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# Investigating the flow of information in a surface iron ore mining operation

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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF MECHANICAL, INDUSTRIAL & AERONAUTICAL ENGINEERING

**INDIVIDUAL DECLARATION WITH TASK SUBMITTED FOR ASSESSMENT**

I **Loeto Levious Sekwati** student number 1433284

am registered for MECN7018A – Research Project in the year 2023

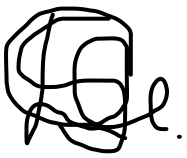
I herewith submit the following task:

"**Investigating the flow of information in a surface iron ore mining operation".**

in partial fulfilment or full fulfilment of the requirements of the above course.

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- This task has not been submitted before, either individually or jointly, for any course requirement, examination or degree at this or any other tertiary educational institution;
- I have followed the required conventions in referencing the thoughts and ideas of others;
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- unaided work or that we have failed to acknowledge the sources of the ideas or words in our writing in this task.
- I have completed and passed the SPC plagiarism test for 2023.

**Signed**  **Signed this day of** 2024/10/18.

## DEDICATION

I dedicate this research to my partner, Tshwanelo Witbooi. I will forever be grateful for your unwavering support. I will forever be grateful for your sources of strength. Thank you for always motivating and inspiring me during this journey to obtain and achieve this milestone. The biggest milestone is indeed completed and Also, to my caring and loving mother, Bontleeng Hilda Sekwati, “umuntu ngumuntu ngabantu”.

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## NOMENCLATURE

| | |
|---|---|
| KPI | Key Performance Indicators |
| GDP | Gross Domestic Product |
| IDC | Industrial Development Cooperation |
| Fe | Iron |
| DMS | Dense Media Separation |
| Mt | Million tonnes |
| LTIFR | Lost Time Injury Frequency Rate |
| R/t | Rand per tonne |
| Km | Kilometre |
| LOM | Life of Mine |
| HME | Heavy Mining Equipment |
| RCFA | Root Cause Failure Analysis |
| LOMP | Life of Mine Plan |
| SOA | Strategic Option Analysis |
| RMF | Risk Management Framework |
| TA | Thematic Analysis |
| FOG | Fall of Ground |
| MIOC | Management of Change |
| MHSA | Mine Health Safety Act |
| BME | Bulk Mining Explosive |
| % | Percentage |
| dB | Decibel |
| CAIS | Centralised and Integrated System |

# CHAPTER 1

# 1. INTRODUCTION

## 1.1. Background

The South African Mining Industry is the fifth largest in terms of the Gross Domestic Product (GDP). The industry contributes approximately 8% of the GDP with direct employment of close to half a million people(Moncks *et al.*, 2023). Kumba Iron Ore is a member of the Anglo-American Group. Anglo American Group is the majority shareholder with 63.4% stake while the rest of the shares are divided between Industrial Development Corporation (IDC) and other minority shareholders. Kumba Iron Ore is the leading supplier of high-quality iron ore to the customers which include the steelmaking industry within and beyond the borders of South Africa. The company specialises in the "exploration, mining, processing and blending, shipping, marketing and selling of iron ore"(Anglo-American, 2023).

As a member of the London and Johannesburg Stock Exchange, Kumba Iron Ore exports high-quality iron ore to countries such as China, Japan, Korea, India and other several European and Middle Eastern countries(African Mining IQ, 2022). Kumba Iron Ore has two mining operations in the Northern Cape, which are Kolomela Mine in Postmasburg and Sishen Mine in Kathu and a port in Saldanha Bay. The mining operations and the iron ore port are connected by a railway which is 861 kilometres long(African Mining IQ, 2022). Kumba Iron Ore high-quality Iron Ore is mainly used for making steel used in train tracks, infrastructure and other materials used in engineering and construction(Anglo-American, 2023). Iron ore is mostly favoured by international customers due to its high iron "(Fe) composition, small size lump ore, low dust generation, good thermal shock resistance, does not break easily" and mostly because it improves plant productivity(African Mining IQ, 2022).

## 1.2. Contexts: Anglo-American Kumba Iron Ore-Sishen Mine

The South African iron ore industry has been dominantly controlled by Kumba Iron Ore and Assmang Iron Ore. These players account for up to 90% of the country's Iron Ore production. The two major players are operating four operations in the Northern Cape namely Sishen, Kolomela, Khumani and Beeshooek Mine. Sishen Mine is one of the oldest Iron Ore mines in the Northern Cape turning 70 years old (in 2023) and currently has a Life of Mine of 14 years. Sishen Mine account for 90% of Kumba Iron Ore production. Iron ore production is done through the open-cast mining method using shovels and trucks. The lumps and fines are processed through dense medium separation (DMS) and JIG beneficiation plants. The final

product is then transported to Saldanha Bay Port through the Transnet Freight Rail(Ratshomo, 2014).

In 2022, the mine achieved its production target of 196.2 Mt which included the ex-pit ore of 36.4 Mt with a lump-to-fine ratio of 69:31 and a stripping ratio of 4:0. The Sishen Mine has not had any fatality since 2016 and currently has a lost time injury frequency rate (LTIFR) of 0.87. The Mine is ranked in the third quarter of the cost curve graph, and this means that it is one of the high-cost operating mines as compared to its peers. An advantage has always been a good iron ore price and a weak dollar and rand exchange rand rate resulting in a unit cash cost of R479/tonne. Sishen Mine comprises 4 293 full-time permanent employees and 3 290 contractors(Kumba Iron Ore, 2022).

The mining industry in the northern cape has mainly been restricted to copper and diamond for years, but since the inception of industrialization in the 21$^{st}$ century the industry has moved into mining other mineral resources such as iron ore and manganese(Mineral Council of South Africa, 2019). The iron ore sector has contributed to and developed the Northern Cape rural areas. Being one of the oldest Iron Ore Mine, Sishen Mine has contributed significantly to the Northern Cape Government and has assisted in developing the local areas including Kathu, and Kuruman. It is one the largest iron ore mines in the country employing close to 12 000 people (Anglo-American, 2023). It is also one of the largest open-cast mines in the world with 3.2 km width and 14 km length (Anglo-American, 2023). The vision and mission of Sishen Mine has always been to be the Anglo-American Flagship mine through producing high-quality iron ore safely, efficiently, and effectively.

As one of the largest iron ore mines in Africa, Sishen Mine's value chain is very complex and made up of a large number of external, and internal sections which are either directly or indirectly involved in the production of iron ore (Kumba Iron Ore, 2011). Due to the complexity of the Sishen Mine structure, there is a significant number of concepts within Sishen and Kumba Iron Ore that have been extensively researched and some that have the potential to be researched. But for this research, the scope of the area will be very tight. The area of scope covered for this research will be the flow of information within and between the three departments that are directly involved in the safe, efficient, and effective production of Iron Ore. Those departments include the mining operations department which is responsible for actual production, engineering maintenance department which is responsible for maintaining the equipment and lastly the mine technical service department which is responsible for planning and ensuring compliance (Kumba Iron Ore, 2016).

## 1.3. Problem Statement

Being one of the largest iron ore open cast in the Northern Cape, Sishen Mine operates using a significant number of resources including large types of equipment such as shovels and trucks, smaller types of equipment such as dozers and graders, autonomous fleets and processes, systems, and people. As a result, there are many interlinks between all these processes, people, and systems. The mining system has a high complexity with many interactions and interlinks between the system elements (people, systems, processes and equipment). The interlinks between these elements illustrate the flow of information between those elements.

The quality flow of information between different sections, departments, tools, systems, and processes throughout the mine value chain in a mining operation is highly critical in ensuring that, the mining activities are done as per the required specifications on time with the highest quality possible. The operation value chain is made up of several sections including block preparation and scaling, staking, drilling, blasting, loading, hauling, and plant feed. These sections occur in sequence. The upstream section receives information from the downstream sections, using the information to complete their task and in return pass the output of their task to the next upstream section. e.g. The upstream work management section collects geology, survey and geotechnical information from all downstream sections and compiles a 12-week plan. The 12-week plan flows to the mining operation to stipulate when the production block must be prepared, drilled and blasted. The block preparation section in the mining operation gets the plan stipulating the start time and duration of the block preparation activity and uses all the resources (equipment and people) needed to complete block preparation on that specific block. The block preparations get information from the downstream section such as survey and mine activity design(Kumba Iron Ore, 2016).

The output of the block preparations sections is a fully prepared block ready for drilling. Once this is done the block is handed over to drilling sections. The drilling section receives a prepared block and other additional information such as drilling plans, hole lengths, collar dimensions and patterns from the drill and blast technical section. The drilling section uses this information to drill the block. Once the block has been drilled it then goes through the handover process to the blasting section and during this process that is where quality is checked. If the block passes all the quality checks it is then ready to be charged and blasted. The blasting section received a drilled block and then proceeded to charge blast it and hand it over to the loading section. The loading section receives a blasted block, which then loads and hauls the material to feed the plant crusher(Kumba Iron Ore, 2016). During this mining

value chain process, there is a flow of information flowing from one section to the other and this is illustrated in **Figure 1**(Mikkela, 2014).

