire value chain.

2.4.3.1. Automation and robotics in ferrochrome production

With the introduction of cutting-edge automation and robots, the 4IR is expected to impact the ferrochrome sector significantly. The potential of these developments points to an increase in sector productivity and improved safety measures (Letaba & Zulu, 2021).

Robotic systems with sophisticated sensors can perform complex operations with unmatched accuracy, resulting in higher-quality ferrochrome outputs. Their capacity to work continuously guarantees top-notch product quality and quicker production cycles, optimising the length and effectiveness of the production process.

Additionally, automated solutions can considerably reduce the dangers of handling molten metal and performing high-temperature tasks throughout ferrochrome production. Flawless operation of these technologies in high risk environments reduces the need for human intervention, lowering workplace accidents' danger.

Incorporating 4IR technologies will create a new paradigm for workforce requirements, even while the advantages, such as decreased labour costs and increased safety, are compelling. A similar emphasis on upskilling and training the workforce to adapt to this new technical landscape will be necessary as the industry's attention shifts to maintaining and programming these systems as automation takes precedence (Siciliano *et al*., 2008).

2.4.3.2. IoT and smart sensors for process optimisation

The ferrochrome industry is undergoing a transition because of the 4IR, with the IoT and smart sensors playing key roles. Due to its intrinsic complexity, ferrochrome production considerably benefits from the real-time data these technologies provide (Pratt, 2023).

Production facilities' embedded IoT devices and smart sensors continuously check equipment performance. In addition to maximising production, this proactive approach avoids expensive unplanned downtimes. Their real-time monitoring of energy use guarantees that operations continue to be energy-efficient, directly affecting the bottom line.

Given the high-temperature operations and potential pollutants, pollution control inside plants is crucial. Sensors continuously monitor these circumstances to maintain worker safety and conformity with environmental regulations. Additionally, a branch of IoT called wearables focuses on workers. By monitoring their vitals in real-time, any health abnormalities result in prompt alarms, improving safety procedures.

The acquired data is an excellent source of useful information for plant managers. Inefficiencies are promptly found and fixed by evaluating this data, streamlining processes and increasing output. In summary, 4IR technologies play a key role in improving the efficiency, safety, and cost-effectiveness of ferrochrome manufacturing by providing a thorough real-time view of the whole production process.

2.4.3.3. AI and ML applications for predictive maintenance and process optimisation

The manufacture of stainless steel depends heavily on the ferrochrome industry, which is about to evolve considerably thanks to 4IR technologies like AI and ML. The operational dynamics of the industry are being reshaped by these once-futuristic technologies (Çınar *et al*., 2020).

Predictive maintenance is a crucial use of AI and ML in ferrochrome production. Artificial intelligence (AI) systems can estimate wear and tear and predict when equipment is likely to break by analysing enormous datasets from production gear. This has significant ramifications since it enables optimised maintenance plans, lowers unexpected downtimes, and reduces operational costs.

The capabilities of AI go beyond predictive maintenance and include quality assurance. AI-powered systems examine sensor data and complex production variables in a market where product consistency is crucial. Any deviation from the predetermined ideal conditions is quickly detected (Letourneau-Guillon *et al*., 2020). With such proactive control, product quality is guaranteed to remain constant, and waste is reduced, resulting in more productive and sustainable production cycles.

With these developments, 4IR technologies like AI and ML provide a better future for ferrochrome production in terms of efficiency and quality.

2.4.3.4. *Advanced* analytics for data-driven decision-making

The 4IR technologies are causing a radical change in the ferrochrome business. In this sector, sophisticated analytics and big data may be game changers (Chen *et al.*, 2014).

With the aid of these technologies, ferrochrome manufacturers may sift through large amounts of data and uncover insightful patterns that might not be visible otherwise. Producers may grasp changing market trends, comprehend complex consumer preferences, and have a comprehensive understanding of the complexities of the supply chain by evaluating these patterns. Such profound perceptions result in better demand forecasting, which enables businesses to match market dynamics and modify output.

Furthermore, these insights directly lead to the ability to make well-informed decisions. Producers can plan the best production routes, allocate resources more wisely, spot potential bottlenecks, and increase production efficiencies. As a result, operational effectiveness increases (Miller, 2023). A company's ability to quickly adjust based on data-driven insights increases its competitiveness in the global market and positions it favourably in an unpredictable market environment.

Fundamentally, incorporating analytics and big data into ferrochrome manufacturing lays the way for a more responsive, effective, and globally competitive sector.

2.4.3.5. Additive manufacturing in the Ferrochrome industry

A new era of productivity and innovation can start in the ferrochrome industry by adopting additive manufacturing, also known as 3D printing. This technology makes fabricating unique parts and components specifically suited to the sector's demands possible. A competitive edge in the market is made possible by such precision, which speeds up prototyping and dramatically reduces lead times in creating new goods (The Steel Printers, 2023). However, the advantages go beyond only speed and customisation. The inherent material efficiency of 3D printing is a key benefit. By building products layer by layer, additive manufacturing significantly reduces material waste compared to traditional manufacturing processes, which frequently cut out products from larger blocks.

This reduces the production process's environmental impact while aligning it with sustainable business principles (Gibson *et al*., 2021). Furthermore, ferrochrome producers can reduce their dependency on large spare component inventories by utilising additive manufacturing capabilities. In addition to freeing up money and space, this simplifies supply chain management, enhancing the industry's responsiveness and agility.

2.4.3.6. Virtual and Augmented reality for training and safety

By offering immersive, accurate simulations of manufacturing processes and hazardous scenarios, using VR and AR technologies in the ferrochrome industry can improve worker training and safety (Cai *et al*., 2021). This can result in increased readiness, quicker emergency responses, lower chances of workplace accidents and injuries, and more (Hall and Takahashi, 2017). Technologies related to the 4IR come with many opportunities for the mining industry, including cost improvement and sustainability.

Numerous South African mining houses have started adopting the 4IR into their mines, although many projects have not been successful (Zulu *et al*., 2021:185). Despite some unsuccess, many companies are making significant leaps in implementing technologies associated with the 4IR. Currently, limited research is being done on the potential implementation of the 4IR in the ferrochrome industry (Letaba & Zulu, 2021:101). It is anticipated that challenges and opportunities could arise with the performance of 4IR technologies in the South African ferrochrome industry.

2.5. CHALLENGES AND OPPORTUNITIES OF THE 4IR IN THE SOUTH AFRICAN FERROCHROME INDUSTRY

For businesses, the inclusion of such technologies can lead to benefits such as increased profit, an increase in the reliability of predictive maintenance measures, increased speed and intelligence due to machine-to-machine communication, and an increase in productivity due to improved human-machine interaction (Bloem *et al*., 2014:4).

Opportunities that come with the 4IR include (Xu *et al*., 2018:91):

- Ease inventor access to markets
- Artificial intelligence can solve complex problems with many benefits, such as new opportunities for economic growth
- The fusion of technologies will allow for new markets and new growth opportunities

- Robots can potentially improve individuals' quality of life at home and work
- The Internet of Things (IoT) can increase connectivity between everyday items, appliances, devices and individuals or businesses who rely on these devices

Challenges that businesses may face in the 4IR are (Xu *et al*., 2018:93):

- The 4IR can lead to a higher level of inequality, disrupt labour markets and increase unemployment
- High risk related to cyber security and hacking
- Education must change with the 4IR; the skills that individuals will require will significantly differ from what was required previously
- Ethical concerns related to the 4IR (AI, automation, robots, and genetic engineering)

The 4IR is much different compared to the previous stages of the Industrial Revolution. Businesses and individuals will be impacted in ways that are not known yet. There are many opportunities and advantages, but the fourth revolution does not come without challenges and ethical considerations. Individuals and businesses must stay educated and updated with the latest trends and information related to the 4IR. The most predominant effects of this revolution on businesses are its impact on consumer expectations, product quality, the move toward collaborative innovation, and innovations in organisational forms.

Other considerations include:

- Workforce transformation and skills development:

  The ferrochrome industry's shift to 4IR technologies could indicate a significant change in its operational dynamics. Removing people from harmful places will require reskilling and upskilling. Adopting technologies associated with 4IR will require a paradigm shift in terms of skill requirements, software, hardware and company culture. This change, therefore, emphasises the necessity of a workforce with a renewed skill set. Data analysis is crucial, considering the industry's increasing reliance on data-driven decision-making processes. This calls for analysing vast amounts of data, identifying patterns, and projecting possible trends to guide strategic decisions. Programming knowledge is becoming increasingly crucial as automated systems and sophisticated algorithms proliferate. Such expertise guarantees the efficient creation, upkeep, and improvement of software solutions suited to the industry's requirements. Additionally, systems integration skills and the capacity to cogently amalgamate numerous hardware and software elements gain relevance when the industry merges diverse technological components (Bughin *et al.*, 2018). The ferrochrome industry's ability to successfully navigate the complexities of 4IR adoption rests on combining these talents.

The ferrochrome industry needs a workforce that is qualified and adaptable in its skill set if it is to succeed in a production environment that is becoming more technologically advanced. This necessitates an ongoing focus on reskilling and upskilling, which requires educating personnel in completely new fields of knowledge and upskilling, which entails increasing the capabilities of the current workforce (Schwab, 2017). However, the industry shouldn't bear all the burden for such initiatives. Collaborations between government organisations, trade unions, business stakeholders, and educational institutions will be crucial. These partnerships can make it easier to develop customised training programs, match curricula to business requirements, and even provide financial support or incentives for lifelong learning. In essence, a diverse and collaborative approach will be essential for assuring a seamless transition and cultivating a competitive edge in the age of technological innovation.

- Infrastructure and investment requirements:

Significant investments in infrastructure are necessary due to the strategic shift that the integration of 4IR technologies signifies. Modern equipment and sensors are crucial to this shift because they allow for the real-time data collecting, monitoring, and automation of intricate operations. Adoption of custom software solutions also becomes crucial in conjunction with this. These platforms will analyse the enormous volumes of data produced, offering insights that may be put to use and assisting in process optimisation. Furthermore, reliable, fast communication networks cannot be overstated because they guarantee constant connectivity and data transfer between various devices and centralised systems.

In conclusion, achieving the potential of 4IR in the ferrochrome sector necessitates a comprehensive infrastructure improvement and modernisation strategy. (McKinsey & Company, 2023b). The industry may utilise the full potential of 4IR technologies with the help of these investments, which government backing, private-sector partnerships, and creative financing structures can facilitate.

- Sustainability and environmental considerations:

Meeting the present demands without compromising future generations' potential to satisfy their needs is called sustainability (Beattie, 2023). Its three primary pillars are:

  - Environmental sustainability:

    Consists of actions that reduce damage to the environment and the planet. This includes tactics for halting global warming, conserving resources, preserving biodiversity, and lowering pollution (Beattie, 2023).
  - Social sustainability:

    Concerned with maintaining the social fabric of communities and guaranteeing a high standard of living for all. This entails supporting social fairness, preserving cultural coherence, upholding human rights, and promoting community resilience (Beattie, 2023).
  - Economic sustainability:

    Ensuring that the current economic structures can function indefinitely without harm. This entails fostering sensible consumption, encouraging ethical trade, and upholding financial restraint (Beattie, 2023).

There are various connections between the Fourth Industrial Revolution (4IR) and sustainability, pertaining to the following:

  - Technological Advancement:

    By incorporating 4IR technology into sustainable development plans, problems with the environment, society, and the economy can be solved (Siekmann *et al*., 2023). Businesses may improve financial services, boost resource management, and encourage sustainable growth by utilising the transformative potential of 4IR (ASCIR, 2023).
  - Economic Growth:

4IR technologies, particularly in underdeveloped countries, can support long-term economic growth. By utilising 4IR technology, such countries (and businesses) can close the digital gap and achieve sustainable economic growth (UNIDO, 2021).

- Impact on the environment:

4IR innovations can lead a systems transformation across environmental and natural resource security objectives. Businesses can look at sustainable solutions to environmental problems by utilising 4IR technologies (PwC, 2017).

- Mitigating Climate Change:

4IR technologies can be used to combat climate change. The use of 4IR technologies, such as AI and IoT, can increase efforts to ensure the sustainability of the world and address climate change concerns (Suryadi *et al*., 2022).

- Eco-efficiency:

4IR changes based on digital and analytics technologies can supplement existing production techniques and green technology, boosting productivity and promoting sustainability. Organisations can achieve eco-efficiency by embracing 4IR-driven change, where sustainability and competitive excellence are intertwined (Betti *et al*., 2014).

In general, integrating 4IR technologies with sustainability can result in better resource utilisation, the optimisation of renewable energy, transparent supply chains, smart cities, and conservation activities. A more sustainable and resilient future can be achieved by utilising the promise of 4IR. It is important to carefully assess potential negative effects, such as electronic waste and higher resource consumption, before adopting 4IR technologies, even if they can enhance energy efficiency and have less environmental impact (de Andres Gonzalez *et al*., 2021). Incorporating life cycle evaluations and circular economy principles into a complete sustainability strategy will assist in reducing these risks and guarantee the ferrochrome industry's long-term survival (Gibson *et al*., 2021).

2.5.1. Regulatory and policy implications

Regulators and policymakers face new issues, given the speed of technological advancement and the growing interconnectedness of the systems and activities connected to the 4IR (Schwab, 2017). Developing appropriate legal frameworks, standards, and recommendations to address data privacy, cybersecurity, and technology transfer issues will be essential to create a stable and encouraging environment for using 4IR technologies in the ferrochrome industry (Bughin *et al*., 2018).

For the ferrochrome industry specifically, policies could focus on incentivising innovation through tax breaks or grants for companies investing in 4IR technologies. Regulatory frameworks could also be adjusted to facilitate smoother technology transfer and collaboration between stakeholders, including the government. Moreover, policies could improve energy efficiency and reduce environmental impact, aligning the industry with global sustainability goals. Importantly, labour policies may need to be updated to address the changing nature of work, including reskilling and upskilling initiatives for workers impacted by automation. A critical aspect of implementing these policies is engaging with labour unions for their input and approval. This ensures that technological enhancements are beneficial and socially accepted, thereby securing buy-in from all parties involved.

2.6. CASE STUDIES AND BEST PRACTICES FROM OTHER INDUSTRIES

The ferrochrome industry may not have many specific case studies of effective 4IR implementation. However, there are still lessons to be learned from similar sectors, including the steel and mining sectors, where 4IR technologies have been incorporated successfully. These examples can act as a guide for ferrochrome companies looking to implement comparable technology and operational techniques.

Considering best practices and lessons discovered from other industries when using 4IR technology in the ferrochrome business is crucial. Key suggestions include the following:

2.6.1. Developing a clear digital transformation strategy

The 4IR offers opportunities and challenges for ferrochrome producers. Given the complexity of the rapidly changing digital environment, a clearly defined digital transformation strategy is essential. Such a plan provides a roadmap for manufacturers to prioritise where to invest their money and resources so they may get the most out of technological improvements. By integrating this approach with broader corporate goals, businesses can ensure that their technical activities align with their vision and mission (Bughin *et al*., 2018). Additionally, this plan offers a unified framework that enables many teams and departments to cooperate toward 4IR integration. For ferrochrome producers, a well-designed digital transformation strategy essentially serves as a compass, guiding them through the 4IR maze and ensuring that each step is deliberate and well-coordinated.

2.6.2. FOSTERING A CULTURE OF INNOVATION AND CONTINUOUS IMPROVEMENT

Organisations must adopt a philosophy of continuous growth and change if they want to benefit from the technologies of the 4IR fully. This entails fostering an environment where innovative ideas are valued and everyone constantly seeks ways to improve existing processes. Companies may easily accept new technology and swiftly adapt to changes by prioritising innovation and continuing development. This strategy aids companies in keeping up with the quick speed of the modern world and preventing them from falling behind (Schwab, 2017). A company must constantly be willing to learn and adapt to succeed in today's tech-driven world. Organisations may successfully integrate 4IR technologies and cope with the rapid speed of change by fostering a culture that values innovation and continual improvement.

2.6.3. Collaborating with external partners and stakeholders

The latest information, skills, and resources required to spur innovation and maintain competitiveness in the 4IR era can be accessed by ferrochrome producers through collaboration with technology providers, research organisations, and other industry stakeholders (World Economic Forum, 2019).

Ferrochrome makers confront the challenge of not only keeping up with but also staying ahead in the race for innovation in the fast-evolving environment of the 4IR. Strategic partnerships are one of the best methods to accomplish this. These manufacturers may get cutting-edge solutions customised to their needs by collaborating with technology providers, ensuring they stay at the forefront of technical developments. Additionally, working with research institutes provides the added advantage of having access to in-depth studies and cutting-edge approaches, which can completely transform manufacturing processes. These partnerships also promote knowledge sharing, ensuring that ferrochrome producers are always up to date on the most recent market insights.

Collaborating with other industry players creates a symbiotic environment where common problems may be solved together. Businesses that manufacture ferrochrome can better manage the challenges of the 4IR era by combining their resources, knowledge, and experience. This will ensure sustainability and increased competitiveness in the global market.

2.6.3.1. Ensuring data security and privacy

Data has emerged as a core component of this revolution, driven by integrating 4IR technologies. Large-scale data collection, processing, and dissemination are inherent to 4IR technology. While the data-centric strategy has many benefits, it also presents severe privacy and data security issues. It's not just about guarding against unauthorised access or potential breaches; it's also about making sure that data is handled and used responsibly, especially when it comes to sensitive data. Businesses must use strong data security measures and cutting-edge encryption methods considering this (Chen *et al*., 2014).

Additionally, adherence to company, local and global data protection rules becomes crucial given the worldwide nature of data movement. These rules offer a legal framework to direct operations and frequently cover user permission, data retention, and rights to erasure. In summary, as enterprises utilise 4IR to its fullest potential, they must also prioritise data integrity, ensuring that it is safeguarded and used morally.

2.6.3.2. Lessons from other industries

The digital revolution, driven by advancements in artificial intelligence and other new technologies, has significant business consequences across all industries. A systematic and rigorous strategy is essential for businesses to realise this potential fully. The findings from McKinsey & Company's "Rewired in Action Case Collection" offer a thorough framework.

The three main aspects of the framework are strategy, capabilities, and change management. The framework highlights the value of inspiring leadership, developing a skilled workforce, embracing agility, and emphasising data as a crucial component. It also highlights the importance of having a strong change management approach to ensure that innovations are smoothly implemented and expanded throughout all business functions. Such insights can be extremely helpful for firms as they embark on this revolutionary path as they navigate the complex problems of the digital age.

The framework proposed by McKinsey & Company's "Rewired in Action Case Collection" is summarised below:

- Creating the Transformation Roadmap:

  CEOs and other senior leaders must envision the future of their company in the digital age, serving as a strategic foundation that emphasises the new capabilities required. Companies must develop transformation plans that target precise, important industry segments without creating significant disruptions (McKinsey & Company, 2023a).
- Building Your Talent Bench:

Digital excellence cannot be attained by relying just on outside resources. Internal digital and AI knowledge development is crucial. Leading companies create comprehensive talent plans centred on hiring the best candidates while fostering a thriving organisational culture (McKinsey & Company, 2023a).

- Adopting a New Operating Model:

A flexible operational framework is necessary to integrate and grow digital and AI technologies. Implementing such a framework is difficult since it impacts fundamental organisational structures and collaborative strategies (McKinsey & Company, 2023a).

- Technology for Speed and Distributed Innovation:

Teams should be able to continuously introduce digital and AI improvements thanks to the technology target. This calls for a dispersed technological environment that provides quick access to information, programs, and tools (McKinsey & Company, 2023a).

- Embedded Data Everywhere:

Data accessibility and quality are crucial to the usefulness of technological solutions. It is crucial to organise data for best utilisation meticulously. The objective is to provide teams with data resources that support innovation and decision-making (McKinsey & Company, 2023a).

- The Keys to Unlock Adoption and Scaling:

Encouraging widespread solution adoption among consumers and business users is difficult. A detailed approach to technological, procedural, and human factors is necessary, along with precise KPI monitoring (McKinsey & Company, 2023a).

2.7. SUMMARY OF KEY LITERATURE REVIEW FINDINGS

The 4IR has tremendous potential for the South African ferrochrome industry, opening a wide range of avenues to promote expansion, improve productivity, and support sustainability measures. Utilising technology like the Internet of Things (IoT), Artificial Intelligence (AI), robotics, and sophisticated analytics may significantly strengthen operational procedures, ensuring streamlined operations, lower overhead costs, and a stronger focus on sustainability.

Adoption of these technologies is not without difficulties, though. A substantial financial commitment is necessary given the sophisticated gear and technological infrastructure involved. The importance of human capital cannot be understated either. A qualified workforce capable of managing these technologies is required to implement 4IR in the ferrochrome sector successfully. To fully utilise the benefits of these breakthroughs, upskilling and ongoing training becomes crucial. Additionally, the regulatory environment must support innovation. The adoption of 4IR technologies must be supported and encouraged while assuring data security, privacy, and responsible technology transfer.

Case studies from other businesses, like the steel and mining industries, offer insightful information. Having a clear digital transformation plan, encouraging a culture of constant innovation, and prioritising engagement with external stakeholders for shared knowledge and resource pooling are all essential takeaways from their experiences. While 4IR's data-centric approach offers priceless insights for process optimisation, it also brings up data security and privacy issues. It becomes crucial to balance technology integration and moral data utilisation. Research from well-known consulting companies like McKinsey & Company highlights the strategic and operational changes required to succeed in this digital age. Not only must technology be adopted, but these changes must also be profoundly ingrained in the organisational DNA, affecting operational frameworks, people management, and leadership visions, among other things.

The literature research clarifies the present prospects and difficulties of 4IR technologies integration into the ferrochrome sector. However, a dynamic environment demands ongoing investigation and study.

First and foremost, thorough sector-specific investigations are required. While information from related industries might serve as a starting point, the difficulties and intricacies of the ferrochrome business in South Africa call for specialised study. This could entail conducting pilot projects using 4IR technologies to evaluate the short- and long-term effects.

It is also critical to regularly evaluate 4IR technologies' relevance to the ferrochrome sector as they develop and new developments appear. New methods and tools might provide answers to problems now being faced or make way for unanticipated opportunities.