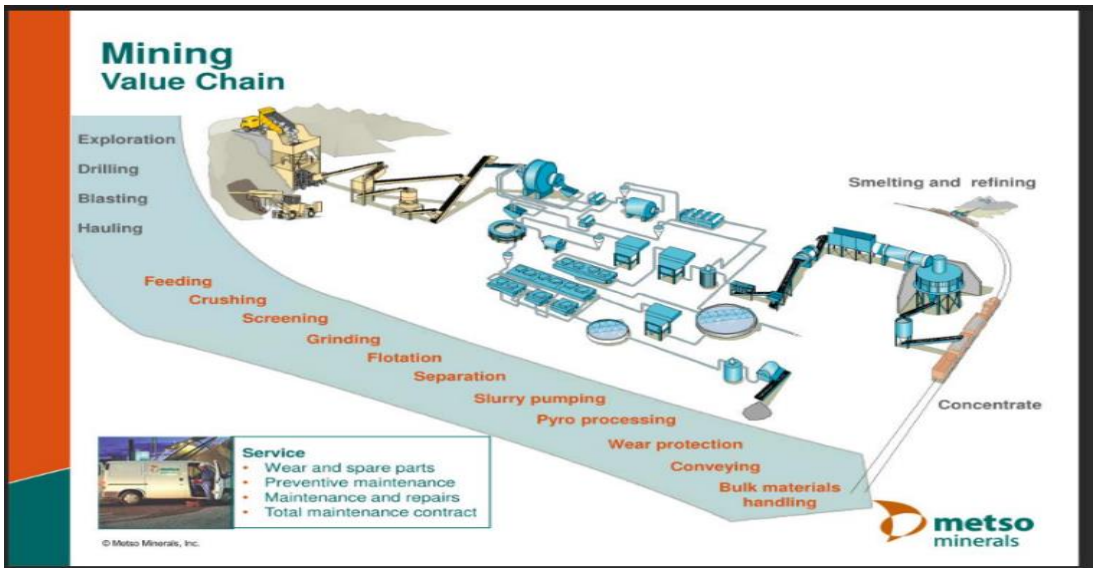



Figure 1: Mine Value Chain (Mikkela, 2014)

During that handover process, there must be an accurate and quality flow of information from one section to another. The information includes critical inputs such as several short holes, the length of drilled holes, the presence of water in the holes, stemming length and other relevant information. The correct flow of information from the downstream section to the upstream section will enable the upstream section to produce quality outputs that will certify the company's key performance indicators (KPI). As a result, the efficiency of the upstream section depends on the quality of the information from the downstream section to help them comply with their required work schedule and plan compliance(Kumba Iron Ore, 2016).

The Sishen Mine's compliance with scheduled work and mining to plan has been declining over the past 8 years and this has negatively impacted the current life of the mine (LOM). The decline has been mostly due to a change of organisation structure resulting in the breaking down of bigger sections into smaller manageable sections. The change in organisational structure and the breakdown of the section has created many sections. This resulted in substantial gaps in the flow of information between all these different sections causing poor compliance to scheduled work and mine to plan. Compliance is one of the critical factors that is used to determine employee bonuses therefore this inefficiency in the flow of information impacts the employees negatively. This has also resulted in other operational issues that impacted the safety, productivity, and costs of the operations. In response, to better manage

this, the company implemented the business framework model called the Anglo-American Operating model(Kumba Iron Ore, 2016).

Even though this improved the management of work, it has not been able to close the gaps in the flow of information between the different sections of the mining operations. Different sections use different information available to them to produce plan or execute activities. As a result, compliance with plans and execution is very low. Some departments make conclusions or decisions without updating or acquiring relevant data from relevant personnel, sections, and departments. This has proved to negatively impact safety, finances, productivity, efficiency, work schedule, mine to plan, LOM, and compliance with the business-critical KPIs. Action tracker, job cards, work notifications and mine to plan compliance are the main KPIs used to monitor the flow of information These are the most critical KPIs that are monitored daily and weekly. Therefore, addressing this problem should have both financial and safety benefits to the employees, company, shareholders, department of minerals resources and energy and the country itself. Silos do exist between people, sections and departments(Kumba Iron Ore, 2016).

## 1.4. Central Research Question

The research aims to answer the following Critical Research Question “How can the flow of information be improved amongst the different sections and departments at Sishen Mine?”

## 1.5. Research Objectives

- To investigate the gaps in the flow of information in a surface iron ore mining operation.
- To identify the impact of the gaps on KPIs.
- Make recommendations on how to close these gaps.

## 1.6. Summary of Research Methods

The research was a field-based study where relevant stakeholders were interviewed to find the key principle around the flow of information and identify the gaps that exist within the system. The sample that was interviewed was section managers and engineers who are experts in the technical flow of information at Sishen Mine. The interviews were semi-structured and done on the team’s platform between 31 October 2023 and 11 January 2024.

To understand the flow of the information system and outline the gaps within the system the qualitative research approach was used to collect, store, and analyse the data. The data was collected from the interviews (Haradhan, 2018). The extensive literature review gave more insight into the maturity and instability of the iron ore mining operation specifically the South African iron ore sector. It also elaborated more on the significant importance of the contribution of the industry(Statistics South Africa, 2023).

The existing literature provided the current structure of the available information and the existing gaps in the flow of information concept. These gaps led to the objectives of the data collection and more specifically the interview line of questioning. As a result, this led to the development of the first conceptual framework.

The entire report was written from the research that was conducted following the Ethics guidelines from the University of the Witwatersrand (**Ethics Clearance Number MIAEC 080/23**).

## 1.7. Delimitations and Assumptions

The Sishen mine system is a Mega-System with numerous interactions of systems, subsystems, and elements. All these different systems and elements talk to each other both directly and indirectly. The beliefs that exist is that as these elements and systems are talking to each other (flow of information between them), there is information that is either lost during transactions or poorly communicated/provided or poorly received. This poor communication or loss of information during the interaction of systems is what in this case we refer to as "the gaps in the flow of information"(Hickethier, Tommelein and Lostuvali, 2013).

## 1.8. Outline of the Chapters

The research report will be structured as follows:

**Chapter 1 Introduction, aims and scope of the research**

This chapter covers the introduction topics covering the background on Sishen Mine, and information flow. It also gives more details on the importance of the iron mining industry to the South African economy. The chapter then details to give more context on Sishen Mine in terms of how it is structured and how operates, where it is situated, what impacts it has on the surrounding people and communities and lastly how Sishen Mine has advanced over the last 70 years. The chapter also includes a detailed analysis of the issues that Sishen Mine is

currently experiencing and how these issues have evolved to negatively impact Sishen Mine's performance and as a result, became the problem statement of this research.

The rest of the chapter covers the research critical question and three main objectives or aims of the research. It then outlines the method that was used to collect, store, and analyse information under given assumptions and limitations.

**Chapter 2 Literature Review**

The literature review chapter covers a full intensive review of the current literature covering a variety of topics. The topics include the analysis of the importance of the three main departments involved in the safe, efficient, and effective production of iron ore. The rest of the topics cover some key business framework principles including process and system coordination, organisational structure and key performance indicators.

**Chapter 3 Research Methodology**

The research methodology chapter covers the type of research analysis used to collect and analyse the data. The chapter also gives more details on the types of interview methodology used to interview the participants. The second part of the chapter involves the process of choosing relevant participants from the population and formulating the interview questions as illustrated by Wengraf's pyramid. The last part of the chapter looks at using thematic analysis to analyse the collected data and lastly addressing the validity and repeatability of the results while maintaining the ethical consideration.

**Chapter 4 Interview findings and analysis**

Chapter 4 covers the core part of the research project. It includes the interview audio transcription of the interview recordings from all 10 participants. The transcribed interviews and audio recorded during these interviews were conducted from October 2023 to January 2024. The data is then presented in the form of tables, figures and schematics to enable the intensive analysis process.

**Chapter 5 Discussions**

Chapter 5 covers the discussions on how the researcher addressed the objectives through the data, analysis and results. This also included the link between the literature review and final results and how the research answered the research critical question. The last part of the chapter elaborates on how the reliability and validity of the research was ensured.

**Chapter 6 Conclusions and Recommendations**

Chapter 6 provides highlights from the discussions, limitations of the research and recommendations.

# CHAPTER 2

# 2. LITERATURE REVIEW

The area of scope covered for this research is the flow of information within and between the three departments that are directly involved in the safe, efficient, and effective production of Iron Ore. Those departments include the mining operations department, which is responsible for actual production, engineering maintenance department which is responsible for maintaining the equipment and lastly the mine technical service department which is responsible for planning and ensuring compliance (Kumba Iron Ore, 2016). This literature review thus explores the principles of the flow of information between these departments in iron ore mining. More clarity is given on the principles of systems coordination and flow of information as illustrated and defined by different committees, organisations, scholars and industries or sectors. The output of the review results in the development of a conceptual framework.

The search criteria used included but were not limited to any crucial "information flow between people, systems and processes both in the mining iron ore sector and the industrial sector". Articles, books, and relevant websites on the structure and operational layout of a typical iron ore mine with a focus on the Sishen Iron Ore Mine. Google Scholar and Kumba Sharepoint were used as the main article and report sources. Key words included information flow, gaps in flow information flow, iron ore mine, Anglo-Americam Kumba Iron Ore Sishen Mine, KPI and mine value chain.

## 2.1. Introduction

The mining operation, mine technical service and engineering maintenance department are the three core and critical departments in any iron ore mining operations. The mine operation department focuses on the actual production (drill, blast, load, haul and crush) of the iron ore using types of equipment such as shovels and trucks. The engineering maintenance department then focuses on maintaining and servicing the equipment that is used by mining operations to mine and move the iron ore. The mine technical service department acts as a service provider to both the mining operation department and the engineering maintenance department. It provides mining and engineering with guidelines, technical advice, support, strategy, plans, schedules, budgets and compliance ratings (Kumba Iron Ore, 2011).

## 2.2. The Engineering Maintenance (HME) Department

Heavy Mobile Equipment (HME) are critical for an effective operation. HMEs are large or heavy-duty equipment or machines that are designed to carry heavy duties such as the transportation of minerals, soil, and large machines. These include but are not limited to dump trucks, hydraulic shovels, rope shovels, dozers, Frond End Loaders, graders, water bowsers, scalers, excavators, and diesel bowsers(Law Insider, 2023). To improve and maintain the reliability of the HME they must be serviced and maintained regularly. This is done by service technicians and mechanics. Technicians and mechanics do repairs, replace and maintain engines, electrical systems, mechanical systems, and hydraulic systems on this equipment (Montego Pet Nutrition, 2023).

The engineering maintenance supervisors and reliability engineers use large electronic equipment and diagnostics computers to check the equipment systems and components to assist in identifying technical defects or issues and if there are any that need to be fixed. Once the defective parts are identified, the engineers, technicians and mechanics use hand tools such as hammers, screwdrivers, and wrenches to repair, replace the parts and calibrate the machine(Truity, 2021). One of the highest capital investment and operational costs in the open cast mines is related to transportation equipment. Diesel or fuel costs are the highest operational costs (Arputharaj, 2015).