The study of human capital is essential. Roles and skill requirements change along with technological advancements. Future research must concentrate on forecasting these developments so that the sector may prepare its staff appropriately. Research on developing efficient training courses specifically for the ferrochrome industry would be beneficial.

Finally, cooperation with international actors in the ferrochrome business can result in comparative studies, an awareness of best practices, and a standard grasp of issues. Such cooperative research projects can offer a more thorough understanding, ensuring that the ferrochrome industry in South Africa maintains its competitiveness on the international scene.

In conclusion, the 4IR offers the South African ferrochrome industry a previously unheard-of chance to address persistent issues while adding innovative solutions. A coordinated strategy integrating technical progress with human capital development, ethical considerations, and strategic foresight becomes crucial as the sector navigates this promising yet complex landscape. The industry will surely be able to maximise the promise of 4IR by learning from related industries and utilising global expertise, putting the industry on a path to sustainable growth and competitiveness.

This chapter, Chapter 2: Literature Study, synthesised the critical insights and frameworks discussed in the preceding chapter. It aims to summarise the existing body of knowledge, highlighting the most relevant theories, methodologies, and empirical findings that pertain to the Fourth Industrial Revolution and its impact on ferrochrome production. This summary sets the stage for the empirical investigation in Chapter 3, where these foundational concepts will be tested and explored. The shift from a literature-centric approach to a qualitative empirical inquiry marks a vital evolution in this research, allowing for a more detailed and context-sensitive understanding of the subject.

CHAPTER 3 - EMPIRICAL INVESTIGATION

3.1. INTRODUCTION

This Chapter serves as a critical component of this research, designed to address the primary and secondary objectives and the research question described in Chapter 1. The primary objective of this research was to explore the impact of the 4IR on a ferrochrome production plant in South Africa. The secondary objectives were to determine the plant's readiness for 4IR, explore 4IR’s future relevance, draw conclusions on 4IR's impact, and make recommendations. This study's overarching research question is: How can the 4IR impact a ferrochrome production plant in South Africa?

In summary, Chapter 3 focuses on the methodology, data collection, analysis, and interpretation processes. It provides a comprehensive overview of how the study was conducted, setting the stage for the findings, conclusions, and recommendations in Chapter 4.

3.2. RESEARCH APPROACH

A qualitative research method was employed, and eight interviewees who met this study's inclusion criteria specified in Section 1.7.2.5. were selected. All interviewees conformed to the criteria, providing a rich primary data source collected through semi-structured interviews. The target population comprised individuals with varying experience and roles within the ferrochrome industry. These participants were interviewed to generate insights informing the study's outcomes.

The qualitative interview guide was divided into two sections. The first section focused on demographic information, providing context and background to the respondents' perspectives. The second section delved into the core issues related to 4IR, its challenges, and its outlook in the ferrochrome industry.

Data analysis was conducted using Atlas.ti software. Transcriptions of the interviews were entered into an Excel spreadsheet, where coding was performed to identify themes and sub-themes, and word clouds were drafted. This facilitated a thorough interpretation of the data, contributing to the study's depth and breadth.

3.3. MEASURING INSTRUMENTS

An interview is one of the most valuable tools for collecting data when conducting qualitative research (Bryman *et al*., 2014:204). Semi-structured interviews promote detailed answers and encourage going off the topic to elaborate on the details while keeping the focus on the research topic (Bryman *et al*., 2014:224). In this study, there are specific topics and questions with a high interest in the participant's personal view; therefore, the primary data generated to achieve the objectives of this study was collected through a semi-structured interview protocol (see Appendix A). The topics and questions identified in the interview addressed the research question. The topics identified were based on existing literature and created by the researcher based on the literature consulted.

The interviews were recorded and transcribed. The interview consisted of two sections. Section A focused on the respondents' demographic information and their role in the company, and Section B focused on topics identified in the researcher's literature study. These sections were developed and aligned with the research objectives in mind. The primary objective of this research was to explore the impact of the 4IR on a ferrochrome production plant in South Africa. The secondary objectives were set: determining the plant's readiness for 4IR, exploring 4IR's future relevance, drawing conclusions on 4IR's impact, and making recommendations.

Section A aimed to collect demographic information from the interview participants. This information was necessary for the study to analyse any potential correlations between the impact of the 4IR and different demographic factors such as generation categories, workplace seniority/authority, and relevant experience. The researcher could identify potential response patterns or variations based on these factors by understanding the participants' demographics.

Section B, on the other hand, focused specifically on exploring the participants' knowledge, perceptions, and experiences related to the fundamental aspects of 4IR (artificial intelligence, machine learning, robots, self-driving vehicles, and the Internet of Things) and its integration into the ferrochrome industry. The questions in this section delved into various aspects such as familiarity with 4IR, the industry's progress in incorporating 4IR technologies, the perceived impact of these technologies on safety, profitability, and sustainability, the readiness of employees for changes associated with 4IR, challenges and changes expected in the industry, and opinions on the implementation of 4IR. This section aimed to gather rich qualitative data directly related to the research objective of examining the impact of 4IR on the ferrochrome production plant in South Africa

For this study, the researcher conducted semi-structured interviews to determine what they know of the 4IR, how the 4IR can impact the ferrochrome business in South Africa, and the possible limitations to a ferrochrome plant when trying to implement technologies associated with the 4IR.

3.3.1. Data saturation

Data saturation is a critical element in qualitative research, signifying the point at which no new information or themes emerge from the data. This study reached data saturation after the seventh interview, even though ten interviews were initially scheduled. This indicates that the information gathered by the seventh interview was sufficient to meet the research objectives and comprehensively address the research question concerning the impact of the 4IR on a ferrochrome production plant in South Africa.

To validate that saturation had been achieved, an eighth interview was conducted. I achieved data saturation after seven interviews, and using the “n+1 method”, the final confirming interview was number 8. This additional interview yielded no new themes or insights, confirming that data saturation had been reached with the seventh interview.

The fact that data saturation was achieved earlier than anticipated speaks to the richness and depth of the data collected and enhances the study's reliability. It suggests that the findings are likely an accurate representation of managerial perspectives on 4IR in the ferrochrome industry. This aligns well with the study's primary and secondary objectives, providing a robust foundation for drawing conclusions and making recommendations.

Moreover, achieving data saturation earlier also indicates that the participants, who are all from the same company and work closely together, share a common sentiment about the subject matter. This adds another layer of internal consistency and reliability to the study's findings.

3.4. TARGET POPULATION AND SAMPLING

The population of this study were managers in a ferrochrome smelting plant in the western limb of South Africa, Rustenburg. Managers typically have a job description that looks at the company's future and overall strategy to reach specific outcomes. This population will be able to address the research gap identified. The respondents were drawn from a database of managers working for ferrochrome smelting plants in the western limb of South Africa, Rustenburg. In addition, the researcher is an employee at a ferrochrome smelting company in South Africa. Therefore, the researcher utilised his working network to get permission to access data sources.

For this study, the inclusion criteria were:

- Managers working at a ferrochrome smelting company in the western limb of South Africa.
- Male and female respondents were included.
- Different management levels were included if they work for a ferrochrome smelting plant in the western limb of South Africa.
- Managers of all ages were included.

The exclusion criteria for this study were:

- Non-management employees working at a ferrochrome plant.

- Management employees in the beneficiation sector who do not work at a ferrochrome smelter.
- Management employees working at a ferrochrome smelter in the eastern limb of South Africa.

The sample size was limited by the number of managers in the company, the willingness to participate, and non-responsive participants also influenced the sample size. The sample size was guided by (Vasileiou *et al*., 2018:2):

- Data saturation: Adding more respondents did not add new information.
- Data richness: Samples with rich data and information could require fewer samples.

3.5. DATA COLLECTION AND ANALYSIS

The interviews were conducted until data saturation was achieved. The interviews were concluded with participant eight. The interviewer noticed a recurring pattern in the responses, indicating that a saturation point had been achieved. All eight individuals approached met the inclusion criteria and were subsequently interviewed. The analysis was based on these eight discussions.

The researcher identified respondents within the organisation and explained the same terms and conditions agreed upon by all respondents. Respondents were contacted via email. The email asked respondents for their participation, presented the purpose of the study, including ethical considerations, consent letters (see Appendix C), and indicated that an interview would not take more than 40 minutes. The consent letter was attached to be signed by the respondent. The interview was facilitated through an online platform such as Teams or in person, depending on the respondents' preference.

The interview process comprised the following phases:

- Interview formulation: The research problem was carefully examined whereafter questions were formulated to produce the best findings. Comprehending the data acquired and identifying people who may provide pertinent insights was essential. The questionnaire underwent a pilot test once the questions were created.

- Interview preparation: Ensure the data is correct and accurate before the interview. Interviewing calls for practising the questions and interview process. The recording device's operation was checked before the interview started.
- The interview: It is crucial to introduce and clarify the study's aim and inform the respondents of the goals of the questions. The interviewer's language and terminology must be clear to the respondents. The interviewer should manage the time. Finding the answers to all the questions within a suitable amount of time is crucial.
- Post-interview: Following the interview, data must be analysed honestly and accurately to reflect the topics covered.

This interview used completely novel, authentic questions that were informed by the broad literature review in Chapter 2. The researcher could find no pre-existing questionnaires that were pertinent to this study. It's critical to ask in-depth, probing questions during the interview process rather than directing the respondents toward predetermined responses.

The interest and willingness among managerial staff to engage in discussions about the 4IR and its potential impact on the ferrochrome production plant in South Africa indicates the seriousness of the research focus. The strong participation rate lends credibility to the study and its findings, suggesting that the data collected represents managerial perspectives within the company.

The interviews also positively impact the study's primary and secondary objectives. With a diverse range of managerial roles represented, the study is well-positioned to offer a comprehensive understanding of the readiness, relevance, and potential impact of 4IR technologies in the ferrochrome production sector. The senior profile of the interviewees contributes to the data richness of the primary data collected. This will be particularly useful for drawing conclusions and recommending how 4IR could affect the ferrochrome production plant in South Africa.

The participants' experience serves as a robust foundation for the study, enhancing the reliability and validity of the research findings.

Thematic analysis was used to find specific themes in the primary data that can be linked to the research question (Saunders *et al.*, 2019:650). This process involved transcribing the interviews through software. The data was transcribed from the original voice recordings into a printable (word) format. Once all data have been transcribed, the data analysis commenced. The data analysis was done through coding. Coding the data was necessary for the researcher to make sense of, analyse, and conclude the findings from the data (Saunders *et al.*, 2019:650).

In qualitative research, recognising themes is essential during and after data collection. These themes can be found by examining field notes. Some analysis techniques include counting frequently used words, comprehending local categories, and examining keywords in context. Contrasting responses, spotting differences, and determining the causes of inconsistencies are crucial. Researchers should review the data if it seems to be missing information to fill in the gaps. New themes may emerge after several readings of the text. Comparing primary research with secondary data thoroughly analyses the obtained data.

The primary data collected from the semi-structured interview protocol was analysed employing thematic analysis and word clouds. Software tools were used to transcribe and encode the data. A software package named Atlas.ti was used to conduct the thematic analysis of the gathered data.

3.6. RESEARCH RESULTS: DEMOGRAPHIC INFORMATION

Demographic data was collected to determine potential correlations between the impact of the 4IR and various demographic factors such as age groups, management levels, and years of experience in the ferrochrome industry and to attempt to identify any gaps between the managerial hierarchy. This information was crucial for identifying response patterns or variations based on these factors, which could offer additional layers of insight into the study's primary research questions. Section A of the semi-structured interview protocol captured the demographic information. Respondents were asked to report on the following:

- Age group: Categorised into Baby Boomer, Generation X, Generation Y, and Generation Z to understand generational perspectives on 4IR.
- Management level and years of experience: To gauge the depth of industry knowledge and decision-making authority in the context of 4IR.
- Job title and brief job description: To understand the role and responsibilities of the respondents within the ferrochrome industry, which could influence their perspectives on 4IR.

The following sections will comprehensively analyse the demographic data, breaking down the responses by each category and examining how these demographic factors might correlate with perceptions and understandings of 4IR in the ferrochrome production sector.

3.6.1. Age group

During the semi-structured interviews, participants were asked to disclose their birth years, which were subsequently used to classify them into generational brackets. This classification examines whether generational viewpoints have a bearing on the readiness, relevance, and potential impact of the Fourth Industrial Revolution (4IR) on ferrochrome production plants in South Africa.

Breakdown of Generational Categories as visually presented in Figure 7 (Age Group) and Figure 8 (Generation Categories):

- Baby Boomer (1946 - 1964): One participant, born in 1961
- Generation X (1965 - 1980): Five participants, with birth years ranging from 1970 to 1979
- Generation Y (1981 - 1996): Two participants, born in 1984 and 1985
- Generation Z (1997 - Ongoing): No participants

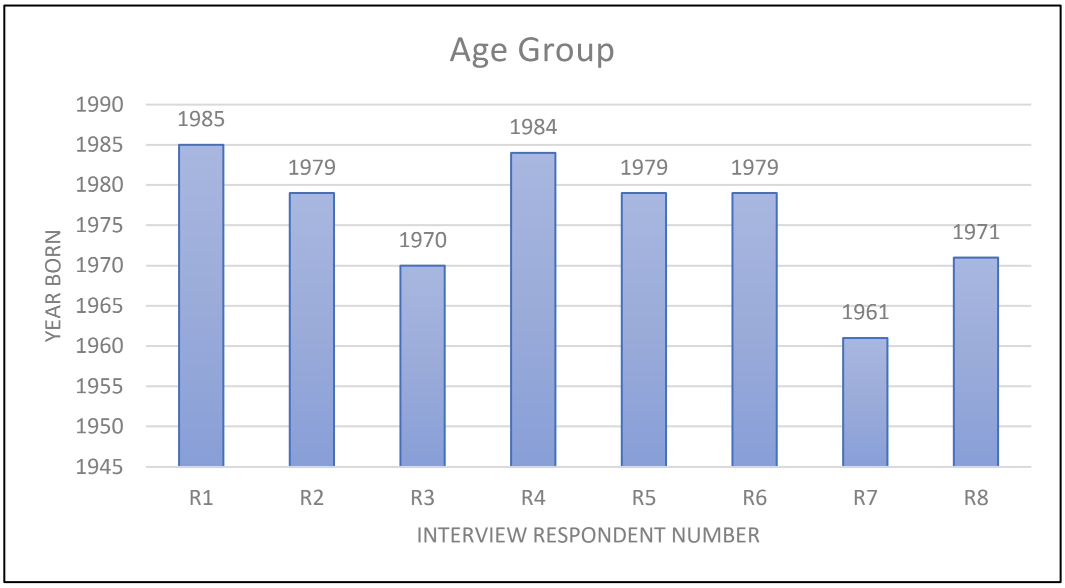

Figure 7: Age Group

(Source: Own compilation)

The Generation Categories in Figure 8 visually present the following results.

- Baby Boomer: One, 12%
- Generation X: Five, 63%
- Generation Y: Two, 25%
- Generation Z: Zero, 0%

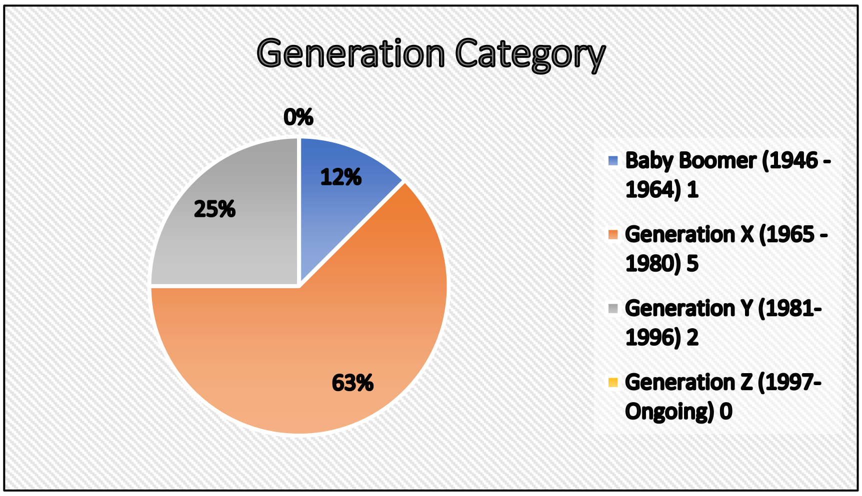

Figure 8: Generation Category

(Source: Own compilation)

Most respondents (63%) are Generation X, making up 5 out of the 8 participants. This dominance suggests that Generation X is likely the most influential group in shaping the ferrochrome industry's approach to 4IR technologies. One participant was a Baby Boomer (12%), and two were from Generation Y (25%). Notably, there were no participants from Generation Z.

The age span of the respondents, calculated based on the current study year of 2023, ranged from 38 to 62 years, with an average age of 47 years.

Given the generational diversity, particularly the strong presence of Generation X, this study aims to delve into how each age group perceives and understands the implications of 4IR on the ferrochrome sector. This will provide valuable insights into generational attitudes toward technological innovation, automation, and data-centric operations within the industry.

The lack of Generation Z representation could signify their limited presence in managerial roles or insufficient industry experience, making them less suitable candidates for this study, which adds to the participants' knowledgeability.

This demographic layer will add depth to the study's analysis, aiding in achieving the research objectives concerning the impact and readiness for 4IR in South Africa's ferrochrome production industry.

3.6.2. Seniority and authority

The participants were categorised based on their level of seniority within the organisation to understand the influence of managerial hierarchy on the perception and implementation of the 4IR in ferrochrome production plants in South Africa.

Figure 9 shows the interviewees' hierarchy in the company organogram.

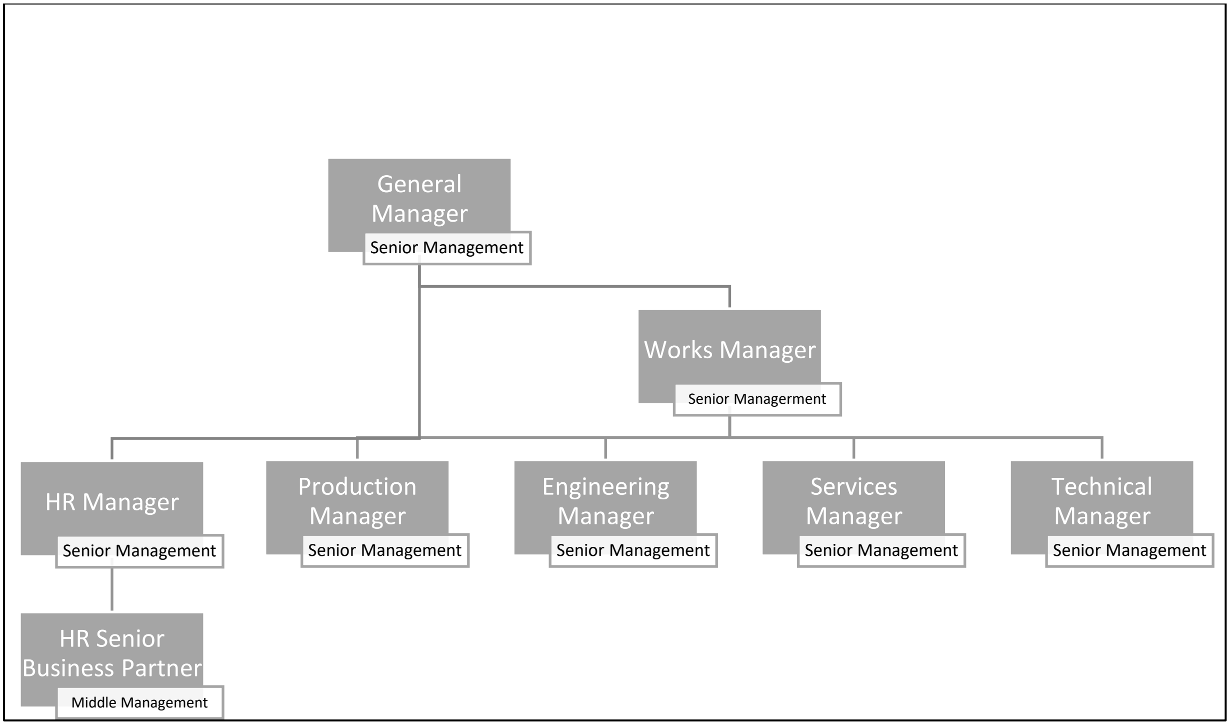

Figure 9: Company Organogram for Participants

(Source: Own compilation)

Breakdown of Seniority Levels as visually presented in Figure 10 below:

- Senior Management: 7 participants
- Middle Management: 1 participant
- Lower Management: No participants

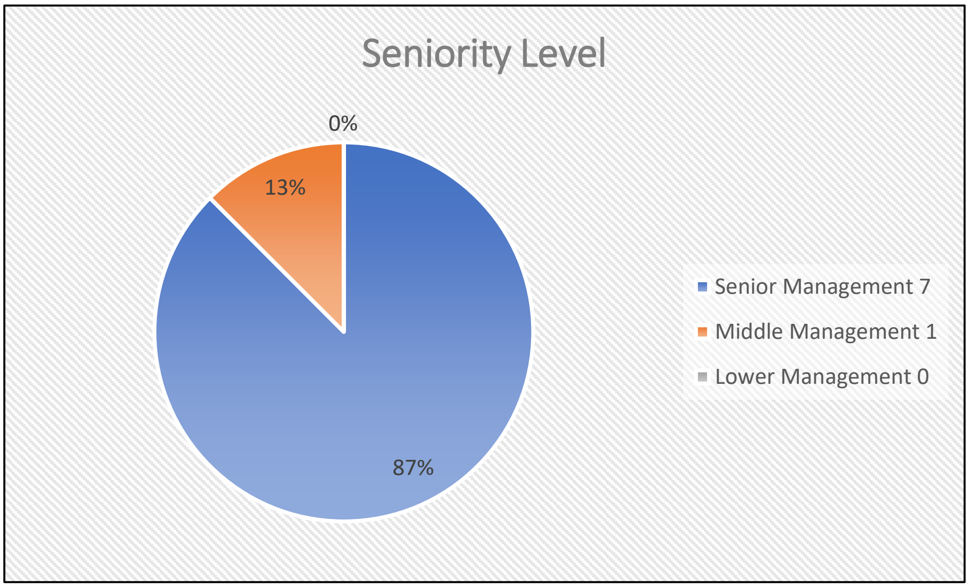

Figure 10: Seniority Level of Interviewees

(Source: Own compilation)

The overwhelming majority (87%) of respondents, 7 out of 8, hold positions in senior management. This could indicate that the perspectives gathered are primarily from decision-makers who significantly influence the strategic direction of their organisations, especially in relation to 4IR technologies and processes.

Only one participant was from middle management (12%). The absence of lower management in the participants could suggest that the study's focus is more aligned with strategic decision-making rather than operational or tactical levels.

The dominance of senior management participants is particularly relevant for this study as it aims to explore the readiness and potential impact of 4IR on ferrochrome production plants. Senior managers are often the individuals who are influencers in decision-making. They also make critical decisions about technological adoption, making their insights invaluable for achieving the research objectives.

Given that most respondents are from senior management, the study is well-positioned to address its primary and secondary objectives, including assessing the readiness for 4IR implementation and exploring its relevance and impact on the ferrochrome industry in South Africa. The insights from these senior leaders will be crucial in drawing conclusions and making recommendations on how the 4IR could shape the future of a ferrochrome production plant in South Africa.

This seniority data will serve as an additional layer in the study's multi-faceted analysis, enriching the understanding of managerial attitudes and strategic approaches to 4IR in the ferrochrome production sector.

3.6.3. Industry related experience

The study gathered data on the years of experience each respondent has in the industry. This was done to gauge the depth of their understanding and their capacity to make informed decisions related to the 4IR in the ferrochrome production sector in South Africa.

A breakdown of years of experience is presented visually in Figure 11.

- Range: 2 to 28 years
- Average: Approximately 16 years
- Special Note: One respondent had only two years in the ferrochrome industry but had an additional 40 years of experience in mining.

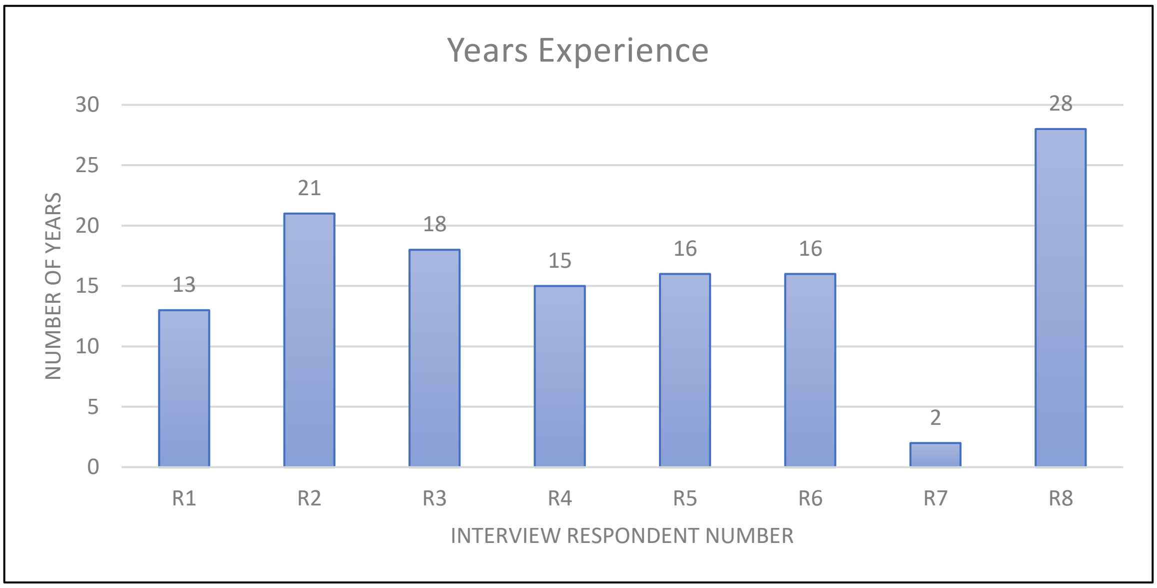

Figure 11: Years Experience

(Source: Own compilation)

The years of experience among the respondents varied widely, ranging from as little as two years to as much as 28 years. Their average years of experience were 16 years, indicating a generally high level of industry familiarity among the participants.

The respondent with only two years of experience in the ferrochrome industry is noteworthy because of an additional 40 years spent in the mining sector. This extensive background in a related field could offer a unique perspective on the adaptability and transferability of 4IR technologies between sectors.

The high average years of experience among respondents could indicate a deep-rooted understanding of the industry's challenges and opportunities. This is crucial for the study's aim to explore the impact of 4IR on ferrochrome production.

Additionally, the high average years of experience suggest that the ferrochrome industry is mature, with key stakeholders having been with the company for many years. This maturity has its advantages and disadvantages. On the one hand, it implies a deep understanding and expertise in the field, which is invaluable for making informed decisions. On the other hand, a mature industry can sometimes be resistant to change, which could pose challenges in adopting new technologies and practices associated with 4IR (Kruger & Steyn, 2023).

The diversity in years of experience can provide a multi-dimensional view of how 4IR is perceived across different career stages. This is particularly relevant for the study's secondary objectives, such as determining the readiness of ferrochrome production plants for 4IR and exploring its future relevance.

The insights gained from these experienced professionals will be instrumental in addressing the research objectives as described in section 1.3 of the study, drawing meaningful conclusions, and making informed recommendations on the role and impact of 4IR in the ferrochrome industry in South Africa.

This experience data will add another layer to the study, enriching the analysis and providing a more nuanced understanding of how industry experience influences perceptions and attitudes towards 4IR.

3.6.4. Job title and job description

Respondents were asked to state their job titles in the semi-structured interviews. This information is crucial for understanding the level of influence and decision-making power each respondent has within their organisation, particularly in matters related to the 4IR and its impact on the ferrochrome industry.

The job titles of the respondents are presented in Table 2.

Table 2: Respondent Designation

Interviewee	Job Title
R1	Technical Manager
R2	Works Manager
R3	Furnace Production Manager
R4	Engineering Manager
R5	Services Manager
R6	Senior HRD Business Partner
R7	HR Manager
R8	General Manager

(**Source:** Own compilation)

The diversity in job titles among the respondents is noteworthy. It suggests that the study captures a broad range of perspectives from different functional areas within the ferrochrome production plant. This is particularly relevant to the study's primary objective, which is to explore the impact of 4IR on a ferrochrome production plant in South Africa.

The range of job titles also indicates that the study includes voices from both technical and managerial roles, as well as from human resources. This is crucial for a well-rounded understanding of the readiness and relevance of 4IR technologies in the ferrochrome industry. The job descriptions suggest that the study included a broad range of perspectives from different backgrounds and experiences within the ferrochrome production plant.

Including various job titles and descriptions will enrich the study's findings, offering a more comprehensive view of how different roles within the organisation perceive and are preparing for the impact of 4IR. This will be invaluable for achieving the study's secondary objectives, such as making recommendations on the impact of 4IR on the ferrochrome production plant in South Africa.

This job title and job description data will serve as another layer in the study, providing context for the more complex research questions and helping interpret the findings in more detail.

The job descriptions of all eight interview respondents are illustrated in a word cloud (see Figure 12). Many interview respondents feel responsible for a plant, operations, HR innovation, and provide training.

Figure 12: Word Cloud on Job Description

(Source: Own compilation)

3.7. RESEARCH RESULTS: INTEGRATION OF THE 4IR INTO THE FERROCHROME INDUSTRY

This chapter explores the complicated relationship between the 4IR and the ferrochrome industry. The focus is on understanding how the industry adapts to the rapid technological advancements of 4IR. Data was collected through Section B of the semi-structured interview protocol. Section B focused on exploring the participants' knowledge, perceptions, and experiences related to the fundamental aspects of 4IR (artificial intelligence, machine learning, robots, self-driving vehicles, and the Internet of Things) and its integration into the ferrochrome industry.

The questions in Section B delve into various aspects such as familiarity with 4IR, the industry's progress in incorporating 4IR technologies, the perceived impact of these technologies on safety, profitability, and sustainability, the readiness of employees for changes associated with 4IR, challenges and changes expected in the industry, and opinions on the implementation of 4IR. This section aims to gather rich qualitative data directly related to the research objective of examining the impact of 4IR on the ferrochrome production plant in South Africa.

The qualitative data from the semi-structured interviews was analysed using software tools to transcribe and encode the data. A software package named Atlas.ti was used to conduct the thematic analysis of the gathered data.

The interviewees' responses and interview questions were coded as described below:

Interview Identification - RX:

- This code serves as a general template for labelling responses from any interviewee. The "X" is a placeholder for the interviewee number. For example:
    - R1: Interviewee #1 Response
    - R8: Interviewee #8 Response

Question Identification: SECY_QZ:

- This general code categorises responses to any question within any section of the interview protocol. "Y" represents the section (either A or B), and "Z" represents the question number within that section. For example:
    - SECA_Q1: Section A, Question #1

- SECB_Q17: Section B, Question #17

This coding system allows easy tracking and categorisation of each interviewee's data. An overview of the main theme allocation and sub-themes are described below. The themes and sub-themes are discussed in detail in Section 3.7.1 – 3.7.6 of this study.

Theme 1: Understanding of 4IR

- The sub-themes are illustrated in Figure 13 and include the following:
  - Artificial Intelligence, Automation and self-driving vehicles, Machine Learning, Familiarity with 4IR, Big Data, Internet of Things, and Robots.
- Related questions: SECB_Q4, SECB_Q5

Theme description: This theme aims to gauge the participants' familiarity and understanding of the term "Fourth Industrial Revolution" (4IR) and its implications.

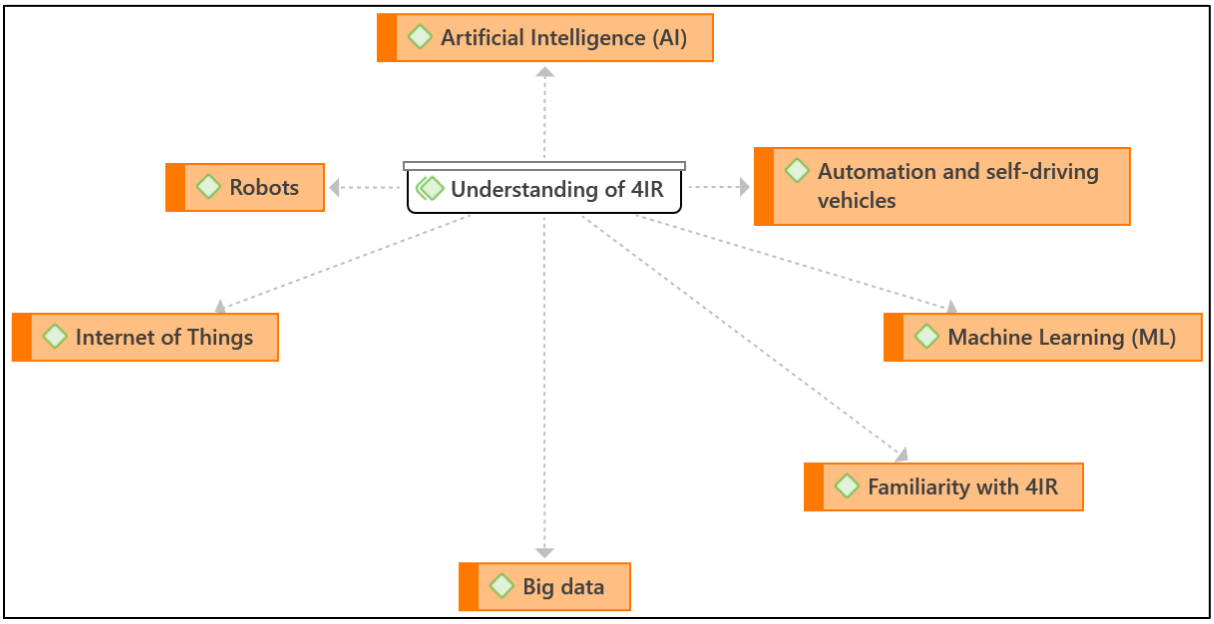

Figure 13: Theme 1 - Understanding of 4IR Network Diagram

(Source: Own compilation)

Theme 2: Industry Progress in 4IR

- The sub-themes are illustrated in Figure 14 and include the following:
  - Robots and automation, Digitalisation (AI and ML), Significant advancement of 4IR tech, Manual process, Limited advancement of 4IR tech, Financial constraints, Limited AI and ML capabilities, Moderate advancement of 4IR tech, Industry constraints.
- Related questions: SECB_Q6, SECB_Q11, SECB_Q12

Theme description: This theme focuses on the extent to which the ferrochrome industry, locally and globally, has made progress in incorporating the fundamental aspects of 4IR.

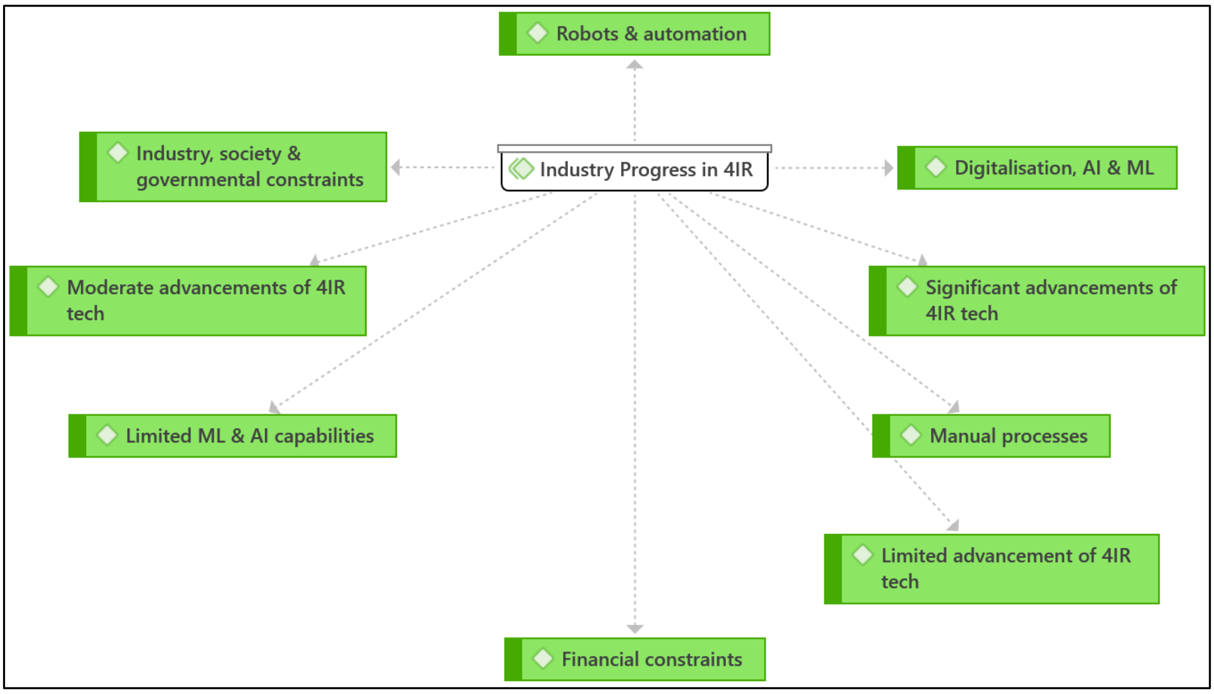

Figure 14: Theme 2 - Industry Progress in 4IR Network Diagram

(Source: Own compilation)

Theme 3: Industry Challenges and 4IR's Impact on Safety, Profitability, and Sustainability

- The sub-themes are illustrated in Figure 15 and include the following:
  - Volatile commodity prices, Challenges can be overcome, Electrical supply and cost, Positive impact on sustainability, Positive impact on profitability and safety, Lack of skills, and volatile regulations.
- Related questions: SECB_Q7, SECB_Q10

Theme description: This theme explores the perceived impact of 4IR technologies on the ferrochrome industry's safety, profitability, and sustainability.

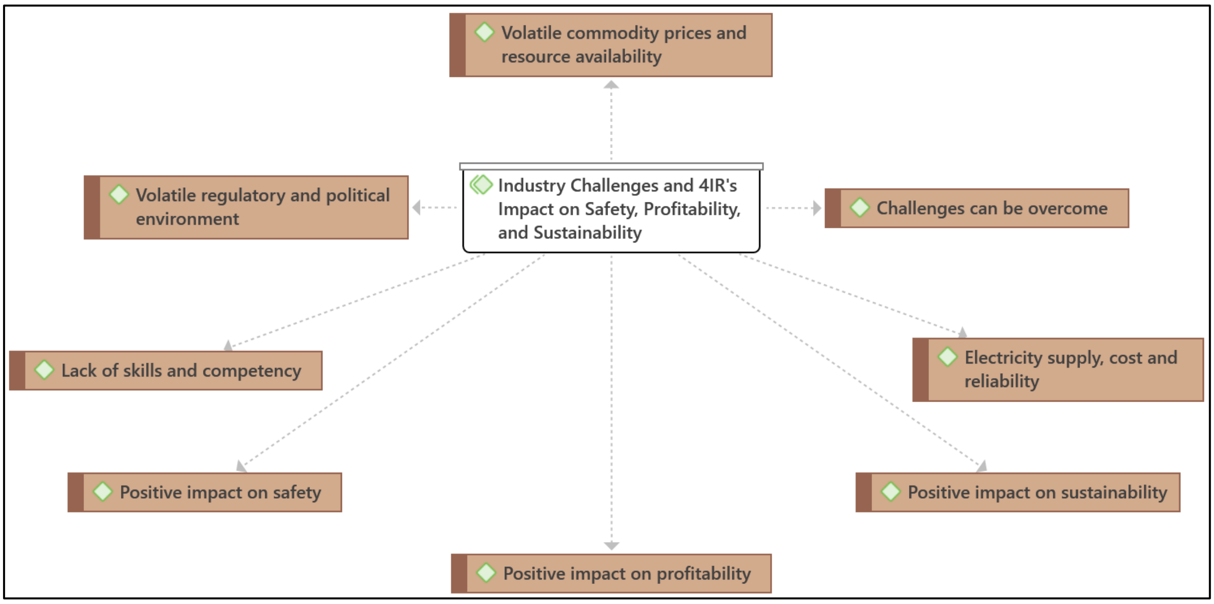

Figure 15: Theme 3 - Industry Challenges and 4IR's Impact on Safety, Profitability, and Sustainability Network Diagram

(Source: Own compilation)

Theme 4: Optimism and Readiness for 4IR Implementation

- The sub-themes are illustrated in Figure 16 and include the following:
  - 4IR implementation will be expensive, 4IR implementation will be affordable, Employees open to change and development, Capital will be available, Employees not open to change, and In support of 4IR.
- Related questions: SECB_Q8, SECB_Q9, SECB_Q15

Theme description: This theme explores the participants' level of optimism and readiness for embracing the changes associated with 4IR. It delves into the perceived ease of securing the necessary financial resources and gauges the willingness of employees to undergo training and development for 4IR technologies.

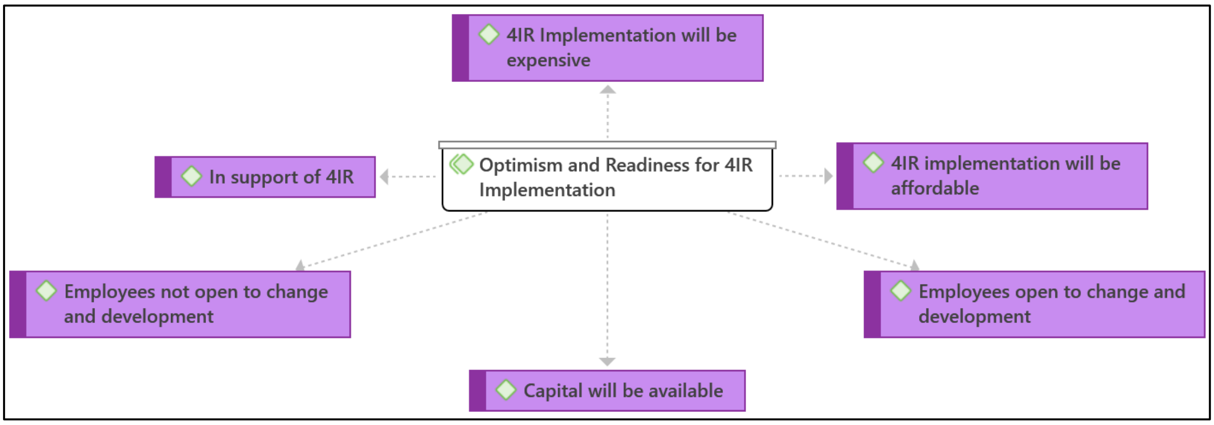

Figure 16: Theme 4 - Optimism and Readiness for 4IR Implementation Network Diagram

(Source: Own compilation)

Theme 5: Challenges and Success Factors for 4IR Implementation

- The sub-themes are illustrated in Figure 17 and include the following:
  - Reskill, upskill and training of employees, FeCr economic outlook, Society and infrastructure constraints, Data quality and validity, Competency and understanding of 4IR, Employee buy-in, Funding, Regulatory policies.
- Related questions: SECB_Q13, SECB_Q17

Theme description: This theme identifies the challenges and critical factors that would influence the successful implementation of 4IR in the ferrochrome industry.