Taking into consideration the significant costs of the HMEs, it is crucial to continuously analyse and improve their performance. The improvements are done to maximize the output, and benefits and “achieve the safe cost-effective operation”. The overall operation or production performance depends mainly on the utilization and availability of this equipment. These are two main Key Performance Indicators (KPIs) of the maintenance department. The HME or engineering maintenance department must continuously measure the availability and utilization of the equipment, especially for primary equipment (Trucks and Shovels) with the main objective of improving them(Arputharaj, 2015).

To reduce the equipment breakdown and downtimes, the optimal maintenance process was evaluated and its application to improve four aspects which are efficiency, productivity, costs, and profit margin. This is a system where several trucks' field operating data is recorded and used to calculate and determine the mean time before failure and outline the maintenance profile for each part. Once the data is adequate, it is analysed to determine the trend and formulate the right “probabilistic model for maintenance profile”(Morad, Pourgol-

Mohammad and Sattarvand, 2014). Different mines use different terms, systems, and processes to collect and maintain different data. Shovels are the common primary equipment as a result the data collected on them is mostly common between different mines. That information includes but is not limited to tempos, direct working hours and the total tonnes handled(Arputharaj, 2015).

The mining HME maintenance department plays a vital role in achieving a safe, efficient, and effective mining operation. The department's responsibility includes “the coordination and supervision of the equipment maintenance”(Zippia Team, 2021). The department headed by the Engineering Manager with the support of engineers, reliability engineers, maintenance foreman, artisans, mechanics, and technicians ensures that all equipment’s maintenance is done safely, and at optimal performance(Kumba Iron Ore, 2014). The responsibility of the department also includes ensuring the service and maintenance schedule are done on time and efficiently, improving the equipment times and mean time between failure, supporting the technical and production team, and maximising the equipment availability and reliability(Zippia Team, 2021).

**Figures 2** illustrate the downtime of the mining machines because of the scheduled outage due to the breakdown of these machines. Taking into consideration the total calendar hours of 8760 hours, the scheduled outage and downtime of the mining equipment are calculated to be 37% and 24% respectively. The extensive calculations show that 1 hour of planned and scheduled outage ends up with 0.2-0.3 hours of downtime related to the breakdown.

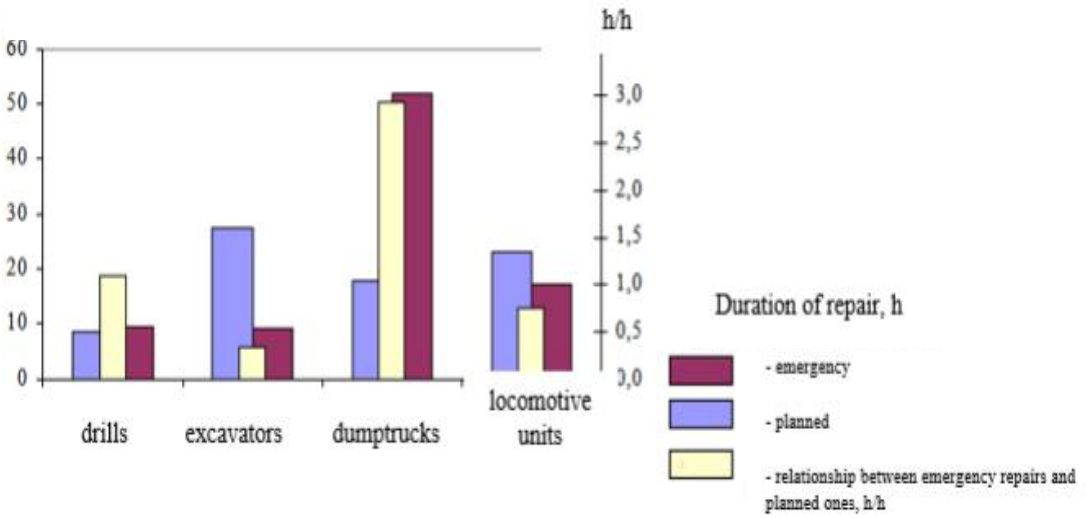



Figure 2:Downtime of the equipment due to planned outage and related to the breakdown of the machines (Andreeva and Krasnikova, 2020).

According to Andreeva and Krasnikova (2020) to optimize the maintenance department and increase its competence the "systematic and complex approach" must be used. This approach is used to approximate and measure the efficiency of the value chain activities of the department. The activities include the services, maintenance and repair of the mining production equipment, scrutinizing the functionality\practicability of the department looking at the outputs/cost ratio, analysing the organogram structure and its efficiency and assessing the working environment and conditions. Above all the approach benefits the operation in two ways, it allows the management to make a data-driven decision by looking at the "economic practicability" of fixing and maintaining the mining equipment. The second major benefit is that the approach allows the operation to maximise the benefits of all existing processes and systems such as "organizational, technical, technological and economic systems"(Andreeva and Krasnikova, 2020). **Figure 3** shows the details around the structure of doing the industrial and technical audit in a mining organisation.

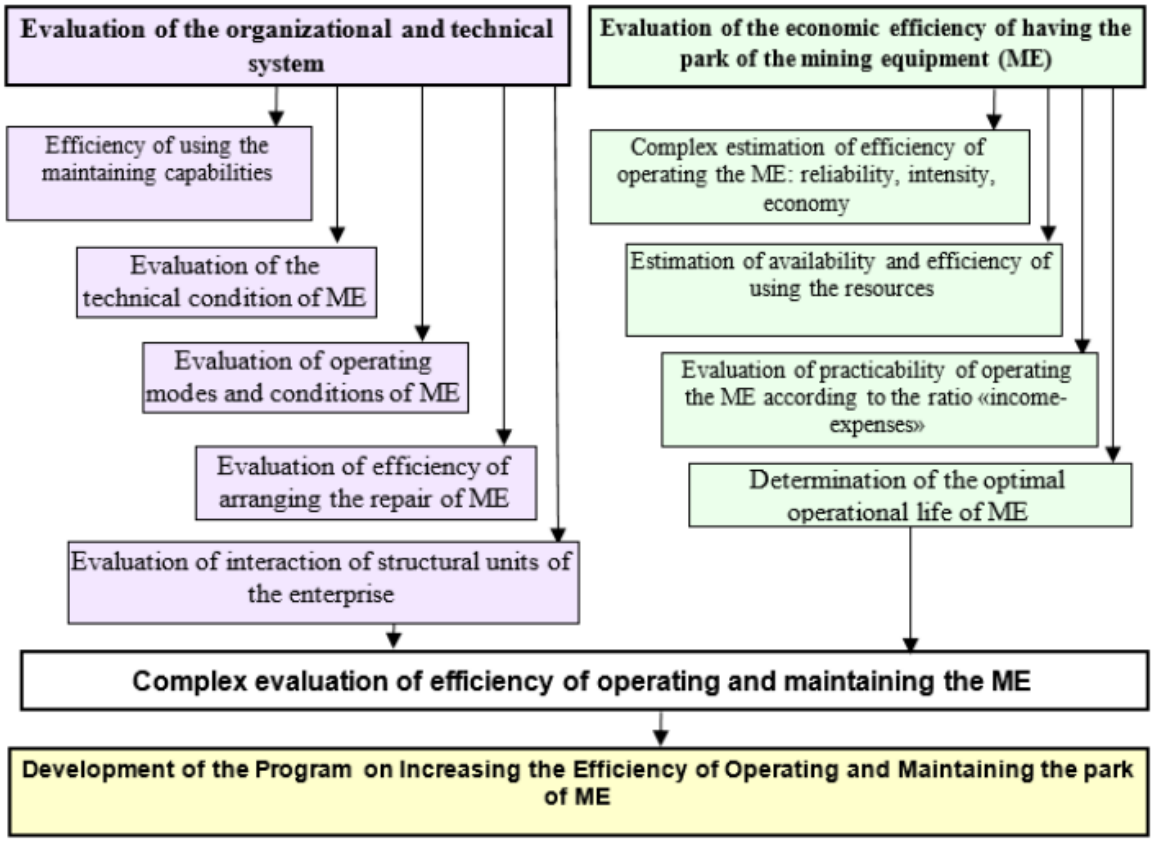



Figure 3: Structure of the industrial and technical audit of the mining enterprise (Andreeva and Krasnikova, 2020).

The mine maintenance department like all other departments has common issues that prevent it from achieving its optimum results. Those issues include low equipment availability, high number of unscheduled maintenance, high noncompliance to preventative maintenance, and high mean time between breakdowns. According to two gold and silver mines in the north of Chile, the blend of these problems may even make it more difficult for the department to cope. To best cope and optimize the department, an "event simulation model was developed to quantify different leadership and management strategies and drive to rectify the situation". The model was able to conclude that a great improvement was possible using initiatives or strategies aimed at reducing the number of unplanned breakdowns/failures and the duration needed to repair them. The reduction of breakdowns using root-cause failure analysis (RCFA) and the development of a system that details tasks, components, tools, and duration needed for an unplanned repair are the two most relevant strategies(Louit and Knights, 2001).

The key critical performance indicators that are used to measure the efficiency of the maintenance department include but are not limited to the total calendar hours which assist the department in determining the total scheduled hours, equipment available hours, total actual hours the machine worked in a shift/day/week/month/ and year, and percentage availability(Arputharaj, 2015). According to Andreeva and Krasnikova (2020), there are three basic principles when assessing the activities of the maintenance department. Those include the "purposefulness of the work, effective communication when executing the tasks, and the applicability of getting feedback from the end user". The study aimed at the systematic and complex study(audit) was carried out in one of the mining organisations in the Republic of Kazakhstan. The study showed that (**Figure 4**) the "efficiency of maintaining and repairing activities are influenced by the factors both in the operation space and in the mining equipment maintenance space".