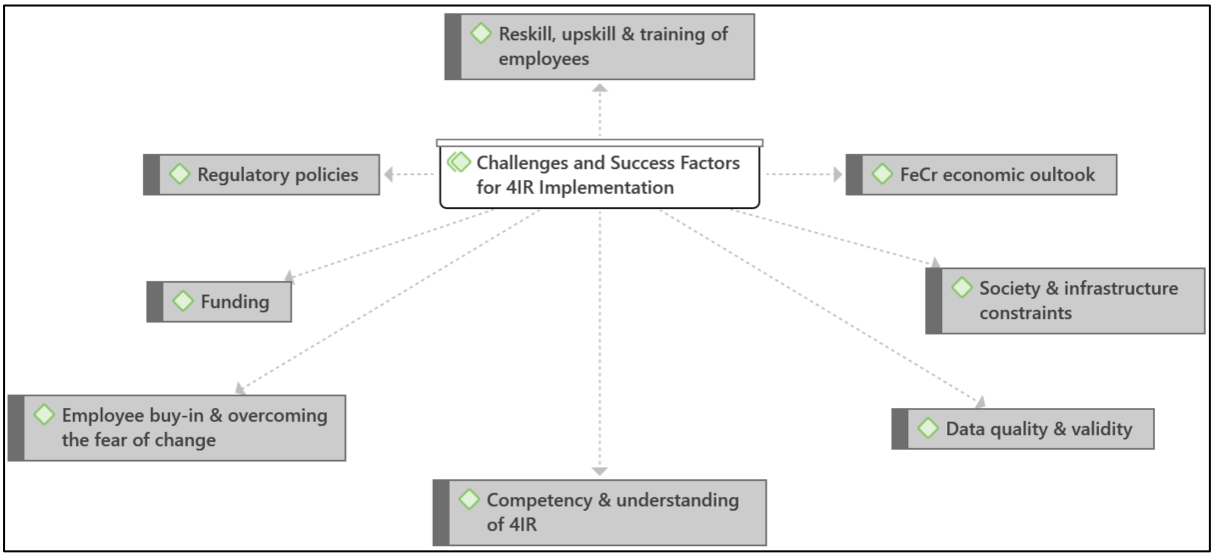

Figure 17: Theme 5 - Challenges and Success Factors for 4IR Implementation Network Diagram

(Source: Own compilation)

Theme 6: Future Outlook

- The sub-themes are illustrated in Figure 18 and include the following:
  - Automation, Improved environmental compliance, Short-term (5Y) operation, Reduced cost of production, Long-term (10Y) closure, Improved process efficiency, Increased profit, Head count reduction, Improved employee skills and competency, Improved safety, Long-term (10Y) operational, Remote working, and short-term (5Y) closure.
- Questions: SECB_Q14, SECB_Q16

Theme description: This theme examines the expected changes in the ferrochrome industry with full 4IR implementation and considers the industry's future if 4IR is not implemented.

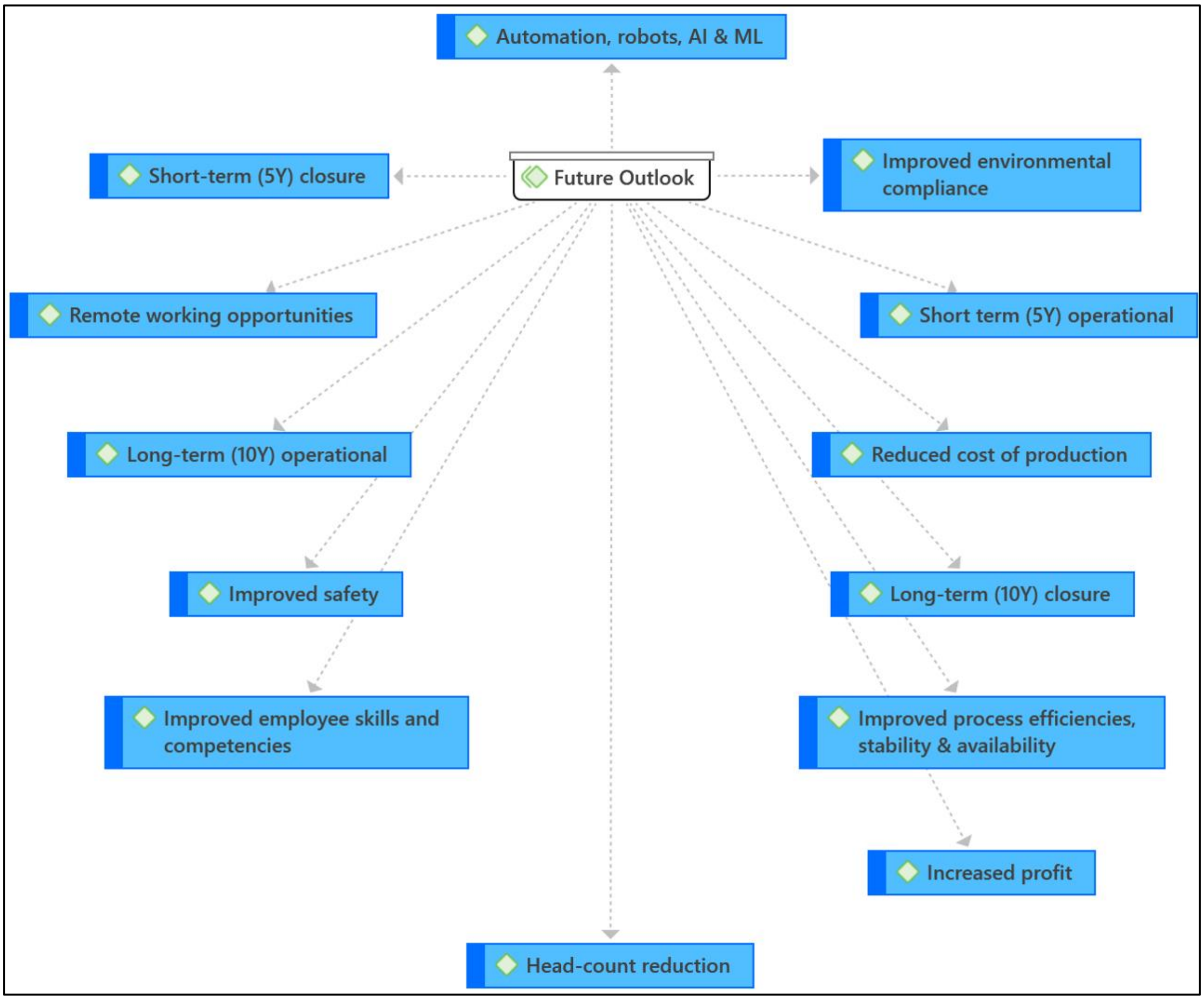

Figure 18: Theme 6 - Future Outlook Network Diagram

(Source: Own compilation)

3.7.1. Understanding of 4IR

This theme explores the participants' familiarity and understanding of the term 4IR and its implications. The focus is mainly on the ferrochrome industry, where the integration of 4IR technologies could be industry-transformative. Despite a general familiarity with the term, a noticeable gap exists in understanding its practical applications within the industry. It appears that the gap is a lack of technical understanding and a lack of strategic direction and initiative for implementing 4IR in the ferrochrome industry. The general awareness of 4IR terms without a deep understanding of their practical application in the industry suggests a superficial engagement with the concept. This is strengthened by a lack of clarity on where to begin the implementation process, indicating an absence of strategic planning and leadership.

Moreover, from the interviews, there seems to be an expectation that the "problem will solve itself". This reflects a passive approach and possibly a lack of urgency or understanding of the critical nature of 4IR adoption for the industry's future. This could be particularly concerning given the numerous challenges the ferrochrome industry faces, from economic pressures to sustainability concerns.

The gap seems to be a complex interplay of cognitive, strategic, and perhaps even cultural factors hindering the effective adoption of 4IR technologies in the ferrochrome industry. This gap must be addressed through targeted education, strategic planning, and perhaps a cultural shift towards proactive innovation and change management.

This lack of depth could hinder the effective implementation of 4IR technologies in the ferrochrome sector.

The sub-themes are tabled in Table 3 below and discussed further in sections 3.7.1.1 and 3.7.1.7.

Table 3: Understanding of 4IR Sub-Theme Frequency

Sub-Theme	Frequency
Familiarity with 4IR	8
Artificial Intelligence (AI)	7
Automation and self-driving vehicles	6
Machine Learning (ML)	5
Robots	5
Big data	4
Internet of Things	3

(Source: Own compilation)

The theme of “Understanding of 4IR” reveals that while there is general familiarity with the term and its associated technologies among the respondents, there is a significant gap in understanding its practical applications, especially within the ferrochrome industry. This suggests more targeted educational and training initiatives are needed to bridge this gap. As mitigating plans, Malaysia has launched a national 4IR policy with four main goals: educating citizens on 4IR, enhancing digital infrastructure, updating regulations to keep pace with technological changes, and speeding up the adoption of 4IR technologies (Suryadi *et al*., 2022). This is a common factor identified in the literature as well.

3.7.1.1. Familiarity with 4IR and the associated technologies

The term 4IR is known generally among the respondents, but the depth of understanding varies significantly. This is a crucial point, as familiarity does not necessarily translate into comprehension or the ability to implement 4IR technologies effectively. The quotes by R2, R8 and R7 also supports this:

- (R2) *“The answer is yes, I am familiar with the Fourth Industrial Revolution terminology.*”
- (R8) *“I think I am. I think everybody's got a perception of what it is.”* (R8)
- (R7) *“Yes, I am.”*

The term 4IR is familiar to most respondents, but there is an apparent lack of depth in understanding its practical implications, particularly in the ferrochrome industry. This could suggest an urgent need for targeted educational initiatives to bridge the gap between general awareness and practical application within the industry.

3.7.1.2. Artificial Intelligence (AI) and Machine Learning (ML)

Artificial Intelligence and Machine Learning are mentioned often in the context of data management and automation. However, the focus here is to understand how the respondents perceive these technologies in terms of their potential applications and limitations within the context of the ferrochrome industry. The quotes by R1, R3 and R8 also supports this:

- (R1) *“Fourth Industrial Revolution is how do you track it? How do you manage it? How do you gather information on it?”*
- (R3) *“4IR is to do with artificial, computers is to do with expert systems.”*

- (R8) *“You can actually simulate, you know, you can make decisions, you can write logarithms, and you can use that data so that you create artificial thinking.”*

The respondents seem to associate AI and ML primarily with data management and decision-making. However, there is a noticeable lack of detailed understanding or discussion about explicitly applying these technologies to the ferrochrome industry. This indicates a need for more in-depth exploration and education on these subjects.

In a ferrochrome smelter, AI and ML could be particularly transformative in optimising the two major cost drivers: raw material consumption and electricity usage. By employing AI algorithms to analyse real-time data, smelters can achieve more precise control over raw material inputs and energy consumption. This leads to improved efficiencies, reduced waste, and cost savings. Machine learning models can also predict equipment failures and optimise maintenance schedules, enhancing operational efficiency. Therefore, the application of AI and ML extends far beyond data management to impact the bottom line directly.

While AI and ML hold immense potential for optimising raw material and electricity usage in a ferrochrome smelter, it's worth noting that these technologies have not yet been implemented with significant success in the industry. However, a few pioneering projects aim to explore the practical applications of AI and ML in this context. Despite the lack of widespread adoption, these initiatives signify a growing recognition of the need to harness advanced technologies for operational efficiencies. Therefore, the industry appears to be in the early stages of what could be a transformative journey.

3.7.1.3. Automation and self-driving vehicles

Automation is discussed frequently in the context of labour reduction and efficiency. However, the conversation often remains superficial, lacking an in-depth exploration of how automation technologies could be specifically beneficial or detrimental to the ferrochrome industry. The quotes by R1, R6 and R7 also supports this:

- *(R1) “It's basically the next step. So, you can automate something and after automation, Fourth Industrial Revolution.”*

- *(R6) "It's leading to automation and reduction of people in the workforce where we're going to rather have machinery doing the jobs that people have been identified to do."*
- *(R7) "The Fourth Industrial Revolution or artificial intelligence, as I understand it, goes about automation, making processes easier via automation and processes that are streamlined in terms of the artificial intelligence process."*

While automation is a topic that garners attention, the discussion among respondents is often limited to generalities. There is a lack of specific dialogue about how these technologies could be tailored to meet the unique needs and challenges of the ferrochrome industry. This suggests a need for more focused discussions and perhaps case studies to explore the practical applications of automation in this specific industrial context.

Automation and self-driving vehicles could be considered low-hanging fruit for 4IR adoption within the ferrochrome industry. These technologies promise to elevate safety standards by removing humans from high risk areas and aim to enhance product quality by reducing human error. While the current implementation has been somewhat limited, several pilot projects are in the pipeline to explore these technologies' practical utility. This suggests a burgeoning recognition of automation's potential to address the industry's safety and efficiency concerns.

3.7.1.4. Big data

Big data is often cited as a cornerstone of 4IR, particularly for its role in analytics and decision-making. However, the respondents seem to lack a nuanced understanding of how big data could be leveraged within the ferrochrome industry for optimal benefits. The quotes by R1, R2 and R8 also supports this:

- *(R1) "It's about having information available at our fingertips or on your computer, on systems, readily available."*
- *(R2) "Advanced process control, data-driven solutions*."
- *(R8) "4IR is like a data revolution for me."*

The concept of big data is understood generally among the respondents, but its specific applications within the ferrochrome industry remain unclear. This suggests a need for more targeted training and perhaps workshops to explore how big data can be utilised effectively for various operational aspects within the industry.

Big data and analytics have the potential to be game changers in the ferrochrome industry, given the multitude of parameters that require meticulous management. Integrating big data with AI and ML enables the industry to achieve enhanced decision-making and optimise efficiencies, particularly in controlling key cost drivers like raw materials and electricity. While the technology is not yet widely adopted, several pilot projects are underway to explore its capabilities, indicating a growing interest in leveraging big data for industry improvement.

3.7.1.5. Internet of Things (IoT)

The Internet of Things (IoT) is another term that appears to be familiar to the respondents. However, the depth of understanding about integrating the IoT into the ferrochrome industry's existing systems is lacking. The quotes by R1, R2 and R4 also supports this:

- (R1) *"It's about having information available at our fingertips or on your computer, on systems, readily available."*
- *(R2) "So according to what I understand, it's the internet-based technology-driven solutions."*
- *(R4) "Fourth industrial revolution is internet-driven."*

While IoT is acknowledged as a component of 4IR, the respondents did not delve into its specific applications within the ferrochrome industry. This indicates a gap in understanding that could be filled through more focused educational initiatives or pilot projects within the industry.

The IoT holds significant promise in the ferrochrome industry, particularly for enhancing safety and equipment monitoring. Live data from human health parameters to machinery monitoring can be collected and analysed, offering real-time insights for better decision-making. Although the technology is still in the early stages of implementation, a few pilot projects are underway to explore its potential. The primary challenge lies in establishing a reliable Wi-Fi infrastructure, making IoT a low-hanging fruit for 4IR adoption in the industry.

3.7.1.6. Robots

Robotic technology is often associated with automation, but the respondents did not provide much detail on how robots could be utilised specifically within the ferrochrome industry. The quotes by R1, R4 and R5 also supports this:

- *(R1) "It's basically the next step. So you can automate something and after automation, Fourth Industrial Revolution."*
- *(R4) "Fourth industrial revolution is internet-driven, technology-driven."*
- *(R5) "I think 4IR has to do with technology advancement, robotics, as well as machines that are programmed and learned and taught to advance the way we do things in this current era."*

Robots are generally understood as a part of the automation process, but the respondents did not offer insights into their specific applications within the ferrochrome industry. This suggests that there is room for more in-depth discussions and perhaps feasibility studies to explore the role of robots in this industry.

Robots offer transformative potential in the ferrochrome smelting industry, particularly in replacing manual processes and human-operated machines. The primary advantage lies in enhancing safety by removing workers from hazardous environments and improving product quality through minimising human errors. Successful implementations have been observed in post-tap-hole machines, including tap-hole drills and lancing equipment. Additional projects are also in the pipeline to further explore its capabilities, making robotic technology a compelling avenue for 4IR adoption in the industry.

3.7.2. Industry progress in 4IR

This theme focuses on the extent to which the ferrochrome industry, both locally and globally, has made progress in incorporating the fundamental aspects of the 4IR. The questions in this section delve into various aspects, such as the industry's progress in 4IR technologies, financial constraints, and the readiness for changes associated with 4IR. It also compares the ferrochrome industries' progress to the general mining sector.

The sub-themes are tabled in Table 4 below and discussed further in sections 3.7.2.1 and 3.7.1.9.

Table 4: Industry Progress on 4IR Sub-Theme Frequency

Sub-Theme	Frequency
Limited advancement of 4IR tech	9
Robots & automation	8
Moderate advancements of 4IR tech	6
Limited ML & AI capabilities	4
Digitalisation, AI & ML	3
Manual processes	3
Financial constraints	2
Industry, society & governmental constraints	2
Significant advancements in 4IR tech	1

(Source: Own compilation)

All (100%) of the respondents believe that the ferrochrome industry has not made significant advancements in implementing 4IR technologies, with global mining being more advanced than the South African ferrochrome industry. The examples cited indicate small steps towards automation and mechanisation but nothing major regarding 4IR and the associated technologies. Compared to other tech-leading industries, the ferrochrome and mining sectors are behind but not entirely off the map. Despite the broader adoption of 4IR technologies among companies, the ferrochrome industry has seen little research on forecasting technology and the potential implementation of these advanced technologies (Letaba & Zulu, 2021). This suggests a need for more targeted discussions and perhaps case studies to explore the practical applications of 4IR technologies in this specific industrial context.

3.7.2.1. Limited advancement of 4IR technology

All respondents believe that the ferrochrome industry has made limited advancements in 4IR technology. The high frequency of this sub-theme reinforces this sentiment. The quotes by R1, R3 and R6 also supports this:

- *(R1)"No, certainly not. Very far from it."*
- *(R3) "No, not yet."*
- *(R6) "No, I don't think so."*

The prevailing sentiment among respondents is that the ferrochrome industry has made limited advancements in 4IR technology. This is evident from the frequency of this sub-theme, which is the highest among all sub-themes in Theme 2.

3.7.2.2. Robots & automation

Robots and automation appear to be the second most frequently mentioned sub-theme. However, the examples cited indicate initial steps towards automation rather than full-scale implementation of 4IR technologies. The quotes by R1, R4 and R5 also supports this:

- (R1) *"I think about our vehicle detection systems while we are monitoring vehicles remotely because we barely it started I think it's in the right direction."*
- (R4) *"In Australia, there is a mine... Mining of the future or something like that. It's like an opencast mine. They operate it 1,500 km away. It's only machinery there."*
- (R5) *"I mean, I've seen that some of the vehicles underground can be driven from the offices."*

While automation and robotics garner attention, the discussion among respondents is often limited to generalities. There is a lack of specific dialogue about how these technologies could be tailored to meet the unique needs and challenges of the ferrochrome industry. Generally, the perception from the interviews is that technology in the global mining sector is more advanced than in the South African ferrochrome smelting industry.

3.7.2.3. Moderate advancements of 4IR tech

The perception of moderate advancements suggests that while there is some progress, it is neither ground-breaking nor industry-leading. The quotes by R2, R4 and R5 also supports this:

(R2) *“I think definitely, in my experience, we have made progress.”*
(R4) *“I would say 50% because there are opportunities out there.”*
(R5) *“I think they are already more advanced than where we are.”*

Respondents who believe in moderate advancements in 4IR within the ferrochrome industry suggest that there is room for growth and improvement but also acknowledge that significant strides have yet to be made.

3.7.2.4. Limited Artificial Intelligence and Machine Learning capabilities

According to the respondents, Machine Learning and Artificial Intelligence are not yet fully utilised within the ferrochrome industry. This is indicative of the industry's slow adoption of these advanced technologies. The quotes by R1, R2 and R6 also supports this:

- *(R1) “Predictive maintenance. I think we've got too many, too often, equipment that failed that could have been predicted way, way before it actually happened.”*
- *(R2) “PVD or the people vehicle detection systems.”*
- *(R6) “In terms of self-driving machines, we don't have that. We don't have AI. We don't have robotics.”*

The limited mentions of ML & AI capabilities suggest that these technologies are not yet a significant part of the industry's 4IR journey. This could be due to various factors, including financial constraints and a lack of skilled personnel.

3.7.2.5. Digitalisation, Artificial Intelligence & Machine Learning

Digitalisation, coupled with AI and ML, is a positive step towards integrating 4IR technologies in the ferrochrome industry. However, these are initial steps and not indicative of full-scale implementation. The quotes by R1, R3 and R5 also supports this:

- (R1) *“Docusign example of 4IR.”*
- (R3) *“I think in the last two or three years there's been a lot of improvement in that area, and we've learned a lot in the past three or four years in terms of artificial intelligence and fatigue management for people driving machines.”*
- (R5) *“There's been a lot of progress that has been implemented whereby machines are now being taught to self-drive or self-stop or to intervene when humankind cannot.”*

While there are mentions of digitalisation and AI & ML technologies, these are often cited as isolated examples rather than as part of a broader, integrated 4IR strategy within the ferrochrome industry.

3.7.2.6. Manual processes

The industry's persistence in manual processes indicates a lag in adopting 4IR technologies that could automate these tasks. The quotes by R1 and R3 also support this:

- (R1) *“Think about our recipe management, there's so many things that we do on a day-to-day basis that are still manually done, like log sheets.”*
- (R3) *“So we still use a lot of people we're just starting to automate drilling and closing of tapholes.”*

More than a third of respondents (37.5%) mentioned manual processes. This suggests that the industry still relies on traditional methods for various tasks, emphasising the need for accelerated 4IR adoption.

3.7.2.7. Financial constraints

Financial constraints are a barrier to adopt 4IR technologies in the ferrochrome industry. The quotes by R1 and R4 also support this:

- (R1) "They've been in more financial trouble than us, and when you are in financial trouble, you don't progress."
- (R4) "Due to cost constraints, some of these projects we can't implement."

The limited financial resources available for 4IR initiatives could significantly hinder progress. This is a critical area that needs to be addressed to facilitate the adoption of new technologies.

3.7.2.8. Industry, society & governmental constraints

External factors such as societal and governmental constraints are also barriers to 4IR adoption. The quotes by R2 and R3 also support this:

(R2) *"We only recently went from analogue to digital in television. So I think not mining specific authorities but definitely authorities in the government."*
(R3) *"We still do the things the same as we've done it 20 years ago. So there's not been so much change in the in the last 20 years."*

These constraints suggest that for 4IR to be implemented successfully, a multi-stakeholder approach involving industry, society, and government may be necessary.

3.7.2.9. Significant advancements in 4IR tech

Significant advancements in 4IR technologies within the ferrochrome industry are rare, as indicated by the low frequency of this sub-theme. The quote by R4 also supports this:

- (R4) *"In Australia there is a mine... Mining of the future or something like that. It's like an opencast mine. They operate it 1,500 km away. It's only machinery there*." (R4)

The lone mention of significant advancements in the global mining industry suggests that such progress is more the exception than the rule in the ferrochrome industry.

3.7.3. Industry challenges and 4IR's impact on safety, profitability, and sustainability

This theme explores the perceived impact of 4IR technologies on the ferrochrome industry's safety, profitability, and sustainability. The theme captures the industry's challenges and how 4IR could address them.

The sub-themes are tabled in Table 5 below and discussed further in sections 3.7.3.1 and 3.7.3.8.

Table 5: Industry Challenges And 4IR's Impact on Safety, Profitability, and Sustainability Sub-Theme Frequency

Sub-Theme	Frequency
Positive impact on sustainability	9
Electricity supply, cost and reliability	8
Positive impact on safety	8
Challenges can be overcome	7
Positive impact on profitability	7
Volatile regulatory and political environment	5
Lack of skills and competency	3
Volatile commodity prices and resource availability	3

(Source: Own compilation)

The overarching sentiment among respondents is optimism regarding the potential of 4IR technologies to positively impact safety, profitability, and sustainability in the ferrochrome industry. This optimism exists despite a lack of detailed understanding of how exactly 4IR fits into the current operational landscape or its specific capabilities.

Respondents also have a high level of awareness about the industry's current challenges. These challenges include electricity supply, cost, and reliability, which are particularly emphasised. Other notable challenges include a volatile regulatory and political environment, a lack of skills and competency, volatile commodity prices, and resource availability. This sentiment is also confirmed by Lotriet *et al. (2022)* in "A

Case Study Analysis of The South African Chrome-ferrochrome Industry". An additional point includes a broad economic analysis that revealed significant fundamental flaws in South Africa's economy, with issues in electricity production and distribution being the most critical. The decision to shut down furnaces is mainly due to China purchasing massive amounts of UG2 chrome ore at extremely low prices, adversely affecting the beneficiation sector (Lotriet *et al*., 2022). The Chinese market was also briefly mentioned by some interviewees.

While respondents acknowledge that not all these challenges are within the control of ferrochrome smelting operations, there is a prevailing belief that these challenges can be overcome. This suggests a level of resilience and adaptability within the industry, which could be crucial for successfully implementing 4IR technologies.

3.7.3.1. Positive impact on sustainability

The majority of respondents believe that 4IR technologies can have a positive impact on sustainability. However, understanding how these technologies can contribute to sustainability is not deeply explored. The quotes by R5, R2 and R6 also supports this:

- (R2) *"We want to produce more using less resources. That's one of our daily, weekly KPIs that have been measured, it's our efficiency when it comes to using our ore, as well as electricity, water, all of the resources that we use. We continuously focus on driving that down."*
- (R5) *"And in terms of sustainability, obviously, when the company is efficient, we are sustainable. We are looking as well in terms of environmental impact, whereby there's a lot of 4IR implemented in terms of managing environmental issues these days."*
- (R6) *"And it will lead to sustainability, because obviously, we're going to grow with the times. Yeah, but especially in terms of technology."*

While respondents are optimistic about the potential for 4IR technologies to improve sustainability, there is a lack of specific examples or in-depth understanding. This suggests a need for more targeted discussions and perhaps case studies to explore the practical applications of 4IR in enhancing sustainability in the ferrochrome industry.

3.7.3.2. Electricity supply, cost and reliability

Electricity supply, its cost and reliability are significant concerns among respondents. The issue is often cited as a major challenge facing the ferrochrome industry. The quotes by R2, R5 and R6 also supports this:

- (R2) *"The first big challenge that comes to mind is obviously our energy reliability and our energy supply. We're a very energy-intensive industry. We use almost four megawatt hours to produce one ton of outward."*
- (R5) *"Currently, it's the cost of electricity, the cost and availability of electricity in our country, I guess, of electricity in our country."*
- (R6) *"ESKOM. Electricity. So power generation plants. ESKOM is for power, electricity."*

The issue of electricity supply, cost, and reliability is a recurring theme among respondents. It is a significant barrier to adopting and effectively implementing 4IR technologies. This suggests that any 4IR strategy for the ferrochrome industry must consider these electricity-related challenges.

3.7.3.3. Positive impact on safety

There is a strong belief among respondents that 4IR technologies can improve safety within the ferrochrome industry. However, the specifics of how these technologies can enhance safety are not deeply understood. The quotes by R2, R7 and R8 also supports this:

- (R2) *"Health and hygiene, how we monitor, how we do biological monitoring, can we identify patterns when it comes to a person's haemoglobin levels, for instance, or some sort of a biological monitoring program that we have where we can predict when a person's levels will go out of limit or not."*
- (R7) *"So, I think that that can even be designed even better to be able to report safety incidents as they happen and to make sure that there's follow-up done on a safety incident to make sure it doesn't happen again."*

- (R8) *“having less people on site, which automatically will reduce the risk for injury for, you know, if there's no people on site then nobody can get injured.”*

While the potential for 4IR technologies to improve safety is acknowledged, the lack of specific understanding or examples indicates a need for more in-depth exploration and education within the industry.

3.7.3.4. Challenges can be overcome

Despite the challenges identified, respondents have a general sense of optimism that these challenges can be overcome, although not all are within the control of the ferrochrome industry. The quotes by R1, R2 and R3 also supports this:

- (R1) *“Yeah, certainly.”*
- (R2) *“Solving that is not necessarily within our control. But I do think that the country can solve the energy crisis.”*
- (R3) *“You will be able to overcome this because businesses get involved and a lot of people get involved with electricity and the supply of electricity.”*

The belief that challenges can be overcome is prevalent among respondents. This optimism may serve as a motivational factor for the industry to seek solutions, particularly in the context of 4IR. How these challenges can be overcome was not discussed in detail.

3.7.3.5. Positive impact on profitability

Respondents generally believe that 4IR can positively impact profitability, although there is a lack of detailed understanding of how this would occur. The quotes by R2, R3 and R7 also supports this:

- (R2) *“I believe that technology has got a big part to play in reducing our consumption and increasing our output, and that in turn will make it more profitable”*

- (R3) *“Yes it's definitely fundamental aspects. So the electrode lengths and things like that is to do with the profitability or stability of the furnace so you will lose a lot of money if we cannot learn from our mistakes”*
- (R7) *“It'll probably streamline the processes, which will then hopefully at the end of the day have an impact on the profitability of the company”*

While there is optimism about the potential for 4IR technologies to improve profitability, the lack of specific examples or in-depth understanding suggests a need for more targeted discussions and perhaps case studies to explore the practical applications of 4IR in enhancing profitability in the ferrochrome industry. This is concerning because the awareness of what is operationally available is lacking.

3.7.3.6. Volatile regulatory and political environment

The regulatory and political environment is a significant challenge, particularly in South Africa. Respondents believe this volatility can impact the industry's ability to adopt 4IR technologies effectively. The quotes by R1, R4 and R5 also supports this:

- (R1) *“And political... Well, maybe it's more short-term, but political stability in South Africa has a bigger impact because currently, I think, on the short-term, political instability might be a massive issue.”*
- (R4) *“We are now using more trucks than trains. And there is a reason behind it. Who owns those trucks? Someone in parliament.”*
- (R5) *“Mean, we are in a country where there's a lot of corruption, and if you have machinery, you're already eliminating that.”*

The volatile regulatory and political environment is a concern among respondents. This suggests that any 4IR strategy for the ferrochrome industry must consider these challenges, particularly in South Africa.

3.7.3.7. Lack of skills and competency

The lack of skills and competency is identified as a challenge, particularly in the South African context. This is seen as a barrier to the effective implementation of 4IR. The quotes by R1, R2 and R3 also supports this:

- (R1) *“And the quality of education, well, you know about the quality of education.”*
- (R2) *“The second big challenge is skills, regardless of if we're talking about the 4IR topic. Skills in South Africa are still a big problem. And I think more so in the heavy engineering field. The impression that I get is that young graduates don't really want to work in the heavy industry field.”*
- (R3) *“Who you must appoint is a challenge.”*

The lack of skills and competency is a recurring theme among respondents. This suggests that any 4IR strategy for the ferrochrome industry must consider these challenges, particularly in South Africa.

3.7.3.8. Volatile commodity prices and resource availability

The volatility in commodity prices and the availability of resources are seen as challenges that could impact the industry's ability to adopt 4IR technologies effectively. The quotes by R5, R7 and R8 also supports this:

- (R5) *“As well as the availability of mineral resources that we are slowly depleting.”*
- (R7) *“The other threat is the fluctuating commodity we produce. The market prices fluctuate extensively over cycles of time, every three to four years. And that could potentially be a threat as well.”*
- (R8) *“The use of resources, because I think water is going to be a scarce resource as well.”*

The volatility in commodity prices and the availability of resources are concerns among respondents. This suggests that any 4IR strategy for the ferrochrome industry must consider these challenges.

3.7.4. Optimism and readiness for 4IR implementation

This theme investigates the participants' level of optimism and readiness for the 4IR in the ferrochrome industry. It explores the perceived financial feasibility of implementing 4IR technologies and assesses the willingness among employees to adapt to these changes.

The sub-themes are shown in Table 6 below and discussed further in sections 3.7.4.1 and 3.7.4.6.

Table 6: Optimism and Readiness for 4IR Implementation Sub-Theme Frequency

Sub-Theme	Frequency
Capital will be available	9
In support of 4IR	8
Employees not open to change and development	6
4IR Implementation will be expensive	5
4IR implementation will be affordable	3
Employees open to change and development	2

(Source: Own compilation)

The overall sentiment among respondents is optimism towards implementing 4IR technologies in the ferrochrome industry. Despite the economic challenges, there is a strong belief that capital will be available for 4IR projects. All respondents support 4IR, mentioning its potential to improve safety, profitability, and sustainability. However, there is a perception that employees, particularly those in unions, may not be as open to these changes. The commercial aspect is crucial. Success is unlikely if businesses view labour merely as a cost to be reduced. In societies where change implementation works well, it's generally a collective effort involving all stakeholders (Bughin *et al.*, 2018). The cost of 4IR implementation is a point of debate, with opinions divided between it being expensive and affordable.

3.7.4.1. Capital will be available

The respondents strongly emphasise the availability of capital for 4IR implementation despite the economic challenges currently facing the ferrochrome industry. All respondents agreed that capital will be available to implement 4IR technologies. The quotes by R1, R2 and R4 also supports this:

- (R1) *“If you have proven that you've done one or another project very successfully, then you apply for money, you get it.”*
- (R2) *“Motivate in terms of either profitability increase in the form of an NPV or an IRR where we've got a hurdle rate in the company above, which the capital project must be to be considered, or in terms of the safety aspect, and that's a big drive for us.”*
- (R4) *“And then in terms of capital, I think we will get that capital because the world is changing.”*

The strong consensus among respondents indicates confidence that the necessary financial resources will be available for 4IR implementation. This suggests an understanding to raise the bar regarding 4IR implementation and that financial constraints may not be a significant barrier to adopting 4IR technologies in the ferrochrome industry.

3.7.4.2. In support of 4IR

All respondents unanimously support 4IR, citing its potential benefits such as increased safety, profitability, and sustainability. The quotes by R2, R4 and R8 also supports this:

- *(R2) “I would definitely support it because I think there are many opportunities still. Making the workplace safer, getting our environmental compliance, and making us more compliant. Increasing our productivity, I think there's a lot of opportunity there. Profitability and efficiency.”*
- *(R4) “I will support it. First, the reason is based on profitability, safety of the people and also it will make producing ferrochrome easier and then sustainable.”*

- *(R8) "I would be stupid not to support 4IR. I cannot see us surviving without it."*

The unanimous support for 4IR among respondents indicates a shared belief in its potential to impact the ferrochrome industry positively. This suggests a strong foundation for successfully implementing 4IR technologies, provided other challenges can be effectively managed.

3.7.4.3. Employees not open to change and development

Several respondents (75%) believe that employees, particularly those affiliated with unions, may resist the changes associated with 4IR. Possible reasons are that the industry has been pushing for head-count reduction, and 4IR technology could potentially replace some labour. The quotes by R1, R2 and R7 also supports this:

- (R1) *"The answer is it's difficult to get people to change."*
- (R2) *"I think it's also our society, specifically in South Africa, has still got a lot of challenges. And I think that plays a bigger part in not getting the acceptance levels that we would like."*
- (R7) *"And given our unionised environment and workforce, and given what the union stands for is to create jobs and to keep jobs and to actually contribute to growing the organisation and also making sure that people stay in their jobs, that I believe we're going to be faced with a potential pushback against it."*

The perception that employees may resist 4IR changes suggests that any implementation strategy must include a robust change management component. This is particularly relevant given the unionised nature of the workforce in the ferrochrome industry.

3.7.4.4. 4IR implementation will be expensive

More than half (62.5%) of respondents believe implementing 4IR technologies will be expensive, citing factors such as automation and legal requirements. A phased approach is advisable to get the implementation going. The quotes by R3, R4 and R7 also supports this:

- (R3) *"I think it will be expensive but it's more a once of capital. So I think your return on investment is just a little bit different than usual capital expenses."*
- (R4) "*It will be expensive, but the results of it, I mean, it will make everything cheaper in the long run."*
- (R7) *"I think that it is going to be expensive because it's going to mean a lot of automation and going beyond automation, having artificial intelligence running in the background and in the forefront."*

The prevailing opinion that 4IR implementation will be expensive suggests that cost considerations will be a significant factor in any implementation strategy. However, a strong belief that long-term benefits will offset these costs indicates that the expense may be justified. Critical evaluation metrics such as a positive Net Present Value (NPV), Internal Rate of Return (IRR), and Return on Investment (ROI) will be calculated as part of the motivation.

3.7.4.5. 4IR implementation will be affordable

A smaller group of respondents (37.5%) believe that 4IR implementation will be affordable, particularly if it is well-planned and if it focuses on long-term benefits. The quotes by R1, R2 and R8 also supports this:

- (R1) *"I don't think it will be that expensive. I think it might be expensive due to mistakes being made, due to us not really thoroughly applying our minds when we implement it."*
- (R2) *"I think there could be solutions that are expensive, but I don't think all of the technological solutions will be expensive is not true."*
- (R8) *"I think the payback of it will be of such a nature that, you know, it will be a no-brainer to spend the money."*

The small minority opinion that 4IR can be affordable suggests that with careful planning and execution, the financial burden of implementation may be less daunting than commonly perceived.

3.7.4.6. Employees open to change and development

Few respondents (25%) believe that employees, particularly the younger generation, will be open to 4IR changes. The quotes by R5 and R6 also support this:

- (R5) *"Yes, I believe that employees will be receptive to 4IR. It might not be all of them, but the younger generations, I know that they embrace it a lot because of the benefits that come with the 4IR, especially when it comes to safety, more especially in our industry."*
- (R6) *"It depends on what generation we're looking at. The younger generation is very, very technologically inclined. So they are open to, so the younger guys coming in now are open to changes, and they wanted to have automated systems."*

The limited but positive feedback about employees being open to change suggests that age and generational factors may play a role in the acceptance of 4IR technologies. This could be an important consideration in change management strategies.

3.7.5. Challenges and success factors for 4IR implementation

This theme aims to identify the challenges and critical factors that could influence the successful implementation of the Fourth Industrial Revolution (4IR) in the ferrochrome industry. The sub-themes range from competency and understanding of 4IR to regulatory policies, each contributing to a multi-faceted understanding of the complexities involved in 4IR implementation.

The sub-themes are tabled in Table 7 below and discussed further in sections 3.7.5.1 and 3.7.5.8.

Table 7: Challenges and Success Factors for 4IR Implementation Sub-Theme Frequency

Sub-Theme	Frequency
Competency & understanding of 4IR	9
Employee buy-in & overcoming the fear of change	8
Funding	6
Reskill, upskill & training of employees	6
FeCr economic outlook	3
Society & infrastructure constraints	3
Data quality & validity	2
Regulatory policies	2

(Source: Own compilation)

The challenges and success factors for 4IR implementation in the ferrochrome industry are complex and closely linked. While there's consensus on 4IR's benefits, barriers such as competency gaps, employee buy-in, and funding persist. These complexities necessitate a comprehensive and multi-dimensional strategy for successful 4IR adoption. Investing in talent and culture is crucial for 4IR adoption and aligning strategic decisions from the board. Quick, iterative actions, guided by well-defined objectives, help overcome barriers like skill gaps and employee resistance (McKinsey & Company, 2023a). The human element is central to overcoming these challenges, which manifests in various forms like employee engagement, training, and understanding of 4IR. This highlights the imperative for a human-centric approach in 4IR strategising.

3.7.5.1. Competency & understanding of 4IR

The competency and understanding of 4IR emerge as pivotal factors, particularly given the industry's current knowledge gap regarding what 4IR can offer.

- (R1) *"We can't strategise now, we don't know enough."*
- (R2) *"The second one is definitely skilled. I don't know whether we've got sufficient skills to drive all these technology-driven applications and technologies."*

- (R8) *“The skill that you've got in terms of employees, you know, thinking out of the box.”*

The recurring emphasis on a lack of competency, understanding of 4IR technologies and the knowledge of what is available suggests that educational and awareness-raising initiatives are beneficial and essential for effective implementation. This is particularly crucial given the industry's current knowledge gap about the specific benefits and applications of 4IR.

3.7.5.2. Employee buy-in & overcoming the resistance to change

Employee buy-in and the fear of job loss are substantial barriers to 4IR adoption, indicating that human factors are central to this theme. The quotes by R2, R3 and R7 also supports this:

- (R2) *“With a specific South African context, I would say acceptance from the workforce and unions when it comes to job security.”*
- (R3) *“So it will be resistance to change, it will be people with a lot of experience that done things the same way.”*
- (R7) *“People must believe that multi-skilling and upskilling is not to put them out of a job, but rather to put him/her in a better position.”*

The resistance to change among employees, particularly concerning job security, underscores the need for robust change management strategies. This is especially relevant in a unionised environment where job security is often a significant concern. The human element is thus central to this sub-theme, requiring strategies that address both emotional and rational aspects of change resistance.

3.7.5.3. Funding and investment

Funding and investment emerge as a potential barrier, contradicting previous themes that suggested capital would be readily available. This contradiction appears to be influenced by the current economic volatility in the ferrochrome industry. The quotes by R3, R4 and R6 also supports this:

- (R3) *“And then capital might be a little bit of an issue to getting to really do everything you want to do, and it might be phased in.”*
- (R4) *“I think it will be funding. We require substantial capital. And we are not sure that the investors will invest.”*
- (R6) *“Obviously money.”*

The issue of funding presents a complex landscape. While previous themes suggested that capital would be available, the current sub-theme indicates that allocating such resources is not straightforward. This complexity is exacerbated by the volatile economic outlook of the ferrochrome industry, making funding a more significant issue than initially perceived. Critical evaluation metrics such as positive Net Present Value (NPV), Internal Rate of Return (IRR) and Return on Investment (ROI) will be calculated as part of the feasibility and motivation.

3.7.5.4. Reskill, upskill & training of employees

The need for reskilling and upskilling employees is emphasised as a critical factor for the successful implementation of 4IR, aligning with the human-centric focus of this theme. The quotes by R5, R6 and R7 also supports this:

- (R5) *“The first one will be the skill. We need to be prepared, and we need to have plans in terms of how to upskill our workforce, our people, to be ready for 4IR, because we cannot just implement it and skill people afterwards.* “
- (R6) *“Training people”*
- (R7) *“We need to take our people with us on the journey.”*

The focus on reskilling and upskilling suggests that human capital development is a priority. This aligns with the concerns about competency and understanding of 4IR, indicating that employee training is integral to overcoming these challenges. The human element is again at the forefront, emphasising the need for strategies that are not just technically sound but also socially sensitive.

3.7.5.5. *Ferrochrome economic outlook*

The economic outlook of the ferrochrome industry is identified as a variable that could influence the pace and scale of 4IR implementation. The quotes by R1, R4 and R7 also supports this:

- (R1) *“Every 12 months, we don't make money again, then we stop a lot of these projects.”*
- (R4) *“I think it will also depend on how the industry performs in other terms these are and also the ferrochrome market because we know sometimes we make money, so it's not a stable, it's a volatile market.*”
- (R7) *“that there probably will be capital made available, but depending on where the market sits and where the company sits from a profitability point of view, that may be a challenge.”*

The economic volatility of the ferrochrome industry could potentially impact the availability of funding for 4IR projects. This aligns with the sub-theme on funding, suggesting that economic stability is a prerequisite for securing the necessary capital for 4IR implementation.

3.7.5.6. *Society & infrastructure constraints*

Infrastructure and societal constraints, particularly in the South African context, are potential barriers to 4IR implementation. The quotes by R2 and R5 also support this:

- (R2) *“The fact that we don't have internet everywhere on the plant. The infrastructure part of connectivity will also be a drawback on infrastructure. In order for us to get there, we need connectivity, reliable connectivity.*”
- (R5) *“And you want to implement new things, it's the infrastructure that's there. It's old buildings, it's old.”*

The lack of reliable infrastructure, such as internet connectivity and access to resources, could hinder the effective implementation of 4IR technologies. This is particularly relevant in South Africa, where infrastructure development may not be at par with the requirements of advanced technologies.

3.7.5.7. Data quality & validity

The quality and validity of data are considered crucial for the successful application of 4IR technologies. The quality and validity of data serve as the foundation for the successful implementation of 4IR technologies in the ferrochrome industry. Without reliable and accurate data, any algorithms or analytical tools applied downstream would produce misleading or ineffective results. The quotes by R2, and R8 also supports this:

- (R2) *"Because that's at the very start of the process, is the data collection step. If you want to apply algorithms and analysis toolkits and so forth downstream, you have to have reliable data to start with. It's crucial. We're not there."*
- (R8) *"Getting proper data. Okay. It's one of the things that I think will be a secret. The better your data, the better your algorithm, the better your knowledge, the better the intelligence you are creating."*

The emphasis on data quality and validity suggests that for 4IR technologies to be effectively implemented, a robust system for data collection and validation must be needed. This should be highlighted in the overall management strategy and driving as a key performance indicator. Poor data quality could compromise the integrity of 4IR applications, making this a critical area of focus.