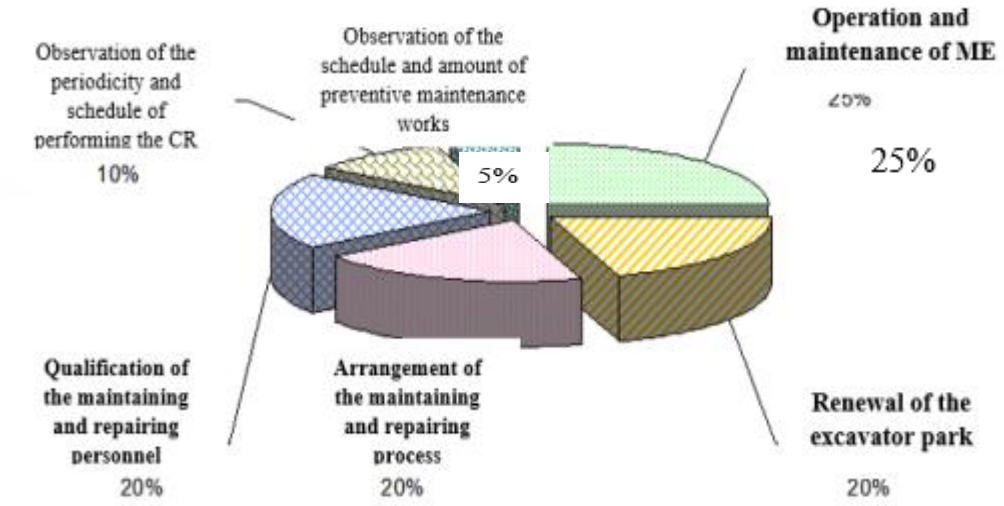


Figure 4: Parameters that impact the efficiency of maintaining and repairing activities (Andreeva and Krasnikova, 2020)

## 2.3. **The Mine Technical Services Department**

The Mine Technical Service department headed by the Technical Service Manager holds the responsibility to offer technical advice, support, strategy, plans, and schedules to the mining production team on a day-to-day and month-to-month basis. It offers the technical solution to improve and maximise production, mine planning, geotechnical, geology, mobile assets, and maintenance in the mine(Mining Technology, 2023). The department specialises in developing long-term strategic mine plans to enhance the company's assets, life of mine planning, compliance, rehabilitation, and reconciliation of short-, medium-- and long-term plans(Holtmon-Jones, 2023).

Mine design and planning include the collection, analysis and compiling of relevant "geotechnical, geological, mining, engineering, and economic data" into a document to outline the strategy to mine the mineral deposit while complying with the specified legal and regulatory requirements. The main reasons behind mine planning and mine technical design are to allow safe extraction and processing of mineral deposits at the lowest unit costs while complying with the relevant customer's specifications under the current economic condition(Fourie and Van Niekerk, 2001). One of the other reasons why good planning is critical is to make sure to identify and manage operational problems as early as possible(Hall, 2023).

The long-term plans outline the overall objectives or goals of the operation while the short-term plans set day-to-day targets to be achieved to achieve the main objective. This is an "integrated planning process" that allows the work to flow from long-term through medium-term to short-term planning. Short-term plans are more detailed in terms of duration, activities, timelines, and resources. As a result, the accuracy and compliance of the short-term plans are more as compared to medium and long-term plans(Hall, 2023).

The objective of short-term plans is mainly to optimize and integrate the mine value chain activities to enable them to achieve the specified targets on unit costs, health, safety, environment, and productivity(Fourie and Van Niekerk, 2001). **Figure 5** on the next page illustrates the five unique planning and design processes across the project life cycle. During the initial stage of the planning process, a series of assumptions are made, discussed and

accepted. As the planning process moves from the long term into the short term more information becomes available and its accuracy increases. This is illustrated in **Figure 6** on the page.

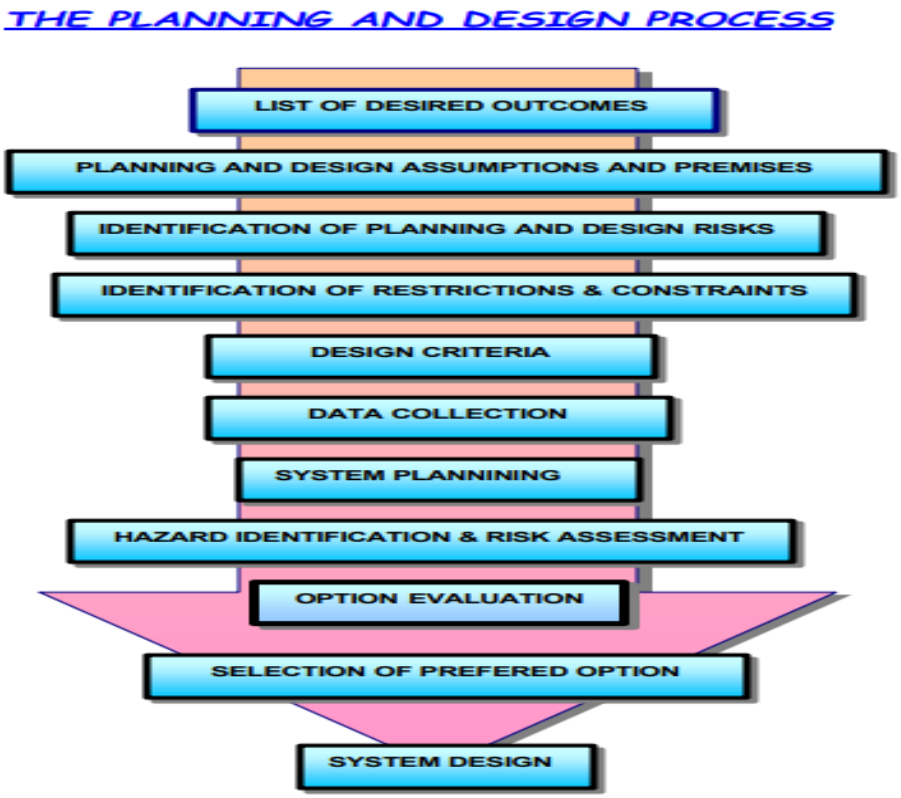



Figure 5: The planning and design process (Fourie and Van Niekerk, 2001).

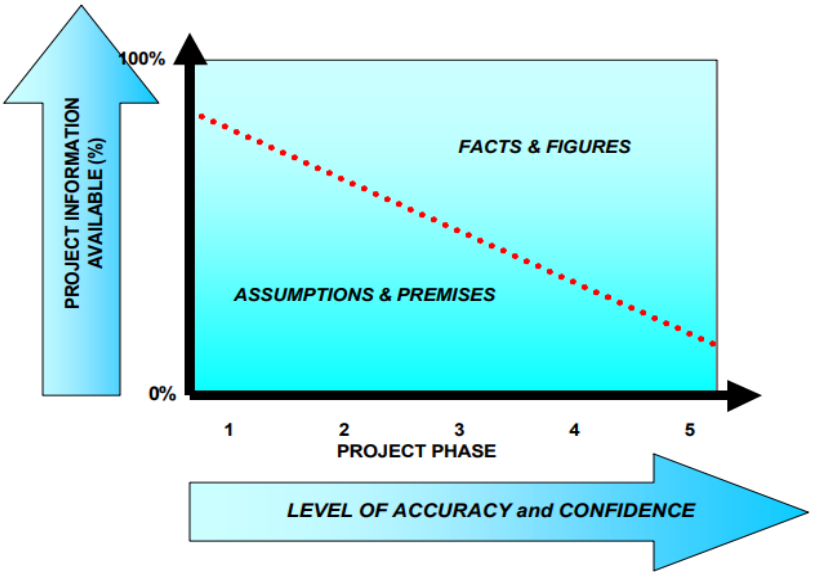


Figure 6: Increased accuracy and confidence with increased data (Fourie and Van Niekerk, 2001).

The Long-Term Plan form the basis of the Life of Mine Plan (LOMP). This is formally approved after an extensive Strategic Options Analysis (SOA). The LOMP is the blueprint report that is approved to best deliver the operation's main objective. These plans provide a scope that enables all other short-term plans to be established and executed. The LOMP is assessed, optimized and updated once a year depending on the current state and progress of events, constraints, and other major changes found during the SOA. An SOA normally occurs between three to five years and it is reviewed annually. The SOA aims to evaluate “the impacts on the value of all the various strategic decisions that the company can make”(Hall, 2023).

The Mine Technical Service department also includes other supporting services such as mine surveying, production geologists and geotechnical engineering. Mine surveyors are responsible for maintaining, and updating the mine's plans including surface plans with all the infrastructure to ensure they are accurate and comply with all the specified legal and regulatory requirements. On a month-to-month basis, surveyors measure the progress of the loading faces including the total volumes moved during production(SAIMM, 2022b).

The mine orebodies are made of different rock types and grades. The responsibilities of mining geologists in collaboration with mining engineers are to assess, evaluate and identify deposits and determine which ones can be extracted economically. The geological data is inserted into the short-term plans. This information is used to guide the production team to mine the different ore bodies with a different grade. On a month-to-month basis, geologists are responsible for drilling the exploration holes to determine the extent of the orebody and how the grade is distributed throughout the orebody. They analyse the data from the exploration holes and from there they determine the structure of the rock formation as a result they will have a broad knowledge of existing minerals, their properties and appearance(SAIMM, 2022a).

The long-term design of the mine takes into consideration the strength of the rock and how it can sustain the high walls of the open pit. The strength is used to determine factors such as striping ratios, bench height and the pit's overall slope angle. Geotechnical engineers together with the geotechnical technicians are responsible for extensive investigation, pit design, and continuous monitoring of the open pit walls. The geotechnical engineering scope includes the

designing and wall monitoring of the stockpiles, dumps, tailings, waste dumps and storage facilities. The data from the continual monitoring software such as radar is used to recommend design parameters(Wardell Armstrong, 2022).

## 2.4. The Mining Operations Department

### 2.4.1. Drilling and Blasting

The mining value chain includes block preparation, drilling, blasting, loading, hauling, crushing and lastly feeding the ore into the plant. The mining operation team work with other supporting services such as grade control, geology, survey, planning, processing, and contractors to ensure the correct tonnages are mined economically and safely. Drilling and blasting is a process where rock mass is drilled charged with explosives and blasted into smaller fragments of rocks. Blasting the ore into smaller size fragments is very crucial as this can impact the costs and productivity(Superior Performance, 2023).

### 2.4.2. Loading and Hauling

Once the charged blocks are blasted the ore material is then loaded out by the shovel into the trucks and dumped at the crusher. The waste material is loaded out by the shovel into the trucks and it is then dumped at the waste dumps. The shovel-truck system is currently the most common system used in open pit mines to move the material. The key indicator in this system is the truck cycle time. The trucks load the material from the loader and drive it to its destination (dumps, crusher and stockpiles) and once it has dumped the material it returns to the loading area as illustrated in **Figure 7** below(Aguayo, Nehring and Ullah, 2021).

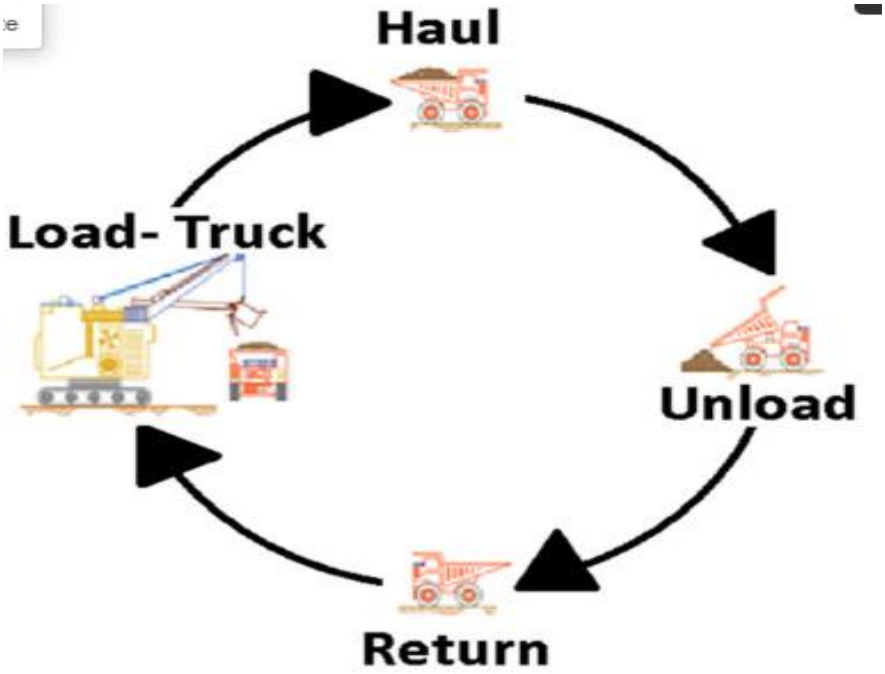



Figure 7: Trucks-shovel system(Aguayo, Nehring and Ullah, 2021)

## 2.5. The Business Process Framework

The Operating Model or The Business Process Framework is the model that is composed of critical and significant parameters that are required to effectively manage the process. The schematic in **Figure 8** illustrates the flow of information flowing from the strategy setting to execution, monitoring and responding to performance. The model motivates visual flow and feedback of crucial information across the process stream that is less tangible than the actual production and service that is applied. What is also evident from the model is that all the activities that are part of the process are affected and/or also affect other Activities. If one activity is not planned, scheduled, and executed correctly at the right time, and in the right way, then automatically the quality and efficiency of the other activity is compromised(Drew, 2023).

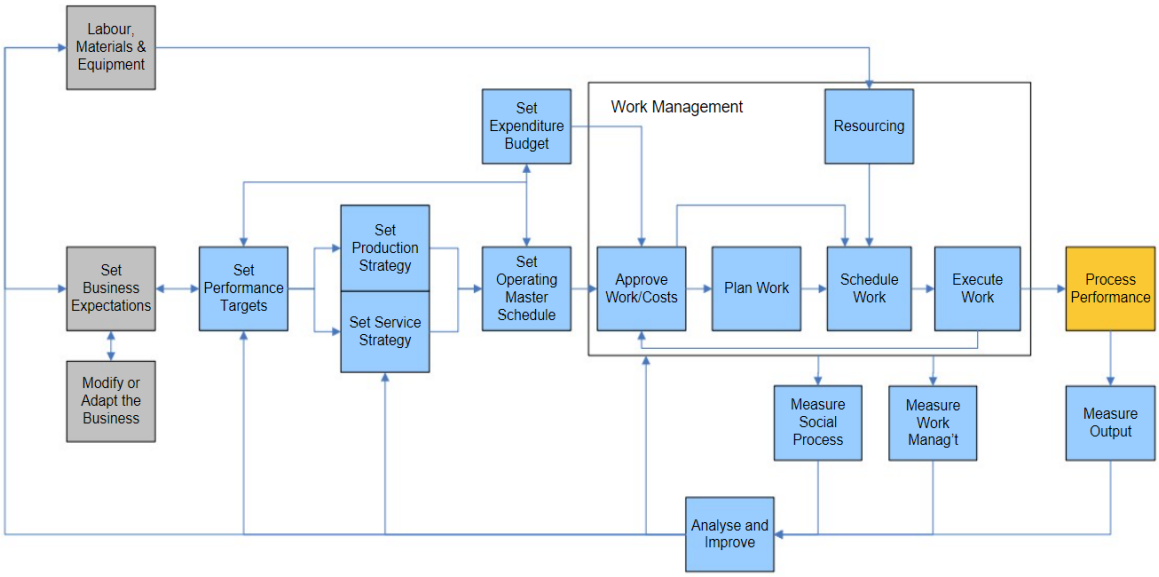



Figure 8:The Business Process Framework(Kumba Iron Ore, 2016)

The operating model is made up of three main categories namely operational planning, work management and feedback. The operational planning category involves high-level business strategy planning such as setting performance targets, setting production strategy, setting service strategy, setting an operating master schedule and setting of expenditure schedule. During the business performance targets setting process, the executive team specify the confidence of meeting business expectations by specifying the business structure, defining business structure measures, developing business performance modes, and defining constraints, opportunities and variation or capacity(Drew, 2023).

The business executive board, executive management, managers, employees, community, and government collectively specify the business expectations that must be achieved for the operation to be profitable. These expectations usually include the safety, environmental, social and economic aspects (McAlear, 2012). The work Management category is composed of work approvals, planning, scheduling, resourcing, and work execution. Doing the right work at the right time in the right way assists the operation in achieving its targets at the lowest unit costs possible in a sustainable manner. The work approval process is aimed at determining the work that is supposed to be done. Once the work is approved then the relevant team must specify the requirements for completing the approved work. Most of the important requirements included in the work approval document are the resources (money, people, machines, equipment, and time). Once all the resources are available they are allocated to the specific activities that need to be done and that leads to execution(Drew, 2023).

## 2.6. Key Performance Indicators- Unit of Measure

Key Performance Indicators (KPIs) are the critical factors that can be used to determine or calculate the performance of either an operation or a company. These factors or parameters can be quantified and they are mainly used to determine the company's performance in terms of safety, operational achievement, and financial means as compared to its peer company. Different companies under different sectors have a significant number of different KPIs. The customer services company will focus on customer satisfaction and response time while a process-based company will focus on safety, operational performance and financial aspects. The final objective of the KPIs is to allow management to be aware of trends and this will assist in making an informed strategic decision(Twin, James and Jackson, 2023).

The most used system or tools by both small and big organisations to monitor operations and business performance are visual dashboards. Visual dashboards are made up of different data visualization techniques such as KPIs. The KPIs provide the management with accurate data on the variation of the current performance as compared to the targets. The tricky part in all business operations is to find the right KPI that is relevant to a specific goal(Peral, Maté and Marco, 2017). Over the years several organizations have implemented the use of the KPI system and most of the reviews were that the system has shown or made little to no difference to performance. Some of these little to no performance changes were mainly because these businesses never created an environment for the KPIs to operate and made such changes. And also, these KPIs were just introduced without a proper planning, development and implementation plan(Parmenter, 2015). **Figure 9** below illustrates the original 12-step process that migrated to the newly developed six-stage model.

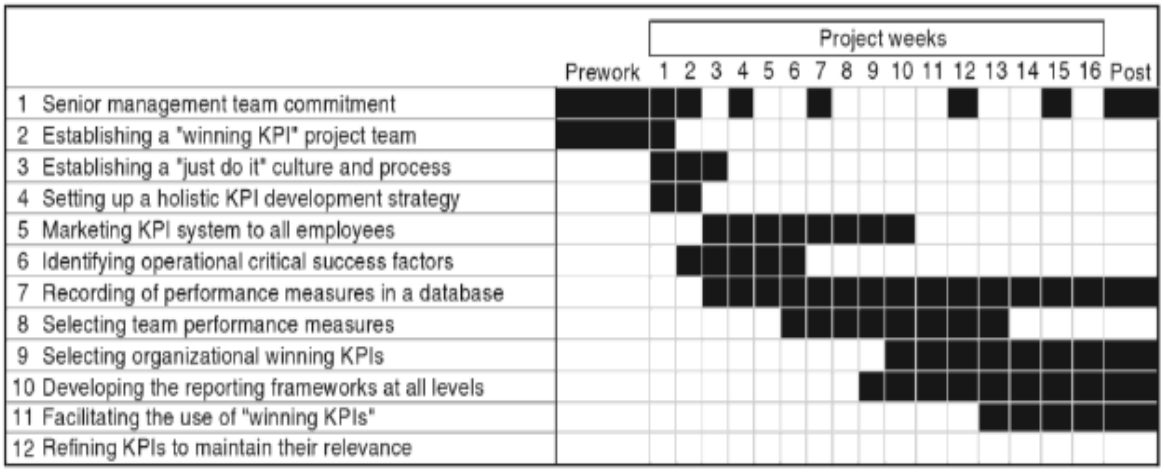



Figure 9: Twelve-step implementation of 16-week timeline(Parmenter, 2015)

Business processes and systems are the essential means that enable organisations to reach their goals and objectives. The assessment of these goals and objectives together with the systems and processes must be looked at in a holistic approach. Well thought, planned, implemented and managed processes are key drivers of the business revenue and strategy implementation. These form part of the critical parameters in the monitoring and controlling process of process management. As a result, it is very crucial to assess and identify relevant KPIs to the specified process. Processes assessment and monitoring can be done from different perspectives including but limited to operation, security, finance or maintenance(Gackowiec et al., 2020). This is illustrated in the following **Figure 10.**