3.7.5.8. Regulatory policies

Regulatory policies such as company policies, procurement policies, governmental policies, and mineral board/ chamber of mines are perceived as potential hurdles that could complicate the 4IR implementation process. The quotes by R1, and R4 also supports this:

- (R1) *"We wanted to get the best of the best to come and install them but P2P dictated and we were required to use the local guy he doesn't even understand what we want to achieve but now we must jump through so many hurdles."*
- (R4) "The first one will still be on the government site."

The regulatory landscape could pose challenges to 4IR implementation, particularly if policies are not aligned with the technological requirements of 4IR. This suggests that policy advocacy and alignment are essential components of a comprehensive 4IR strategy.

3.7.6. Future outlook

This theme explores the anticipated shifts in the ferrochrome industry with full 4IR implementation and the industry's prospects if 4IR is not adopted. The sub-themes range from automation and safety improvements to potential closures, painting a complex picture of the industry's future.

The sub-themes appear in Table 8 and are discussed in Sections 3.7.6.1 to 3.7.6.13.

Table 8: Future Outlook Sub-Theme Frequency

Sub-Theme	Frequency
Long-term (10Y) closure	7
Improved safety	6
Short-term (5Y) operational	6
Automation, robots, AI & ML	4
Head-count reduction	4
Improved process efficiencies, stability & availability	4
Increased profit	3
Remote working opportunities	3
Improved employee skills and competencies	2
Improved environmental compliance	2
Reduced cost of production	2
Short-term (5Y) closure	2
Long-term (10Y) operational	1

(Source: Own compilation)

Despite challenges, the outlook is optimistic if 4IR technologies are implemented. While 4IR promises greater safety, efficiency, and profitability, not adopting it poses a real risk of long-term closure. Navigating this intricate landscape calls for a nuanced, human-centric strategy. Implementing 4IR is not merely an option but imperative for the industry's continued viability. The industry has shown signs of efficiency improvements over the past years, adding to an optimistic view of the future of ferrochrome smelting in South Africa. Between 2007 and 2020, ferrochrome production in South Africa grew by 18.9%, while the chromite ore needed for each ton of ferrochrome decreased by 20% (Dlamini & von Blottnitz, 2023).

3.7.6.1. Long-term (10y) Closure

The long-term closure of the South African ferrochrome industry is perceived as an almost certain outcome if 4IR is not implemented. Despite this awareness, there appears to be a lack of concerted effort to understand how 4IR could be beneficial. The quotes by R2, R3 and R7 also supports this:

- (R2) *"We'll have more smelters that close down because it could become more profitable to export the ore and not smelt it in South Africa."*
- (R3) *"In 10 years time, it will definitely not survive."*
- (R7) *"In 10 years time we'll probably be out of business."*

Seven participants strongly believe that the ferrochrome industry will close in the long run if 4IR is not implemented. However, it seems that although the respondents realise the gravity of the situation, a futile effort is made to understand how 4IR can help. This suggests a critical gap in strategic planning and underscores the urgency for immediate action. A focused and systematic approach to developing a technology roadmap is essential.

3.7.6.2. Improved safety

Improved safety is highly anticipated as a major benefit of 4IR implementation, and participants are most excited about this prospect. If was noteworthy how much emphasis is placed on safety. The quotes by R2, R3 and R4 also supports this:

- (R2) *"Where we can completely remove human beings from high-risk areas."*

- (R3) *“So there will be early warning, early detection. We will have systems to tell you when people are fatigued, people are not alert.”*
- (R4) *“Okay, key changes will be in terms of safety.”*

A high focus was placed on 4IR implementation and the safety benefit. Six participants were most excited about this sub-theme, indicating that safety improvements could motivate 4IR adoption.

3.7.6.3. Short-term (5y) operational

According to the participants, the ferrochrome industry is expected to survive in the short-term, regardless of whether 4IR is implemented. Despite a volatile market and many industry issues, such as reliable and affordable electricity, these are pressing matters. The quotes by R1, R2 and R5 also supports this:

- (R1) *“If electricity is low enough, we will be here, irrelevant if we implement 4IR.”*
- (R2) *“Well, you'll obviously have an industry that's stagnant or even deteriorating in terms of the level of efficiency.”*
- (R5) *“In five years, we still have other backups that we have, so we might survive, but we will see the trend going down of our survival.*”

Six participants believe that the ferrochrome industry will continue to operate in the short-term, even without 4IR. However, there is a consensus that the industry will face challenges, including declining efficiency and profitability.

3.7.6.4. Automation, robots, Artificial Intelligence and Machine Learning

Automation and the use of advanced technologies like AI and ML are expected to be integral components of the industry's future. This will also contribute to safety and process efficiencies. The quotes by R2, R4 and R8 also supports this:

- (R2) *“Where that assists operators in making decisions. I don't think it will be an operator-less environment but I do think we can assist operators and engineers immensely in making decisions.”*
- (R4) *“People will be gone. It will only be the machines or robots.”*

- (R8) *"Tapping process is much more automated. Plant process is much more automated with much less people operating the process."*

Four participants expect a significant increase in automation, robots, AI, and ML in the industry. The anticipation of increased automation, AI, and ML in the ferrochrome industry presents a complex scenario. These technologies promise to revolutionise production capabilities and significantly enhance process efficiencies. For instance, automation could streamline operations, reduce manual errors, and increase production speed. AI and ML could provide real-time analytics and predictive maintenance, improving productivity and reducing downtime. These advancements could be particularly beneficial in an industry under constant pressure to improve its economic performance. This is a double-edged sword: while it could lead to efficiency gains, it raises concerns about head-count reduction.

3.7.6.5. Head-count reduction

Head-count reduction is a concerning prospect, especially for employees who fear job loss due to automation. The quotes by R4, R5 and R8 also supports this:

- (R4) *"You won't injure anyone. People will be gone."*
- *(R5) "It would be an operator-less operation*"
- (R8) *"Much less people"*

Four participants expect to see fewer employees, which worries the workforce. This is an inevitable part of digitalisation. This ties back to the human element, emphasising the need for strategies that consider the social impact of technological changes; reskilling and removing employees from danger zones was also emphasised.

3.7.6.6. Improved process efficiencies, stability & availability

Improved process efficiencies are anticipated as one of the benefits of 4IR, contributing to the stability and availability of operations. The quotes by R1, R2 and R3 also supports this:

- (R1) *"I think it will be improved availability."*
- (R2) *"I think in terms of process efficiency we have real-time data analytics in control rooms."*
- (R3) *"You will have a stable operation."*

Four participants expect improvements in process efficiencies, stability, and availability. This is viewed as a positive development that could enhance the industry's competitiveness. Process stability is considered a key element of furnace operation.

3.7.6.7. Increased profit

According to three participants, increased profitability is expected due to 4IR implementation, although this is contingent on various factors, including cost reduction and process efficiencies. The quotes by R1, R3 and R4 also supports this:

- (R1) *"I think the differences will be profitability."*
- (R3) *"So I think that in terms of profit, the profitability will be better."*
- (R4) *"It will be more profitable."*

Three participants expect to see an increase in profitability due to 4IR implementation. This is contingent on various factors, including cost reduction and process efficiencies.

3.7.6.8. Remote working opportunities

Remote working opportunities are expected to increase, potentially attracting better talent to the industry. It was mentioned on several occasions that the industry has many people working for extended periods, which could have contributed to the lack of implementation of 4IR technologies. The quotes by R3, R5 and R8 also supports this:

- (R3) *“People might sit at home, and the safety will improve if they're right or something. You can operate the furnace from home if you want to.”*
- *(R5) “And we would be working from home.”*
- (R8) *“They'll sit somewhere else.”*

Three participants expect to see an increase in remote working opportunities. This is viewed as a positive development that could make the industry more attractive to skilled talent.

3.7.6.9. Improved employee skills and competencies

Improving employee skills and competencies is a crucial aspect of 4IR implementation, particularly for adapting to new technologies.

- (R2) *"It is to get employees away from dangerous areas and to upskill those employees."*
- (R7) *"A more skilled workforce."*

Participants believe that upskilling employees is essential for the successful implementation of 4IR. This aligns with the overarching theme of the human element being central to 4IR strategies, emphasising the need for comprehensive training programmes.

3.7.6.10. Improved environmental compliance

Improved environmental compliance is expected as a byproduct of 4IR, contributing to a more sustainable industry.

Quotations:

- (R5) *"It would be environmentally conducive if I can call it that way, an environmentally clean environment."*
- (R7) *"I'll probably see a cleaner environment."*

Participants expect 4IR to lead to improved environmental compliance, which could make the industry more sustainable and socially responsible. This is in line with global trends towards greener industrial practices.

3.7.6.11. Reduced cost of production

Reduced cost of production is anticipated as a significant benefit of 4IR, which could contribute to increased profitability.

- (R1) *"Being a lower-cost producer in other words making more money."*
- (R4) *"It will be a significant reduction in terms of cost."*

Participants expect that 4IR will lead to a reduction in production costs, thereby increasing profitability. This is vital for the industry's competitiveness, especially in a challenging economic landscape.

3.7.6.12. Short-term (5y) closure

The possibility of short-term closure exists but is not as imminent as long-term closure, primarily if 4IR, is not implemented.

- (R4) *"We will be mining ferrochrome and shipping to European countries, then the smelters will not be busy in South Africa in 5 years."*
- (R8) *"So in the short-term and the long-term, if we don't start implementing it now, we'll close our doors."*

While the risk of short-term closure is acknowledged, it is not considered as pressing as long-term closure. Nevertheless, the need for 4IR implementation to mitigate this risk is evident.

3.7.6.13. Long-term (10y) operational

Long-term operational viability is considered unlikely without the implementation of 4IR, although one participant expressed some optimism.

Quotations:

- (R1) *"I'm 90% sure we will be here but make less money and will not be expanding."*

The consensus is pessimistic regarding the long-term operational viability of the industry without 4IR. However, one participant expressed optimism, suggesting that while the industry might survive, it would likely not thrive or expand.

3.8. SEMI-STRUCTURED INTERVIEW CONCLUSION

The demographic information gathered from eight interviews revealed a rich background of experience among the participants, with many having high years of experience in the industry and occupying senior positions. This diversity in viewpoints enriched the study's findings and ensured a comprehensive understanding of the subject matter. The data reached a saturation point, indicating that the research captured a full range of insights relevant to the study.

Integrating the 4IR into the ferrochrome industry presents a complex landscape of diverse challenges and success factors. Key challenges include competency and understanding of 4IR, funding, and employee buy-in. Despite these hurdles, the industry outlook remains optimistic if 4IR technologies are implemented effectively. The human element emerged as a central theme, highlighting the need for a human-centric approach in strategising for 4IR implementation. Interestingly, Figure 19 shows that "people", “safety”, and “profitability” also emerged as the most used words in a word cloud of the main themes, further emphasising its importance.

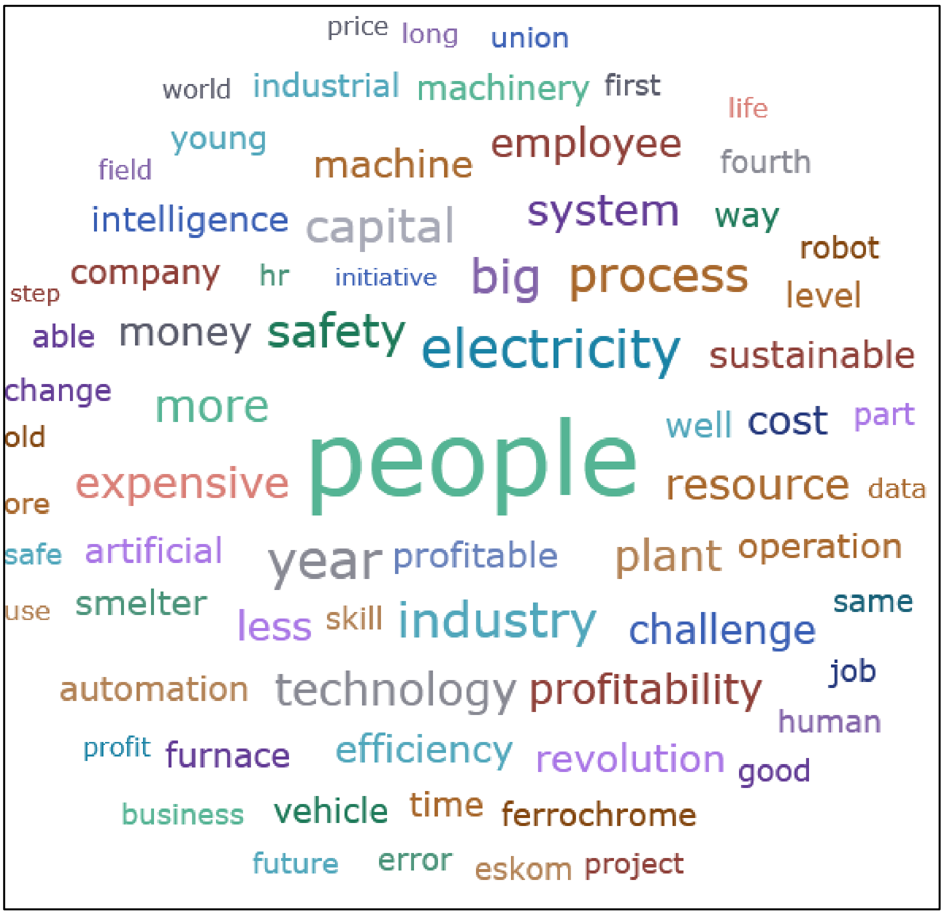

Figure 19: Word Cloud of Main Themes

(Source: Own compilation)

Understanding 4IR is crucial; however, the study found that while there is a general awareness of its importance, there is still a lack of comprehensive understanding of how it can be beneficial. This gap needs to be addressed to fully realise the potential advantages of 4IR, such as increased safety, efficiency, and profitability. The research also indicated that 4IR will be crucial for safety, profit, and sustainability. The long-term operation of the ferrochrome industry is highly dependent on the successful implementation of 4IR technologies. Failure to adopt 4IR could result in stagnation or even the industry's demise, making its implementation not just an option but a necessity for survival.

3.9. CHAPTER SUMMARY

This chapter served as the empirical centre of this study, particularly designed to explore the impact of the Fourth Industrial Revolution on a ferrochrome production plant in South Africa, thereby directly addressing the primary objective. The research methodology, informed by the literature reviewed in Chapter 2, employed a qualitative approach. This ensured an in-depth understanding of the complexities surrounding 4IR in the ferrochrome industry, fulfilling the first secondary objective of determining the plant's readiness for 4IR implementation.

The demographic information, featuring eight interviews that reached data saturation, revealed a wealth of participant experience. This lends credibility to the study's findings, which are organised into themes and sub-themes. These findings directly contributed to the second secondary objective by exploring the relevance of 4IR for the plant's future. The research clearly showed that the long-term sustainability and profitability of the ferrochrome plant are tied to the successful implementation of 4IR technologies. This aligns with the study's primary objective and comprehensively answers the research question.

The human element emerged as a central theme, emphasising the need for a people-centric approach to 4IR. This is particularly relevant given the industry's current challenges and directly contributes to the third and fourth secondary objectives by drawing conclusions and setting the stage for recommendations.

The study concludes that while there are complex challenges to 4IR adoption, such as skills, funding and regulatory policies, the future remains optimistic if these technologies are implemented. This fulfils the study's objectives and provides a robust foundation for Chapter 4, the final chapter. It presents the main findings from the research study, limitations, and recommendations based on these insights.

CHAPTER 4 – CONCLUSIONS AND RECOMMENDATIONS

4.1. INTRODUCTION

Chapter 4 serves as the culminating chapter of this comprehensive study. It aims to synthesise and critically discuss the empirical findings obtained through the interviews and the theoretical insights gained from the literature review.

The primary objective of this study is to explore the impact of the 4IR on a ferrochrome production plant in South Africa as guided by the research question: *How can the 4IR impact a ferrochrome production plant in South Africa?* This research employs a qualitative approach, utilising semi-structured interviews to gather in-depth insights from industry experts.

This chapter will delve into several key areas: firstly, it will assess the validity of the qualitative research methods employed; secondly, it will offer a comprehensive discussion of the literature and study findings, categorised the latter by themes and sub-themes; thirdly, it will evaluate how well the research has met its primary and secondary objectives; followed by an outline of the limitations encountered during the study. Finally, actionable recommendations are provided for industry stakeholders, and concluding remarks will offer directions for future research in this vital and evolving field.

4.2. VALIDITY

Ensuring the validity of the research was a critical aspect of this study. The interview protocol was designed carefully, informed by the literature review conducted in Chapter 2. The questions and themes for the semi-structured interviews were developed in line with the objectives and research question, targeting management within the ferrochrome industry. These interviews were comprehensive, with an average duration of approximately 40 minutes, allowing for an in-depth exploration of the subject matter.

Before the interviews were conducted, the interview guide was reviewed to ensure that it would effectively capture the insights and complexities of 4IR's impact on a ferrochrome production plant. The interviews were recorded, and careful notes were taken during each session to ensure accuracy. Subsequently, the data was transcribed and prepared for analysis.

Antoinette Bisschoff has performed language and technical editing to ensure the highest academic rigour. The language editing certificate is attached in Appendix E. This further enhances the validity of the study's findings. All data collected for this research is available upon request, adhering to the principles of transparency and replicability."

4.3. DISCUSSION OF THE MAIN FINDINGS

This section combines insights from the literature review and the empirical study to offer a well-rounded understanding of 4IR's impact on South Africa's ferrochrome industry. In comparison, the first part outlines the theoretical frameworks, and the second presents real-world perspectives from industry professionals. Together, they provide key findings that inform the study's objectives.

4.3.1. Findings from the literature review

The literature review in Chapter 2 served as a foundation for this study, offering a deep understanding of the 4IR and its potential impact on the ferrochrome industry in South Africa. The review was instrumental in shaping the research question: "*How can the Fourth Industrial Revolution (4IR) impact a ferrochrome production plant in South Africa?*" the primary objective is to explore this impact. Below are the main findings from the literature review.

- Ferrochrome Production in South Africa:
    - The literature emphasised the economic significance of the ferrochrome industry in South Africa. However, it also pointed out that the industry is burdened with high energy costs and stringent regulations. The

implication is that 4IR technologies could solve some of these challenges, directly impacting the industry's sustainability and profitability. This aligns with the primary objective of understanding 4IR's impact on a ferrochrome production plant.

- Technologies Driving 4IR
  - Technologies like IoT, AI and ML, Robotics, and Advanced Analytics were identified as the key drivers of 4IR. Each of these technologies has specific applications that could revolutionise various aspects of ferrochrome production, from operational efficiency to worker safety. The potential for these technologies to positively impact the industry addresses the research question and underscores the need for effective implementation, fulfilling the study's primary objective.
- Implications of 4IR
  - The literature discussed the global implications of 4IR and its specific impacts on the South African economy and the ferrochrome industry. For instance, automation and IoT could lead to more efficient and sustainable production processes. These insights are crucial for understanding how 4IR could be a game-changer for the ferrochrome industry in South Africa, thereby directly contributing to the research question and primary objective.
- Challenges and Opportunities
  - Regulatory challenges and policy implications were highlighted, along with the opportunities that 4IR presents. The literature suggests that while there are hurdles to overcome, the long-term benefits of 4IR adoption could be transformative for the industry. This aligns with the study's secondary objectives, which include exploring the challenges and readiness of the industry for 4IR.
- Case Studies and Best Practices
  - The review also brought in lessons from other industries successfully implementing 4IR technologies. These case studies offer a roadmap for the ferrochrome industry, providing insights into developing a digital transformation strategy and fostering a culture of innovation. This

information is invaluable for addressing the secondary objectives related to industry readiness and challenges.

In conclusion, the literature review findings offer a comprehensive framework for exploring the complexities of 4IR in the ferrochrome industry. They provide the necessary context and depth to address the research question and fulfil the study's primary and secondary objectives. The themes and insights gleaned from the literature were instrumental in shaping the research methodology and ensuring that the study remains focused and relevant.

4.3.2. Findings from the empirical investigation

The findings from the empirical study were based on the information gathered by the semi-structured interview. Below in Figure 20 is a word cloud of the Total Interviews conducted. Lots of focus was on the words think, we, people, 4IR, questions, and industry.