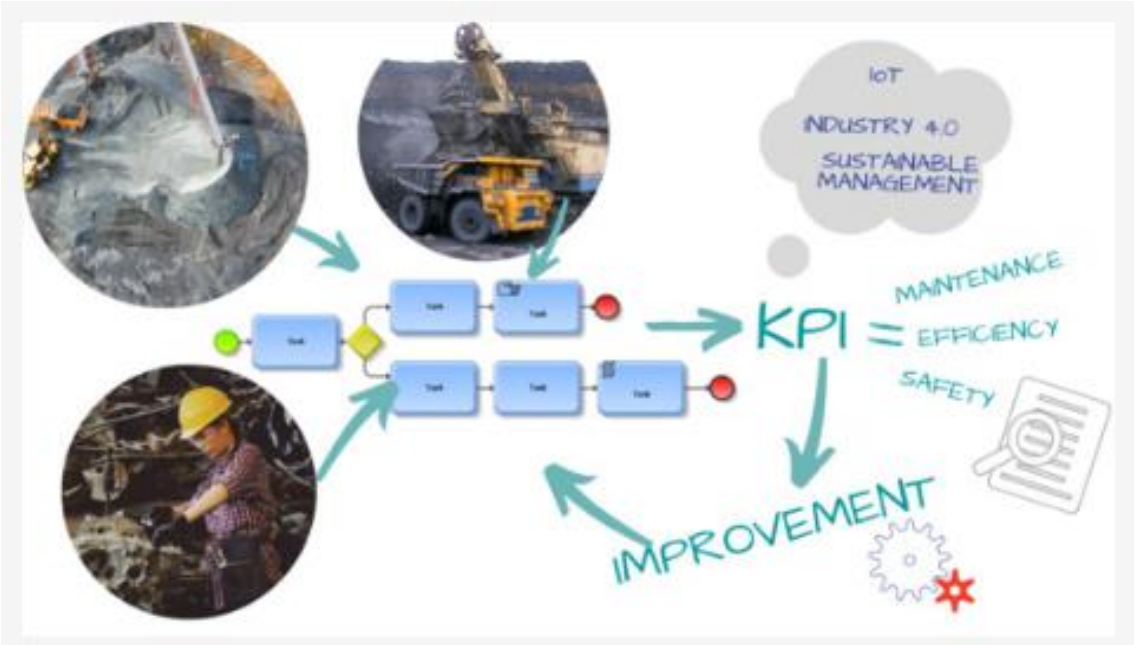



Figure 10: Graphic abstract Key Performance Indicator (Gackowiec et al., 2020)

Depending on the characteristics, timeframe and users the KPIs have four main categories. The four categories are Strategic KPIs, Operational KPIs, Functional KPIs, and Leading/Lagging KPIs. Strategic KPIs are high-level screens short on the performance of the business and those include but are not limited to business revenue, profit margin and return on investment. Operational KPIs are the KPIs used by managers and leaders on a month-to-month basis (or even day-to-day basis) to analyse different processes or segments of the process. A typical example of operational KPIs will be used in an instance where a company

is not doing well financially (revenue decreased), such tools are used to “investigate which process/product line is struggling”(Twin, James and Jackson, 2023).

## 2.7. Organisational Structure

Organizational structure is the framework or build-up of an organization or project. This framework describes in detail how any organization operates. It outlines the chain of command, rules, roles, and responsibilities. It also outlines how the information flows from one part of the organisation to the other(Kenton, 2023). An organization chart is a simple representation of the organizational structure which shows how the entire organisation or project team is connected who is responsible for doing what and who conveys what message to whom. This chart is different from one organization to the other depending on the size, sector, and purpose(Adzo, 2022).

These structures ensure that the organization operates efficiently and effectively by making sure that the right work is assigned to the right person at the right time. They clear the management and supervision confusion by clearly stating different employee’s roles in the company, who report to and who they oversee. The structure goes into detail to describe how different people from different sections and departments must work together. Who or which department /section must provide what information of which quality to whom and when? (Sherman, 2019).

Kampini (2018) investigated the “effect of organizational structure on employee performance”. The research was mainly focused on the “effect of hierarchy on employee performance” and the study concluded that a good organizational structure is essential to motivate employees to perform. In addition, the study also revealed that team decision-making and consensus have a great impact on job output quality. The Aston Research Program elaborates on the three main dimensions of organizational structure. These organizational structures are based on the extent to which decision-making is centralised at a certain point in an organization. The more centralised an organization, the stricter the chain of command is and as a result, this does not allow flexibility of working therefore tasks are strictly guided and governed by the company's standards and procedures(Kampini, 2018).

According to Khan (2009), there was an industrialization era where finding the right information at the right time was a huge challenge. The need for establishing tools to manage the information flow in organisations has been on the rise since issues of information overload have been a major issue for both small and big organisations. The tools to manage information can either be IT and technology systems or the organisational structure alignment(Khan,

2009). The effective management of the information flow requires computer hardware and technology streams to enable the storage, transfer, monitoring, and control of this information. All these tools must take into account the relevance or priority of information needed at different levels in an organization(Nowakowska-Grunt and Nowakowska, no date).

## 2.8. Processes, Systems and People Coordination

Coordination of systems, processes and people is crucial for the allocation, and reallocation of resources including information. The fact that coordination has an objective of re-allocation of information means that the flow of information was not right from the beginning. A key indicator for an efficient allocation is adequate information(Casson, 2001). To improve the coordination between different stakeholders, it is quite crucial to promote an early common understanding of the organization's mission, vision, and strategies between all stakeholders. As more people, systems and processes are integrated into the overall system, the need for coordination increases. The coordination in this regard means management of information flow and that applies mostly to the manufacturing and construction sector(Hickethier, Tommelein and Lostuvali, 2013).

The success of the operation and project is mostly in the hands of certain people as their position gives them more power and influence. These people hold account of most of the information, and they simultaneously control the information flow(Hickethier, Tommelein and Lostuvali, 2013). Chinowsky, Diekmann and Galotti, (2008) iterate the important aspect of ease of flow of information to improve the communication of teams to help them reach their optimum performance. Developing and enabling high-performing teams requires a well-structured project or organisation network. Coordination of information flow between systems, people and processes enables decision-making to enable the quality of output product. Information flow takes place in both directions which is different from material flow which only occurs in one direction(Casson, 2001).

Wasserman and Faust, (1994) performed research on the “number network properties with corresponding indices to assess a social network”. The research mainly focused on the centrality and components aspect of the network. A thorough deep dive was done on the relationship of these aspects to the coordination methods and organisational structuring. A person, system or process is called “central” if it is well connected directly or indirectly to other larger number of other people, systems and processes(Hickethier, Tommelein and Lostuvali, 2013). This is described well by Opsahl, Agneessens and Skvoretz, (2010) where centrality is defined in different indices “(1) degree centrality, (2) closeness centrality, (3)

betweenness centrality, and (4) eigenvektor centrality". **Figures 11 and 12** show the schematic of two different centralities.

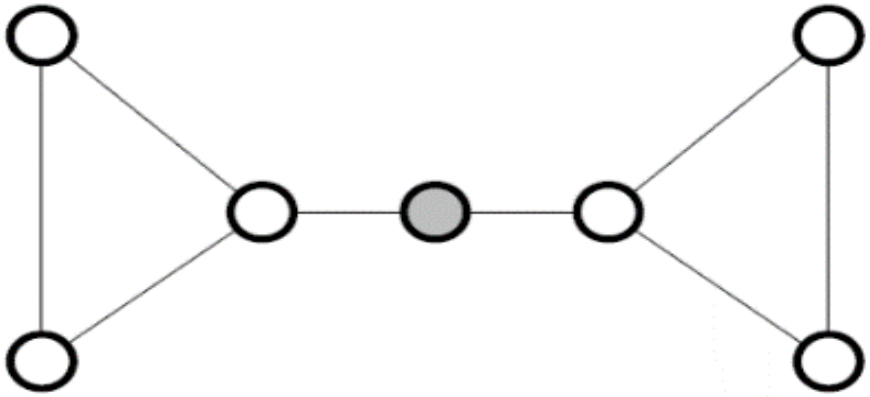


Figure 11: High degree centrality (Opsahl, Agneessens and Skvoretz, 2010)

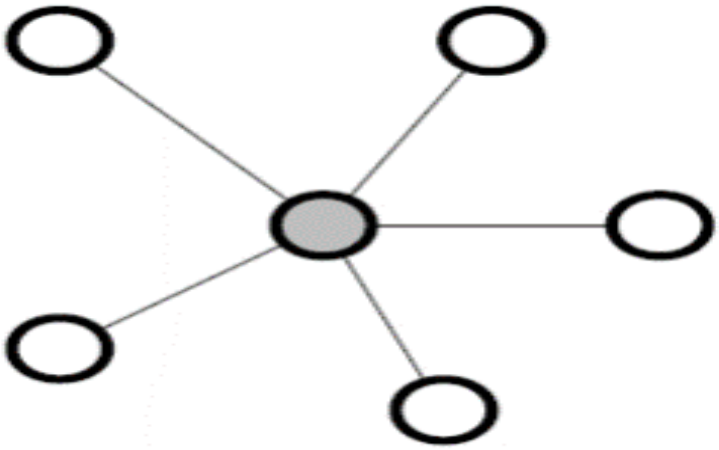


Figure 12: High betweenness centrality (Opsahl, Agneessens and Skvoretz, 2010)

**Figure 11**: The people, systems and processes that have a high degree of centrality are responsive, communicative, and directly or indirectly connected with all the people, systems, and processes in the network. Cross-functional teams' leads are mostly suited for this since they are linked with their team members and to the leads of other teams and as a result, they have more power and influence in the entire network. **Figure 12:** The person, system and process with high betweenness centrality is the middle position in the network and this enables

it to excise a huge degree of power and influence in the organisation. This person or system acts as the overseer or connector for all other parts of the network that seem to be disconnected from the overall network(Hickethier, Tommelein and Lostuvali, 2013). According to Burt (2004), the person in this position is likely to be more creative and have more creative ideas that are more likely to be accepted in the network.

## 2.9. Information flow systems

Over the years many organizations have had challenges with maintaining good communication and providing the right people with the right information on time. The quality and quantity of the information provided is very crucial. Quality and quantity of the information in such a way that it is not too much or too little to create the information overload. Information overload makes it difficult to determine and separate the insignificant data from the significant one(Eckert, Clarkson, and Stacey, 2001). The gap in the flow of information is most of these large-scale projects and organizations result in a variety of problems around decision-making, safety, productivity, efficiency, and effectiveness(Eckert, Clarkson, and Stacey, 2001).

Nonaka (1990) illustrated the impact that adequate quality information has on the quality of the output in the value chain. The more information is provided to the teams, the more the teams become more creative and proactive. The research and development sector also has an increasing number of staff focusing on different aspects of project research. As with other sectors and organizations, the leadership has had difficulties managing these vast teams successfully. The study was carried out to "investigate the alignment of formal and informal network structure and their effect on the challenges to balance project creativity and time efficiency". The research found that informal communication is more complex as compared to formal communication because it has lots of links and connections. Informal communication lacks the structure and the sequence needed to allow efficient and effective transfer of data. The efficiency in the flow of data is directly proportional to the creativity of the workmen and the productivity of the operation (Kratzer, Gemeunden and Lettl, 2008).

Eckert, Clarkson and Stacey, (2001) describe a list of factors that result in an inadequate information flow that was observed after interviews with several professionals from the different large engineering organizations. Firstly, the stakeholders do not understand the overall bigger picture of the process. The lack of understanding of the overall process or product results in relevant stakeholders not knowing what kind of information they need/need to request to execute their task or the kind of information they must provide to other

stakeholders to execute their task. This mostly happens because team members are not aware of the interdependencies. Team members do not fully understand how they fit into the bigger picture and how their actions impact the other part of the process. Secondly, the change of management where not all members are kept up to date with the new plans or targets as a result they are not aware of the changed requirements or scope. Thirdly, the gaps in information flow occur because the right people are not provided with the right information on time so they improvise. People from other departments such as contractors are not updated on their milestones, process status, feedback briefing and other crucial decision-making processes (Eckert, Clarkson and Stacey, 2001).

## 2.10. Conceptual Framework

### 2.10.1. Risk Management Model

Previous research has confirmed the importance of having a well-structured business process in an organization. Quite several mandates and acts have been highlighting the focus needed on the drafting of the documents and assessing the risk associated with information flow in the business processes. This article by Bai et al. (2013) looks at some of the economic consequences that are a result of information errors in the business processes information flow. The risks that are associated with these information errors are managed by "process modelling-based methodology"(Bai *et al.*, 2013).

The flow of information risk ecosystem can be evaluated and unlocked through the following steps. The first step is to identify all the relevant stakeholders, how they are connected and how they impact each other. Once the risk ecosystem has been established the second step is for each stakeholder to understand their roles and how they blend into a bigger picture. Different stakeholders must know which relevant information is available, its location, and the data owner. All other stakeholders must be aware of which information is needed by other stakeholders for them to perform their work. The third step is to create a strong risk culture environment where clear structure communication is used to guide day-to-day conduct within the organisation (Riskonnect, 2019).

The fourth step is to enable data to be accessible to the relevant stakeholders at the right time. The last step is identifying and implementing the right processes, systems and technology. The right systems and technology reduce and eliminate the delays that are caused by manual labour or analysis of the processes. Different data from different systems are automatically gathered, validated, verified, and displayed in a graph to show links and trends between

them(Riskonnect, 2019). The main aim of the article was to outline the management of risk associated with the flow of information. These analysis findings were used as a baseline foundation for the conceptual framework that is used for this research study.

According to the article by NIST (2018), the Risk Management Framework (RMF) outlines a well-structured, and flexible process that facilitates the management of security and privacy risk and this includes but is not limited to "information security categorization, control selection, implementation, assessment, system, common control authorization and continuous monitoring". It also includes other activities that are critical for the implementation and execution of the framework at different levels of management. The Framework also motivate the need for real-time risk management processes and continuous information systems. This can be achieved by implementing full-time monitoring systems and processes which will provide the senior management with critical and relevant information to make cost-efficient, productive, and risk management decisions that are crucial to the business mission and vision(NIST, 2018).

Risk management has become more crucial over the years as senior executives and stakeholders are becoming more concerned about all different types of risks. It has become clear that risks can act as both a business strategic decision driver and/or driver for uncertainty in an organization. After the global financial crisis that occurred in 2008, more risk management standards were established and those included the international standard, ISO 31 000 "Risk Management-Principles and guidelines". This process has assisted ample organizations to pay more attention to identifying and understanding the risk associated with the execution of activities to achieve the overall business vision. It is very important for businesses to "recognise and prioritise significant risk"(AIRMIC, ALARM and IRM, 2010).

The organization boards, executives and senior management must take all necessary measures to swiftly integrate risk management into the organization's culture. The high-level company strategy risks are translated into tactical and operational aims and objectives. Every risk management responsibility must be allocated to the right department, section or individuals across the organization. This will ensure accountability and performance measurements and as a result, this improves overall operational efficiency across the entire business. **Figure 13** illustrates "a suitable structure in terms of the risk architecture, strategy and, protocol and gives a clear brief of every feature of the components"(AIRMIC, ALARM and IRM, 2010).

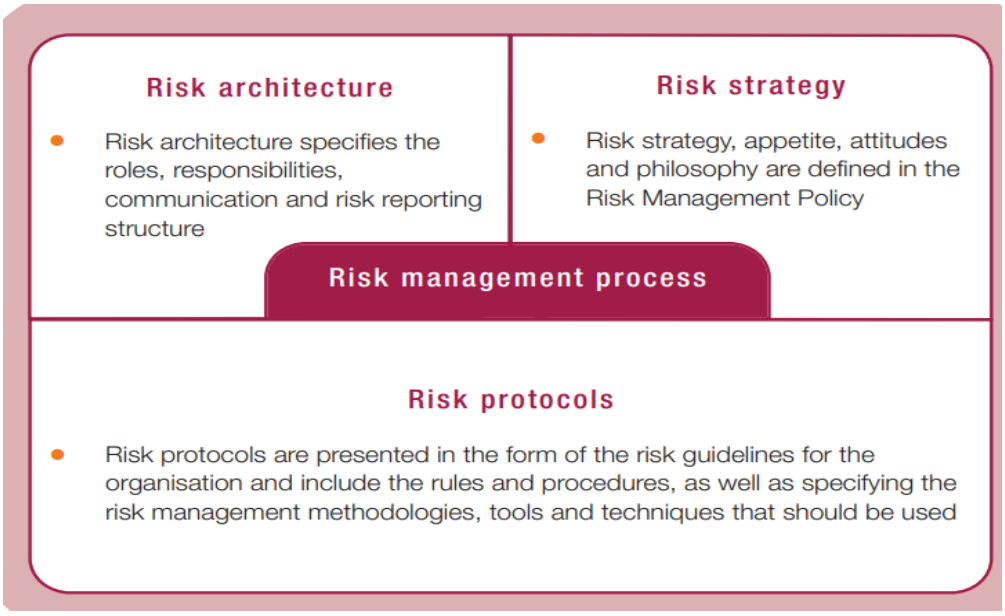



Figure 13: Risk architecture, strategy and protocol (AIRMIC, ALARM and IRM, 2010)

As illustrated in **Figure 14, "**simplified version of the implementation framework". It outlines the crucial steps necessary for implementation and continuous support of the risk management process. The framework also gives a review of the ISO 31000, which gives details on the elements of the "risk management implementation framework". These elements include "mandate and commitment, design of the framework, implement risk management, monitor and review framework, and improve framework"(AIRMIC, ALARM and IRM, 2010).

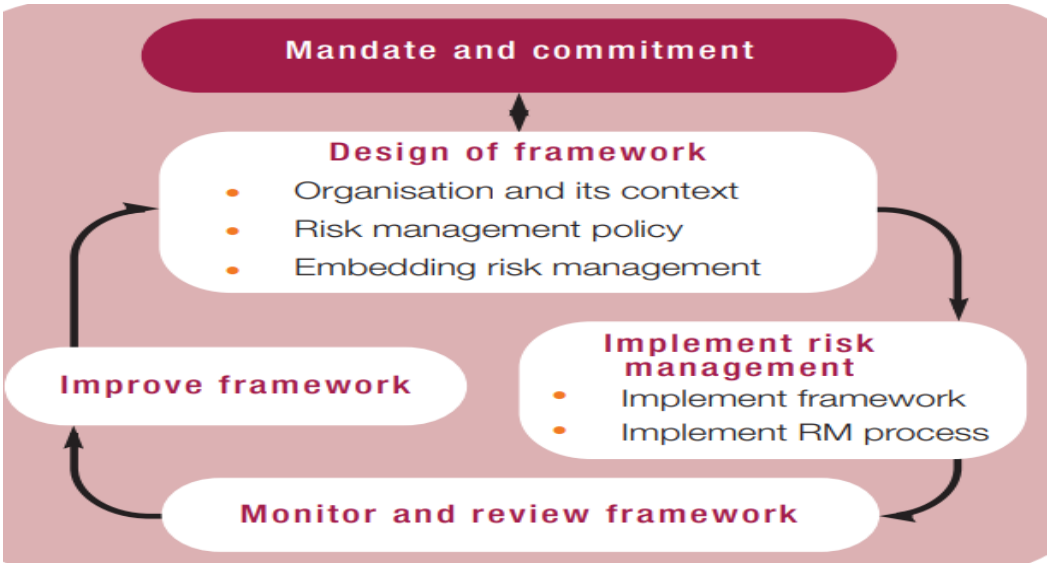


Figure 14: Framework for managing risk (based on ISO 31000) (AIRMIC, ALARM and IRM, 2010)

**Figure 15**, illustrates a detailed risk management process based on ISO 31 000. It clearly outlines the two main stages in the process risk assessment and risk treatment. Risk identification is a process where all the risks that the organization is exposed to are identified. This requires intensive knowledge of the organisation and those include but are not limited to the "legal, social, political, markets, and cultural environment". Risk treatment is then a process of identifying and implementing the right control measures for the known risks. The crucial components of the risk treatment process include "risk control, risk avoidance, risk transfer, and lastly risk financing(AIRMIC, ALARM and IRM, 2010).