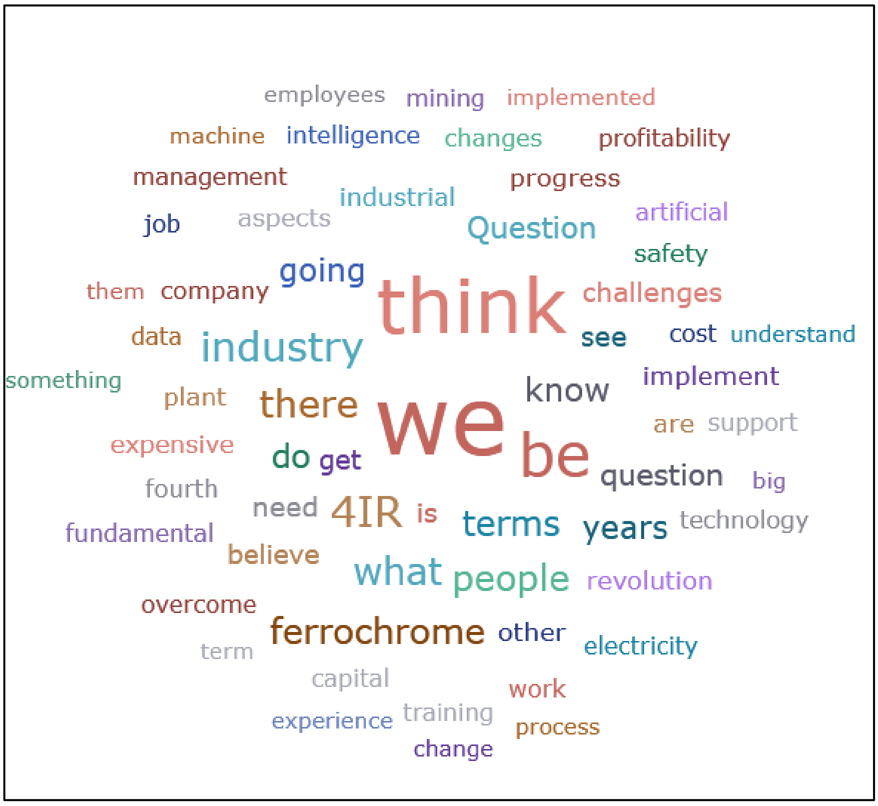

Figure 20: Word Cloud of All Interviews

(Source: Own Compilation**)**

The following main findings were observed from these interviews:

- Age group.
    - The generational breakdown of the participants reveals a dominance of Generation X, making up 63% of the respondents. This suggests that this age group will most likely influence the industry's approach to 4IR. The average age of 47 indicates a mature workforce that could offer valuable insights into the adoption and impact of 4IR technologies. The absence of Generation Z from the study could imply their limited presence in managerial roles, which may affect the industry's future approach to technological adoption.
- Seniority and authority.
    - With 87% of respondents holding senior management positions, the study is well-positioned to capture strategic perspectives on 4IR. These insights are invaluable for achieving the research objectives, as senior managers are often the decision-makers in technological adoption. The absence of lower management could indicate that the study focuses more on strategic decision-making than operational levels.
- Related experience.
    - The range of experience among respondents varied from 2 to 28 years, with an average of approximately 16 years. Notably, one respondent had only two years in the ferrochrome industry but had an additional 40 years of experience in mining. This high average suggests a deep-rooted understanding of the industry's challenges and opportunities, which is crucial for the study's aim to explore the impact of 4IR. The diversity in years of experience, including the unique case of the respondent with extensive mining experience, adds a multi-dimensional view to the study. This enriches the analysis and deeply explains how industry experience influences perceptions and attitudes towards 4IR. The insights gained from these experienced professionals will be instrumental in fulfilling the research objectives, drawing meaningful conclusions, and making informed recommendations on the role and impact of 4IR in the ferrochrome industry in South Africa.
- Job title and description.

    - Respondents' diversity in job titles suggests that the study captures various perspectives from different functional areas within the ferrochrome production plant. This is particularly relevant to the study's primary objective, which is to explore the impact of 4IR on a ferrochrome production plant in South Africa. Including various job titles and descriptions will enrich the study's findings, offering a more comprehensive view of how different roles within the organisation perceive and are preparing for the impact of 4IR.
- Understanding of 4IR.
    - The findings indicate a notable discrepancy between general awareness and practical understanding of 4IR technologies within the ferrochrome industry. While participants demonstrated a basic familiarity with the term 4IR and its associated technologies, there was a significant gap in grasping how these technologies could be applied practically in their industry. This lack of in-depth understanding could substantially hinder the effective and meaningful implementation of 4IR technologies in ferrochrome production plants.
    - The study suggests a strong need for targeted educational and training initiatives to bridge this knowledge gap. Such programmes could focus on real-world applications of 4IR technologies in the ferrochrome industry, enhancing the readiness for technological adoption. The alignment of these findings with existing literature indicates that this challenge is not unique to the South African ferrochrome industry but is a common issue that warrants focused attention.
- Industry progress in 4IR.
    - The study reveals that the ferrochrome industry has lagged in making substantial progress in adopting 4IR technologies. Most respondents perceive the global mining sector as being more advanced in this regard than the South African ferrochrome industry. While there have been minor advancements towards automation and mechanisation, the industry has not made significant strides in fully embracing 4IR technologies.

- The findings suggest that the ferrochrome and broader mining industries are trailing but are not entirely left behind compared to tech-leading sectors. These industries have made some progress in digitalisation, automation, and mechanisation, but IoT, Big Data, Machine Learning and Artificial intelligence have not been implemented. Most of these technologies are still in development and were only recently launched to the public. Despite the slow pace of adoption, there is a noticeable lack of targeted research and case studies exploring the practical applications and potential benefits of 4IR technologies within the ferrochrome industry. This indicates an immediate need for more focused discussions and research to accelerate the adoption of 4IR technologies in this industrial context.

- Industry challenges and 4IR's impact on safety, profitability, and sustainability.
  - The study delves into the perceived impact of 4IR technologies on the ferrochrome industry, focusing on safety, profitability, and sustainability. Despite a general lack of detailed understanding of 4IR's specific capabilities, respondents are optimistic about its potential to influence these areas positively. It was clear that respondents did know about the term and the concept of 4IR. However, they could not provide exact details on how it can be implemented in their industry. Some respondents also mentioned that the lack of in-depth understanding of the concept is a barrier to implementing the associated technologies.
  - Respondents are acutely aware of the current challenges facing the ferrochrome industry. These include issues related to electricity supply, cost, reliability, and a volatile regulatory and political environment. Other challenges cited include lacking skills and competencies, volatile commodity prices, and resource availability. The Chinese market's influence, particularly its low-price purchases of UG2 chrome ore, was also mentioned as affecting the industry negatively. This is an important consideration for the ferrochrome industry in South Africa and the entire beneficiation industry and its value chain. Exporting unprocessed minerals is a significant risk for the South African economy. The government approved a detailed and strategic approach towards mineral

beneficiation to leverage the nation's abundant mineralogical assets for economic development, employment creation, and social upliftment.

    - While not all these challenges are directly controllable by the ferrochrome industry, respondents strongly believe that they can be overcome. This indicates some resilience and adaptability within the industry, which could be pivotal for successfully implementing 4IR technologies. The study findings align with broader economic analyses, suggesting that addressing these challenges is crucial for leveraging 4IR to improve safety, profitability, and sustainability in the ferrochrome industry.

- Optimism and readiness for 4IR implementation.
    - The study explores the level of optimism and readiness for 4IR within the ferrochrome industry, focusing on financial feasibility and employee willingness to adapt. The overarching sentiment among respondents is optimistic, and the respondents believe that capital will be available for 4IR projects despite economic challenges. All respondents support 4IR, citing its potential to enhance safety, profitability, and sustainability mainly through better productivity and efficiencies in the industry.
    - However, employees, particularly those affiliated with unions, perceive resistance towards the changes that 4IR would bring. This suggests that the successful implementation of 4IR technologies may require a collective effort involving all stakeholders rather than viewing labour merely as a cost to be reduced.
    - The cost aspect of 4IR implementation is debated among respondents. Opinions are divided on whether implementing these technologies is expensive or affordable. This indicates that while there is optimism and readiness for 4IR, there are still hurdles to overcome, particularly regarding financial feasibility and employee acceptance. The study findings agree that a multi-stakeholder approach may be essential for successfully implementing 4IR in the ferrochrome industry. This approach could be a strategic focus point for companies who want to be early adopters.
- Challenges and success factors for 4IR implementation.

    - The study identifies various challenges and success factors that could influence the successful implementation of 4IR in the ferrochrome industry. While there is a consensus on the benefits of 4IR, several barriers persist, including competency gaps, employee buy-in, and funding constraints. These challenges necessitate a multi-dimensional and comprehensive strategy for successful 4IR adoption.
    - Investment in talent, upskilling or reskilling employees, and organisational culture is critical for successful 4IR implementation. Strategic alignment from the board level downwards is also essential. Quick, iterative actions, guided by well-defined objectives, are recommended to overcome barriers such as skill gaps and employee resistance.
    - The human element is central to overcoming these challenges, which manifests in various forms like employee engagement, training, and understanding of 4IR. The study findings underscore the importance of a human-centric approach in 4IR strategising, suggesting that addressing the human element could be vital to overcoming the identified challenges and ensuring successful 4IR implementation in the ferrochrome industry.
- Future outlook.
    - The study paints a complex but generally optimistic picture of the ferrochrome industry's future, particularly with the actual implementation of 4IR technologies such as ML, AI, IoT, and Big Data. The industry significantly gains safety, efficiency, and profitability if 4IR is adopted. Conversely, the failure to adopt 4IR technologies poses a real risk of long-term closure for ferrochrome plants, making 4IR implementation an option and imperative for the industry's continued viability.
    - Participants agree that the ferrochrome industry could manage to operate for the short-term (next five years) without implementing 4IR. However, they also strongly agree that failing to adopt 4IR in the short-term (within a 10-year timeframe) would jeopardise the industry's long-term viability. Despite this awareness, there is a notable lack of strategic planning to understand and utilise 4IR, highlighting an urgent need for immediate action. Developing a technology roadmap systematically is

essential to mitigate future challenges, including declining efficiency and profitability.

- Navigating this intricate landscape will require a strong, human-centric strategy that considers the challenges and opportunities presented by 4IR. Resistance to change must be managed, and the people must be taken along on the journey to 4IR implementation. The study findings suggest that the industry is at a critical juncture, and the decisions made now regarding 4IR adoption will significantly impact its future.

4.4. RESEARCH ASSESSMENT

This section evaluates how well the study's objectives and research question have been met through the literature review and empirical study. It serves as a checkpoint to ensure alignment between the study's aims and findings.

4.4.1. Primary objective assessment

Primary objective: The primary objective of this study, as described in Section 1.3.1 of this study, is to explore the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.

Assessment: The literature review laid the theoretical groundwork for understanding 4IR's potential impacts on the ferrochrome industry in Section 2.3 and Section 2.4 of this study. The empirical study complemented this by capturing real-world perspectives from industry stakeholders in Section 3.3. Together, these components successfully met the primary objective.

4.4.2. Secondary objectives assessment

Secondary objective 1: A secondary objective of this study, as described in Section 1.3.2, is to determine the readiness of a ferrochrome production plant to implement the fundamentals of the Fourth Industrial Revolution (4IR) into the production processes.

- Assessment: The literature review outlined the key elements required for 4IR readiness in industrial settings in Section 2.6. The empirical study specifically addressed this by capturing the perceptions of readiness among key stakeholders in the ferrochrome industry in Section 3.3. The findings indicate varying levels of readiness, with a focus on the need for upskilling and infrastructure development.

Secondary objective 2: A secondary objective of this study, as described in Section 1.3.2, is to explore the relevance of the Fourth Industrial Revolution (4IR) on the future of a ferrochrome production plant in South Africa.

- Assessment: The literature review discussed the potential relevance of 4IR technologies across industries in Section 2.4. The empirical study focused on the ferrochrome industry, revealing a general optimism about 4IR's relevance in enhancing operational efficiency and sustainability.

Secondary objective 3: A secondary objective of this study, as described in Section 1.3.2, is to use the study's outcome to conclude the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.

- Assessment: The literature review set the theoretical framework for understanding 4IR's impact in Chapter 2, while the empirical study provided real-world data in Section 3.3. Together, these components have been used to draw substantive conclusions on 4IR's potential impact on the ferrochrome industry's safety, profitability, and sustainability.

Secondary objective 4: A secondary objective of this study, as described in Section 1.3.2, is to make recommendations on the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.

- Assessment: Specific recommendations have been formulated based on the insights gathered from the literature review in Chapter 2 and the empirical study in Chapter 3. These recommendations aim to guide the ferrochrome industry in South Africa in effectively implementing 4IR technologies to achieve the desired outcomes.

4.4.3. Research question assessment

Research Question: How does the Fourth Industrial Revolution impact a ferrochrome production plant in South Africa?

- Assessment: The impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa is complex and potentially vital. The literature review provided a theoretical framework, discussing the broader impacts of 4IR technologies, such as automation, data analytics, and IoT, on industries. The empirical study enriched this framework by capturing direct insights from industry professionals in the ferrochrome sector.
- The key impacts identified are as follows:
    - Operational Efficiency: 4IR technologies have the potential to improve operational efficiencies through automation and real-time data analytics significantly.
    - Safety: Advanced technologies can enhance safety measures, reducing workplace accidents and improving working conditions.
    - Profitability: While initial investment costs are a concern, the long-term benefits include reduced operational costs and increased production capabilities, thereby improving profitability.
    - Sustainability: 4IR allows for more sustainable practices, including better waste management and energy efficiency.
    - Workforce: There is a significant impact on the workforce, requiring upskilling and training to adapt to new technologies.
    - Regulatory Compliance: 4IR technologies can aid in better compliance with environmental regulations through real-time monitoring and reporting.
    - Competitive Advantage: Early adoption of 4IR technologies can provide a competitive edge in the global market.
    - Challenges: Despite the benefits, challenges such as a lack of understanding, financial constraints, and resistance from employees were identified.

In summary, the Fourth Industrial Revolution can potentially bring about transformative changes in the ferrochrome industry in South Africa, affecting various aspects, from operations to profitability and sustainability. The implementation of 4IR technologies is not a choice but a necessity. However, successful implementation requires overcoming several challenges, including financial constraints and workforce readiness. Therefore, the impact is substantial but contingent on various internal and external factors.

4.5. LIMITATIONS OF THE STUDY

This study aims to significantly contribute to understanding the impact of the 4IR on a ferrochrome production plant in South Africa. However, it is essential to acknowledge its limitations. A notable constraint is the limited knowledge of previous research on this topic, which could introduce gaps in the study's theoretical foundation.

The study's sample size is confined to one ferrochrome production plant, part of a larger company with multiple smelters. This limitation affects the generalisability of the study's conclusions. It suggests that future research should include a more diverse range of subjects, such as different plants within the same company, different companies, different sectors in beneficiation, and even different countries. Due to this scarcity, caution should be exercised when interpreting the study's findings, particularly given the limited body of knowledge and sample size.

Data access also posed a challenge, as the study focused on a limited number of senior managers. This constraint impacts the depth and breadth of the data collected.

This study serves as a critical exploratory investigation into the effects and promises of 4IR within South Africa's ferrochrome industry. These limitations should be carefully considered because they indicate the need for more comprehensive, larger-scale research within and outside South Africa. Future studies could include a broader and more diverse range of subjects to provide a more thorough understanding.

4.6. RECOMMENDATIONS

The recommendations section is divided into *Practical Industry Recommendations* and *Research Recommendations*. This division aligns with the contributions outlined in Chapter 1, Section 1.4, aiming to provide theoretical and practical insights into the subject matter. The theoretical contributions seek to fill existing knowledge gaps. In contrast, the practical contributions aim to offer actionable insights for the ferrochrome industry in South Africa, particularly in areas like training, safety, profitability, and sustainability. By doing so, the study augments the existing body of knowledge and provides a roadmap for industry stakeholders.

Practical industry recommendations:

- Educational initiatives: Develop targeted educational and training programmes to bridge the identified gap in understanding the practical applications of 4IR within the ferrochrome industry.
- Strategic investment: Make strategic investments in technology and infrastructure to accelerate the implementation of 4IR solutions in line with a well-developed technology roadmap.
- Safety and sustainability: Initiate pilot projects focusing on safety, profitability, and sustainability to validate the optimistic claims surrounding 4IR's potential benefits.
- Employee engagement: Adopt a human-centric approach approved by all stakeholders, including unions, to ensure successful 4IR implementation.
- Regulatory alignment: Engage with policymakers to ensure regulations are conducive to 4IR adoption, given the volatile regulatory and political environment.
- Financial feasibility: Conduct a detailed financial analysis to assess the economic viability of implementing 4IR technologies.
- Resilience and adaptability: Develop strategies to enhance the industry's resilience and adaptability, which are crucial for successfully implementing 4IR technologies.

- Designated champion to drive 4IR in the company: To ensure focused leadership, streamline the implementation process, and accelerate the adoption of new technologies for long-term sustainability and competitiveness.

Research Recommendations:

- Scope expansion: Future research should include multiple plants, companies, sectors in beneficiation, multiple employee levels, and countries to provide a more comprehensive understanding of 4IR's impact on the ferrochrome industry.
- Comparative studies: Given the lack of previous research in this field, further studies are recommended for comparison. These could explore the readiness and impact of 4IR in different sectors or countries.
- In-depth analysis: Due to this study's limited scope and sample size, future research should aim for a more in-depth analysis, possibly incorporating qualitative methods alongside quantitative ones.
- Longitudinal studies: Given the evolving nature of 4IR technologies, longitudinal studies could provide insights into the long-term impacts and effectiveness of these technologies in the ferrochrome industry.

These recommendations provide a structured approach for the industry and researchers to explore, implement, and study 4IR technologies in South Africa's ferrochrome production.

4.7. CONCLUSION

This chapter has provided a comprehensive analysis of the research findings, offering valuable insights into the impact of the 4IR on a ferrochrome production plant in South Africa. The chapter addressed the primary and secondary objectives and research questions, fulfilling the study's aims. The following conclusions based on findings from the research were made.

- Validity: The study employed thorough methodologies to ensure the findings' credibility, transferability, and dependability. The literature review laid a theoretical foundation, while the empirical study offered specific, industry-focused data.

- Findings: The study's key findings indicate a general awareness but a notable gap in understanding the practical applications of 4IR within the ferrochrome industry. The industry's progress in 4IR is still in emerging stages. However, the potential for a positive impact on safety, profitability, and sustainability is evident. The importance of implementing 4IR technologies is underscored by the ferrochrome sector's critical role in South Africa's economy. Given the industry's significance, adopting 4IR is beneficial and essential for its continued viability in South Africa. The sector's importance extends beyond economic contributions to include social aspects like employment, making its modernisation crucial for the country's overall well-being.
- Research Assessment: Both the literature review and empirical study effectively met the primary and secondary objectives. They also provided an answer to the research question, thus fulfilling the study's purpose.
- Limitations: The study was not without its limitations, including a limited sample size, restricted geographical scope, and a lack of prior research in this specific area. These limitations suggest avenues for future research, which could involve a broader geographical area, multiple companies, and different sectors in beneficiation.
- Recommendations: The study offered both research and practical industry recommendations. These aligned with the theoretical and practical contributions outlined in Chapter 1, focusing on training, safety, profitability, and sustainability.

Adopting Fourth Industrial Revolution (4IR) technologies is not a luxury but a necessity for the ferrochrome industry to remain competitive and sustainable. While the industry has shown efficiency improvements, it faces mounting pressures that are not solely operational but also environmental, social, and political. Constraints on essential resources like water, electricity, and raw materials are expected to tighten, and regulatory pressures related to environmental sustainability are on the rise. Additionally, the industry must navigate a complex social and political landscape that poses challenges. The 4IR offers transformative solutions to help the industry adapt and thrive in this context. Being early adopters of these technologies is advantageous and essential for future-proofing the industry. Failure to integrate 4IR into strategic planning and operations could jeopardise the industry's long-term viability.

In conclusion, this study serves as an exploratory investigation into the effects and promises of 4IR within the ferrochrome industry in South Africa. While it has its limitations, it opens the door for future, larger-scale research that could offer a more comprehensive understanding of 4IR's impact on the industry. The recommendations aim to guide academic and industry stakeholders in navigating the complexities of 4IR implementation.

REFERENCE LIST

Acemoglu, D. and Restrepo, P. 2020. Robots and jobs: Evidence from US labour markets. *Journal of Political Economy*, 128(6): 2188-2244.

Arntz, M., Gregory, T. and Zierahn, U. 2017. Revisiting the risk of automation. *Economics Letters*, 159:157-160.

ASCIR. (2023). *How Fourth Industrial Revolution can aid sustainable development in African cities: Lessons from China*. Available at: https://ascir.org/2023/01/21/how-fourth-industrial-revolution-can-aid-sustainable-development-in-african-cities-lessons-from-china/ [Accessed: 27 Aug. 2023].

Babbie, E.R. (2016). *The practice of social research*. 14th ed. Boston, MA: Cengage Learning.

Backeberg, N.A., Bedder, J. & Sardain, E. 2021. *Bulk and stainless ferroalloys markets: Fundamentals, trends and forecasts. Trends and Forecasts.* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3927686 [Accessed: 27 Aug. 2023].

Basson, J., Curr, T. & Gericke, W. 2007. *South Africa's Ferroalloys industry-present status and future outlook*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://scholar.sun.ac.za/server/api/core/bitstreams/ab12c357-b252-46fd-a432-462c7b43f552/content [Accessed: 21 Aug. 2023].

Beattie, A. 2023. *Three pillars of corporate sustainability.* Investopedia. https://www.investopedia.com/articles/investing/100515/three-pillars-corporate-sustainability.asp [Accessed: 27 Aug. 2023].

Betti, F., de Boer, E. & Giraud, Y. (2021). *Lighthouses unlock sustainability through 4IR technologies*. McKinsey & Company.

https://www.mckinsey.com/capabilities/operations/our-insights/lighthouses-unlock-sustainability-through-4ir-technologies#/ [Accessed: 27 Aug. 2023].

Bhorat, H., Ewinyu, A., Lilenstein, K., Rooney, C., Steenkamp, F. & Thornton, A. 2019. *Economic complexity and employment expansion: The case of South Africa*. https://ideas.repec.org/p/ctw/wpaper/201905.html [Accessed: 27 Aug. 2023].

Bloem, J., Van Doorn, M., Duivestein, S., Excoffier, D., Maas, R. and Van Ommeren, E. 2014. The Fourth Industrial Revolution. *Things Tighten*, *8*(1):11-15.

Bryman, A., Bell, E., Hirschsohn, P., Dos Santos, A., Du Toit, J., Masenge, A., Van Aardt, I. & Wagner, C. (2014). *Research methodology: Business and management contexts*. Cape Town: Oxford University.

Bughin, J., Hazan, E., Lund, S., Dahlström, P., Wiesinger, A. & Subramaniam, A. 2018. *Skill shift: Automation and the future of the workforce*. New York, NY: McKinsey Global Institute.

Cai, Y., van Joolingen, W. & Veermans, K. eds. 2021. *Virtual and augmented reality, simulation and serious games for education.* Singapore: Springer.

Chen, M., Mao, S. & Liu, Y. 2014. Big data: A survey. *Mobile Networks and Applications*, 19(2):171-209.

Chui, M., Manyika, J., Miremadi, M., Henke, N., Chung, R., Nel, P. & Malhotra, S. 2018. *Notes from the AI frontier: Insights from hundreds of use cases*. New Yorek, NY: McKinsey Global Institute.

Çınar, Z.M., Abdussalam Nuhu, A., Zeeshan, Q., Korhan, O., Asmael, M. and Safaei, B. 2020. Machine learning in predictive maintenance towards sustainable smart manufacturing in industry 4.0. *Sustainability*, 12(19):8211-8221.

Creamer, M. 2021a. *Glencore ferrochrome business evaluating clean energy projects.* https://www.engineeringnews.co.za/article/glencore-ferrochrome-business-evaluating-clean-energy-projects-2021-02-17/rep_id:4136 [Accessed: 4 April 2023].

Creamer, M. 2021b. *Ferrochrome is part of the green revolution*. Glencore. https://www.miningweekly.com/article/ferrochrome-is-part-of-the-green-revolution-glencore-2021-08-06 [Accessed: 3 April 2023].

de Andres Gonzalez, O., Koivisto, H., Mustonen, J.M. & Keinänen-Toivola, M.M. 2021. Digitalisation in just-in-time approach as a sustainable solution for maritime logistics in the Baltic sea region. *Sustainability,* 13(3):1159-1173.

Department of Mineral Resources. (2023). *Beneficiation economics*. https://www.dmr.gov.za/mineral-policy-promotion/beneficiation-economics [Accessed: 23 Sep. 2023]

Diale, C.D., Kanakana-Katumba, M.G., Maladzhi, R.W., von der Ohe, H., Diale, C.D. & Kanakana-Katumba, G.M. 2022. *Ecosystem for 4th Industrial Revolution to Accelerate Sustainable Development Goals in the South African Context: A Conceptual Framework.* Nsukka: IEOM Society.

Dlamini, R. and von Blottnitz, H. 2023. Resource Intensity Trends in the South African ferrochrome industry from 2007 to 2020. *Minerals,* 13(1):44-58.

du Preez, S.P., van Kaam, T.P., Ringdalen, E., Tangstad, M., Morita, K., Bessarabov, D.G., van Zyl, P.G. and Beukes, J.P. 2023. An overview of currently applied ferrochrome production processes and their waste management practices. *Minerals*, 13(6):809-820.

Forti, V., Balde, C.P., Kuehr, R. & Bel, G. 2020. *The Global E-waste Monitor 2020:* Quantities, flows and the circular economy potential. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf [Accessed: 10 Oct. 2023].

Fuso, N., F., Sovacool, B., Hughes, N., Cozzi, L., Cosgrave, E., Howells, M., Tavoni, M., Tomei, J., Zerriffi, H. & Milligan, B. 2019. Connecting climate action with other Sustainable Development Goals. *Nature Sustainability*, 2(8):674-680.

Gibson, I., Rosen, D.W., Stucker, B., Khorasani, M., Rosen, D., Stucker, B. & Khorasani, M. 2021. *Additive manufacturing technologies*, 17:160-186).

Hall, S. & Takahashi, R. 2017, September. Augmented and virtual reality: The promise and peril of immersive technologies. *World Economic Forum*, 2:1065-1069.

Hooker, J. & Kim, T.W. 2019. *Ethical implications of the Fourth Industrial Revolution for business and society*. London: Emerald.

Jegede, O. 2021. *South Africa's capacity to deploy Fourth Industrial Revolution technologies post-COVID-19*. https://www.unido.org/stories/south-africas-capacity-deploy-fourth-industrial-revolution-technologies-post-covid-19 [Accessed: Date 9 Aug. 2023].

Kagermann, H. and Wahlster, W. 2022. Ten years of Industrie 4.0. *Science*, 4(3):13-26.

Karaś, H. 2020. *Why robotics in mining*. Euromines, https://euromines.org/system/files/events/pushing-boundaries-beyond-circular-2020/08-henryk-karas.pdf [Accessed: 10 may 2023].

Kruger, S. & Steyn, A.A. 2023. Leveraging technology adoption to navigate the 4IR towards a future-ready business: A systematic literature review. *Engineering Reports*, p.e12762.

Lasi, H., Fettke, P., Kemper, H.G., Feld, T. & Hoffmann, M. 2014. Industry 4.0. *Business & Information Systems Engineering*, 6:239-242.

Letaba, P.T. & Zulu, S. 2021. The development of a technology roadmap for ferrochrome producers. South African *Journal of Industrial Engineering*, 32(2):100-109.

Letourneau-Guillon, L., Camirand, D., Guilbert, F. and Forghani, R. 2020. Artificial intelligence applications for workflow, process optimisation and predictive analytics. *Neuroimaging Clinics*, 30(4):e1-e15

Levin, S. 2018. *World Economic Forum and the Fourth Industrial Revolution in South Africa*. Trade & Industrial Policy Strategy. Pretoria: TIPS.

Liedtke, S. 2021. *South African ferrochrome industry 'running out of time' as it fights for survival, sustainability*. Engineering News. Available at: https://www.engineeringnews.co.za/print-version/south-african-ferrochrome-industry-running-out-of-time-as-it-fights-for-survival-sustainability-2021-04-13 [Accessed 9 August 2023].

Lind, B.B., Fällman, A.M. and Larsson, L.B. 2001. Environmental impact of ferrochrome slag in road construction. *Waste Management*, 21(3):255-264.

Lotriet, R.A., Rossouw, J., Grater, S., Campbell, Q., Croucamp, P., Idsardi, E. & van Dyk, H. 2022. *A Case Study Analysis of The South African Chrome-Ferrochrome Industry*. In: 2022 International Business Conference (p. 501). Potchefsdtrtoom: NWU.

McAfee, A. and Brynjolfsson, E. 2017. The business of artificial intelligence. *Havard,* 110(4):1-20.

McKinsey & Company 2023b. *What are Industry 4.0, the Fourth Industrial Revolution, and 4IR?* McKinsey & Company. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir [Accessed 9 August 2023].

McKinsey & Company. 2023a. *Rewired in action case collection*. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/how%20we%20help%20clients/rewired%20in%20action/pdfs/rewired%20in%20action%20case%20collection.pdf [Accessed: 27 Aug. 2023].

Mhlanga, D. 2022. Stakeholder capitalism, the Fourth Industrial Revolution (4IR), and sustainable development: issues to be resolved. *Sustainability*, 14(7): 3899-3902.

Miller, J. 2023. Data-driven decisions: Leveraging analytics to drive business. [online] LinkedIn. Available at: https://www.linkedin.com/pulse/data-driven-decisions-leveraging-analytics-drive-business-miller [Accessed: 9 Aug. 2023].

Mining Technology 2022. Robotics: The future of mining. Mining-technology.com. https://www.mining-technology.com/comment/robotics-future-mining/ [Accessed: 9 Aug. 2023].

Mokyr, J., Vickers, C. and Ziebarth, N.L. 2015. The history of technological anxiety and the future of economic growth: Is this time different? *Journal of Economic Perspectives*, 29(3):31-50.

Mutanga, S.S., Hongoro, C., Kaggwa, M., Chavalala, B., Pitso, T., Mohlala, S., Siame, J., Sichilima, S. & Tshililo, F. 2021. *The 4th Industrial Revolution and its Implications for Mining-dependent Countries: Insights from South Africa and Zambia*. Pretoria: HSTRC.

Okpala, I., Parajuli, A., Nnaji, C. & Awolusi, I. 2020, March. *Assessing the feasibility of integrating the Internet of Things into safety management systems: a focus on wearable sensing devices.* In: Construction Research Congress 2020 (pp. 236-245). Reston, VA: American Society of Civil Engineers.

Parliamentary Monitoring Group. 2020. *Challenges facing the ferrochrome and cement industries Meeting Summary. Parliamentary Monitoring Group*. https://pmg.org.za/committee-meeting/31316/ [Accessed: 9 Aug. 2023]

Particle. 2023. *The Top 5 applications for industrial IoT*. https://www.particle.io/iot-guides-and-resources/industrial-iot-applications/ [Accessed: Date 9 Aug. 2023].

Pellegrini, G. 2019. Successful use case applications of artificial intelligence in the steel industry. Iron & Steel Technology (AIST), *Digital Transformations*, 2019: 44-53.

Pratt, M.K. 2023. *Top 12 IoT applications and examples in business. [online] TechTarget IoT Agenda*. https://www.techtarget.com/iotagenda/tip/Top-8-IoT-applications-and-examples-in-business [Accessed 8 Aug. 2023].

PwC. 2017. *Fourth Industrial Revolution for the Earth: Harnessing the 4th Industrial Revolution for Sustainable Emerging Cities*. https://www.pwc.com/gx/en/sustainability/assets/4ir-for-the-earth.pdf [Accessed: 27 Aug. 2023].

Rahi, S. 2017. Research design and methods: A systematic review of research paradigms, sampling issues and instruments development. *International Journal of Economics & Management Sciences*, 6(2):1-5.

Rasool, F. & Botha, C.J. 2011. The nature, extent and effect of skills shortages on skills migration in South Africa. *SA Journal of Human Resource Management*, 9(1):1-12.

Rodrigues, J.F., Florea, L., de Oliveira, M.C., Diamond, D. & Oliveira, O.N. 2021. Big data and machine learning for materials science. *Discover Materials*, 1:1-27.

Saunders, M., Lewis, P. & Thornhill, A. 2016. *Research methods for business students.* 7th ed. Harlow: Pearson.

Saunders, M., Lewis, P. & Thornhill, A. 2019. *Research methods for business students*. 8th ed. Harlow: Pearson.

Schwab, K. 2017. *The Fourth Industrial Revolution*. Currency. Geneva: World Economic Forum.

Serumaga-Zake, J.M. & van der Poll, J.A. 2021. Addressing the impact of Fourth Industrial Revolution on South African manufacturing small and medium enterprises (SMEs). *Sustainability*,13(21):11703-11712.

Siciliano, B., Khatib, O. & Kröger, T. eds. 2008. *Springer handbook of robotics.* Vol. 200. Berlin: springer.

Siekmann, F., Schlör, H. & Venghaus, S. 2023. Linking sustainability and the Fourth Industrial Revolution: A monitoring framework accounting for technological development. *Energy, Sustainability and Society*, 13(1):1-18.

Smith, W., Maier, W., Barnes, S., Moorhead, G., Reid, D. & Karykowski, B. 2021. Element mapping the Merensky Reef of the Bushveld Complex. *Geoscience Frontiers*, 12(3):101101-101115.

Soori, M., Arezoo, B. & Dastres, R. 2023. Artificial intelligence, machine learning and deep learning in advanced robotics, A review. *Cognitive Robotics*, 3:54-70

Stahl, N.A. & King, J.R. 2020. Expanding approaches for research: Understanding and using trustworthiness in qualitative research. *Journal of Developmental Education*, 44(1):26-28.

Stungwa, S. & Daw, O.D. 2021. Infrastructure development and population growth on economic growth in South Africa. Potchefstroom: NWU.

Suryadi, B., Larasati, A.S., Verniastika, R. and Firdaus, S.N. 2022. Harnessing Fourth Industrial Revolution (4IR) technologies for climate change mitigation in the Asia-Pacific region. Delhi: Asian and Pacific Centre for Transfer of Technology.

The Steel Printers. 2023. *An analysis of the impact of additive manufacturing in the mining industry.* TheSteelPrinters.com. https://www.thesteelprinters.com/news/an-analysis-of-the-impact-of-additive-manufacturing-in-the-mining-industry [Accessed: 8 Aug. 2023].

United Nations Industrial Development Organisation (UNIDO). 2021. *Propelling LDCs in the digital age: A 4IR perspective for sustainable development*. Fifth United Nations Conference on Least Developed Countries (LDC5). Vienna, Austria. https://www.un.org/technologybank/sites/www.un.org.technologybank/files/4ir_ldc_v_1.20-single_page_version.pdf [Accessed: 27 Aug. 2023].

Van der Lingen, E. & Paton, A. 2018. Market implications for technology acquisition modes in the South African ferrochrome context. *Journal of the Southern African Institute of Mining and Metallurgy*, 118(10):1087-1094.

Vasileiou, K., Barnett, J., Thorpe, S. & Young, T. 2018. Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. *British Medical Research Journal,* 18(148):1-25.

World Economic Forum. 2019. *Leading through the Fourth Industrial Revolution*. Geneva: World Economic Forum. https://www3.weforum.org/docs/WEF_Leading_through_the_Fourth_Industrial_Revolution.pdf [Accessed 9 Aug. 2023].

Xu, M., David, J.M. & Kim, S.H. 2018. The Fourth Industrial Revolution: Opportunities and challenges*. International Journal of Financial Research*, 9(2):90-95.

Zulu, M.S., Pretorius, M.W. and van der Lingen, E. 2021. Strategic competitiveness of the South African mining industry in the age of the Fourth Industrial Revolution. *South African Journal of Industrial Engineering,* 32(3):185-200.

APPENDICES

APPENDIX A: SEMI-STRUCTURED INTERVIEW PROTOCOL

Exploring the impact of the Fourth Industrial Revolution (4IR) on a ferrochrome production plant in South Africa.

Semi-Structured Interview Protocol:

Section A aims to collect demographic information from the interview participants. This information is important for the study to analyse potential correlations between the impact of the Fourth Industrial Revolution (4IR) and different demographic factors such as generation categories, workplace seniority/authority, and relevant experience. By understanding the participants' demographics, you can identify potential response patterns or variations based on these factors.

Section B, on the other hand, focuses specifically on exploring the participants' knowledge, perceptions, and experiences related to the fundamental aspects of 4IR (artificial intelligence, machine learning, robots, self-driving vehicles, and the Internet of Things) and its integration into the ferrochrome industry. The questions in this section delve into various aspects such as familiarity with 4IR, the industry's progress in incorporating 4IR technologies, the perceived impact of these technologies on safety, profitability, and sustainability, the readiness of employees for changes associated with 4IR, challenges and changes expected in the industry, and opinions on the implementation of 4IR. This section aims to gather rich qualitative data directly related to the research objective of examining the impact of 4IR on the ferrochrome production plant in South Africa

Section A: Demographic Information:

Question 1

What is your age?

Baby Boomer Generation X Generation Y Generation Z

1946-1964 1965-1980 1981-1996 1997 onwards

Question 2

Are you in a lower management, middle management, or senior management position, and how many years of experience do you have in the ferrochrome industry?

Question 3

What is your job title and give a brief overview of your job description.

Section B: 4IR and Ferrochrome Information:

Question 4

Are you familiar with the term "Fourth Industrial Revolution" (4IR)?

Question 5

If yes to Question 4, can you explain what you understand under the term 4IR? If no to Question 4, end of the interview.

Question 6

Do you think the ferrochrome industry has made significant progress in incorporating the fundamental aspects (artificial intelligence, machine learning, robots, self-driving vehicles, and the Internet of Things) of 4IR in the industry? Please elaborate with examples.

Question 7

Do you believe that the fundamental aspects (mentioned in Question 6) of 4IR are critical to the ferrochrome industry's safety, profitability, and sustainability? Please elaborate.

Question 8

Do you believe the implementation of 4IR in the industry will be expensive, and will the required capital be readily available?

Question 9

Do you believe the employees are ready to embrace the changes associated with 4IR in the workplace, and will they be open to training and development related to 4IR?

Question 10

What challenges will determine the future of a ferrochrome company in South Africa, and do you think these challenges can be overcome, and will 4IR help to overcome this? Please elaborate on your answer.

Question 11

How much progress have other ferrochrome smelting companies made regarding 4IR in the area where you operate?

Question 12

How much progress has the mining sector made regarding 4IR in South Africa and Worldwide?

Question 13

What do you think the top 3 challenges would be to fully embrace and implement the fundamental aspects of 4IR in the ferrochrome industry in South Africa?

Question 14

What key changes do you expect in a ferrochrome smelting company when 4IR is fully implemented?

Question 15

Why would you support or not support 4IR in the ferrochrome industry?

Question 16

If 4IR is not implemented in the ferrochrome industry, where do you see the South African ferrochrome industry 5 (short-term) and 10 (long-term) years from now?

Question 17

What factors do you believe will be crucial for successfully implementing the Fourth Industrial Revolution (4IR) in the ferrochrome industry in South Africa?

APPENDIX B: COMPANY PERMISSION LETTER

Permission to Conduct Research
North West University – South Africa
Master in Business Administration

Title of the Study: Exploring the impact of the fourth industrial revolution (4IR) on a ferrochrome production plant in South Africa.

Researcher: Gerrie Fouche

<u>Permission to Conduct the Research at Glencore</u>

Dear Christof,

As you are aware, I am in the process of studying towards a Master's Degree in Business Administration at North-West University.

I would like to do the research at Glencore. The information gathered in this study will be used in a mini dissertation to complete my MBA degree. The primary objective of this study is to explore the impact of the fourth industrial revolution (4IR) on the future of ferrochrome production in South Africa.

The research will entail collecting data from various levels of management. If they agree they will be requested to take part in semi-structured interviews. The interviews will take no longer than 40 minutes and will be scheduled on an appropriate date for the participants and the organisation. All responses will be confidential, and the identities of participants will remain anonymous. I will ensure that I do not refer to "Glencore" but rather use coding such as "the smelting company".

1

The results can be communicated if you are interested in the outcome of the research study.

I, therefore, request official permission in writing to conduct my research at Glencore. Please complete the below table and let me know if you require any further information. I look forward to your response as soon as is convenient.

Thanks in advance,
Gerrie Fouche

Approved	Name	Surname	Company	Designation	Date	Signature
Yes	Christof	Bester	Glencore	General Manager		[illegible]

DocuSign

APPENDIX C: NWU CONSENT FORM

Informed Consent
North-West University – South Africa
Master in Business Administration

Title of the Study: Exploring the impact of the fourth industrial revolution (4IR) on a ferrochrome production plant in South Africa.

Researcher (email): Gerrie Fouche (gerrfou@gmail.com)
Study Leader (email): Prof Ronnie Lotriet (ronnie.rotriet@nwu.ac.za)

Dear Participant,

This informed consent form is an agreement between the researcher and the respondent participating in the semi-structured interviews. The information gathered in this study will be used in a mini dissertation to complete my MBA degree. The primary objective of this study is to explore the impact of the fourth industrial revolution (4IR) on the future of ferrochrome production in South Africa.

All the information gathered in the interview will be confidential. The data obtained will be used only in this research project. The data will be stored on a password-protected laptop. The data will be permanently destroyed within 12 months of collection. The outcomes of the study will be published and stored at North-West University. There will be no incentive given to participants, who willingly agree to participate in the study. The interview will be recorded, and a participant can terminate the interview at any time if he or she feels like it. The researcher will follow the regulations of POPIA. The interview will take 40min or less and any complaints can be sent to the researcher.

Participant Signature: ____________________ Date: ____________________

Researcher Signature: ____________________ Date: ____________________

APPENDIX D: ETHICAL CLEARANCE

Private Bag X1290, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Fax: 018 299-4910
Web: http://www.nwu.ac.za

Senate Committee for Research Ethics
Tel: 018 299-484
Feziwe.Mseleni@nwu.ac.za

1 June 2023

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the **Economic and Management Sciences Research Ethics Committee (EMS-REC)** on, 23/05/2023 the Economic and Management Sciences Research Ethics Committee hereby approves your study as indicated below. This implies that the North-West University Senate Committee for Research Ethics (NWU-REC) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Exploring the impact of the fourth industrial revolution (4IR) on a ferrochrome production plant in South Africa.

Study Leader/Supervisor (Principal Investigator)/Researcher): Prof R Lotriet

Student: GJ Fouche (22755349)

N	W	U	-	0	0	5	9	5	-	2	3	-	A	4
Institution				Study Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type:
Commencement date: 1/06/2023 **Risk:** **Minimal**
Expiry date: 1/06/2024
Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special in process conditions of the research for approval (if applicable):

-

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The study leader/supervisor (principle investigator)/researcher must report in the prescribed format to the EMS-REC:*
  - *annually (or as otherwise requested) on the monitoring of the study, whereby a letter of continuation will be provided, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the study leader/researcher must apply for approval of these amendments at the EMS-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*

- *Annually a number of studies may be randomly selected for an external audit.*
- *The date of approval indicates the first date that the study may be started.*

n the interest of ethical responsibility, the NWU-SCRE and EMS-REC reserves the right to:

- *request access to any information or data at any time during the course or after completion of the study;*
- *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
- *withdraw or postpone approval if:*
  - *any unethical principles or practices of the study are revealed or suspected;*
  - *it becomes apparent that any relevant information was withheld from the EMS-REC or that information has been false or misrepresented;*
  - *submission of the annual (or otherwise stipulated) monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and / or*
  - *new institutional rules, national legislation or international conventions deem it necessary.*

The EMS-REC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the EMS-REC or the NWU-SCRE for any further enquiries or requests for assistance.

Yours sincerely,

Mark Rathbone

Digitally signed by Mark Rathbone
DN: cn=Mark Rathbone, o=North-West University, ou=Business management, email=mark.rathbone@nwu.ac.za, c=ZA
Date: 2023.06.05 12:23:33 +02'00'

Prof Mark Rathbone
Chairperson: NWU Economic and Management Sciences Research Ethics Committee

APPENDIX E: PROOF OF LANGUAGE EDITING

Dynamic Language & Translation Specialists

Antoinette Bisschoff
71 Esselen Street,
Potchefstroom
Tel: 018 293 3046
Cell: 082 878 5183
Language@dlts.co.za
CC No: 1995/017794/23

Thursday, 26 October 2023

To whom it may concern

Re: Confirmation of language edit, typography and technical precision

The MBA mini-dissertation "**Exploring the impact of the fourth industrial revolution on a ferrochrome production plant in South Africa**" by **GJ Fouche** (22755349) was edited for language and technical precision. Referencing and sources were checked to comply with the Harvard guidelines specified by the 2020 NWU Reference Guide.

Final, last-minute corrections remain the responsibility of the author.

Antoinette Bisschoff

BA Languages (UPE – now NMU); MBA (PU for CHE – now NWU); Translation and Linguistic Studies (NWU)

Officially approved language editor of the NWU since 1998
Member of SA Translators Institute (no. 100181)

Precision ... to the last letter