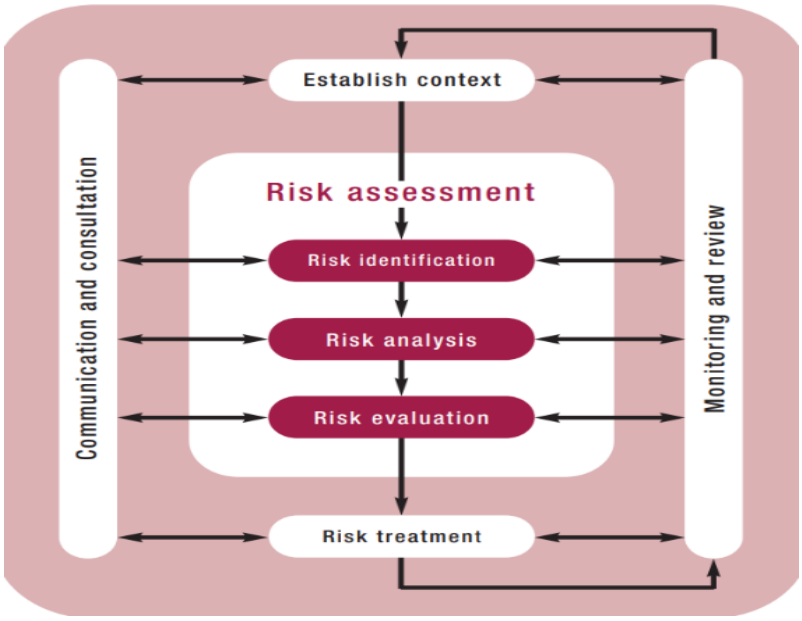



Figure 15: Risk management process (based on ISO 31000) (AIRMIC, ALARM and IRM, 2010)

### 2.10.2. Risk Profiling Approach

A Risk Profile is described as the given tolerable level of an individual or a company's willingness, extent and ability to take risks. The organization's risk profiling aims to show how the willingness to take a risk impacts the business's strategic decision-making. As a result, most organisations use risk profiling to assist in alleviating potential risks and threats(Barone, 2020). It is mostly the quantitative analysis of the threats that the organization, project and assets are experiencing. The quantitative analysis process is done to produce a

"non-subjective experience" of all the risks by giving numbers to parameters representing all types of threats and dangers they present(Pratt, 2023).

Different sectors and organization have their distinctive risk profile depending on the vision and mission they want to achieve and assets that must be protected. There are mainly four main risk categories that each organization risks will eventually fall under and those include strategic risks, operational risks, financial risks, and compliance, legal and regulatory risks. A risk profile will be made up of the following components "nature of the threats, degree of impacts on the organization, likelihood of the threat impact on the organization, types of disruptions as a result of the impacts, costs, and lastly the controls that the business must implement to control, monitor and eliminate the identified risk"(Pratt, 2023).

Creating a risk profile process must be made of all relevant systems, processes and stakeholders, and it must follow the steps:

- Developing the business risk appetite taking into consideration the business's ability to deal with the identified risk.
- Name all the risks that can impact the business
- Arrange all the identified risks using the priority matrix taking into consideration the level of impact they can have on the business and the likelihood that can happen **(**using **Figure 16).**
- Also arrange the risk by looking at the risk types, geographies, strategies objectives and all other relevant parameters.




Figure 16: Color-coded heat map (Pratt, 2023)

### 2.10.3. Risk-adjusted Framework Model

Managing information flow taking into consideration the organization's security and privacy is a very extensive and complicated process that requires all stakeholders from all levels in the organization. Those include high-level strategic decisions by executives, overall planning, execution and monitoring by senior management, and actual development, implementation and operation of systems or processes by middle management, supervisor, and operators. Risk management impacts every aspect of the organisation across different levels as a result communication and reporting across different levels must occur simultaneously with the risk management (as illustrated in **Figure 17)**(NIST, 2018).

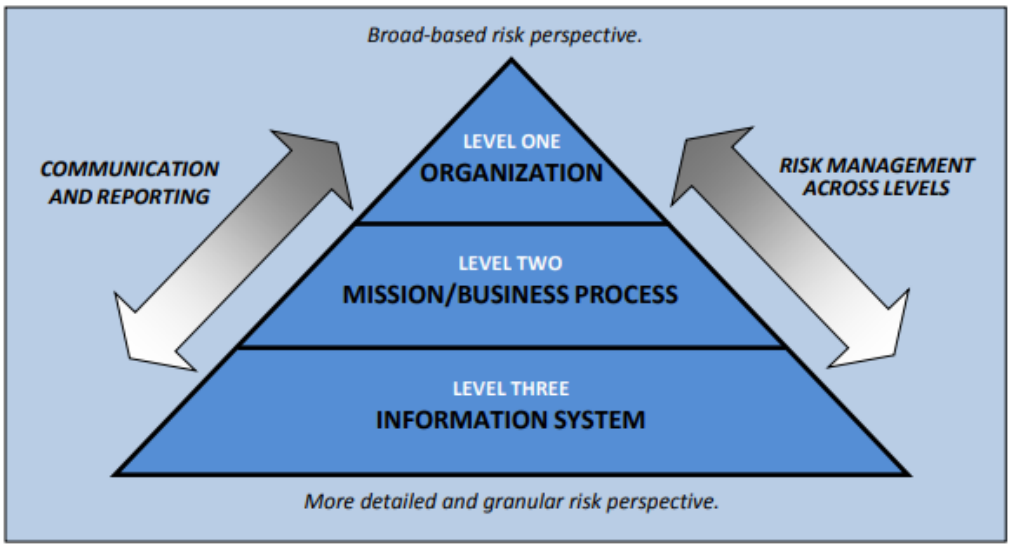



Figure 17: Business-wide risk management (NIST, 2018)

**Figure 18,** illustrates the Risk Management Framework (RMF)and its steps for information flow across different systems, processes and organizational levels. The RMF applies to all organization levels illustrated above in Figure 25. An intensive review of the literature, clearly shows different types of work management models, key performance indicators and organisational structures that are currently used to manage, control and monitor information flow from and to different systems and processes in the mine. **Figure 18** gives a clear illustration of the existing RMF for information systems and organization and therefore this Framework will be used as a conceptual framework model for this study. The model will be intensively tested, verified and validated through the qualitative reasoning technique in Chapter 3.

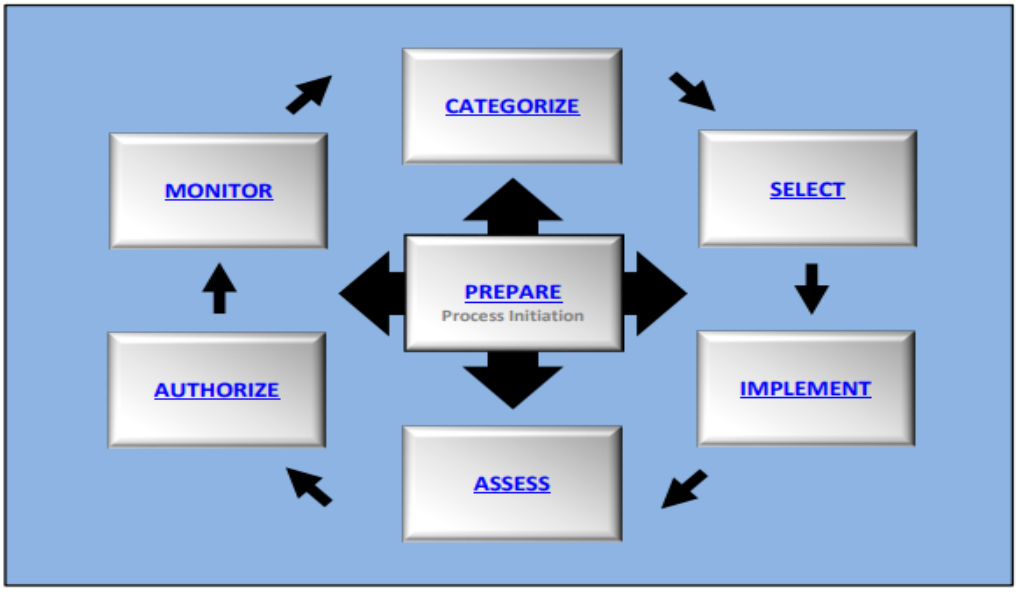



Figure 18: Information Flow Risk Management Framework (NIST, 2018)

# CHAPTER 3

# 3. RESEARCH METHODS

## 3.1. Qualitative Reasoning

The two main research analysis methods used are based on the elements and scope of the research and those are quantitative and qualitative research methods. According to Apuke (2017), the quantitative research method has to do with "quantifying and analysing variables or parameters to get results". It aims at determining the who, how much, how many, when, and where part of the research by analysing data using statistical methodologies or techniques. It also gives a clear path of the numerical data collection process to show trends, events or series of problems. The quantitative method can be classified into "survey research, correlation research, experimental research and casual-comparative research"(Apuke, 2017).

When the research aims at trialling and testing the hypotheses or to make predictions using statistical techniques then correlation and experimental research are mainly used. An intensive part of qualitative research is where there are many abstract concepts such as feelings or moods involved. In such cases, the researcher must develop an "operational definition" to give these abstract concepts a quantifiable measure such as a self-rating scale (moods\happy-1 to 10 scale). Another critical concept in quantitative research has to do with research bias. There is a high risk of biases including but not limited to information and sampling biases (Bhandari, 2020).

Besides the two most used research approaches the researcher may still choose a mixed or a combined approach. If the data required to respond to the research critical question is mostly made up of textural data then the qualitative research approaches will be best suited for that. In case there is a combination of numerical and textural data then the mixed method approach will be used(Williams, 2011). Taking into consideration the type of textual data required to answer the question of the flow of information the qualitative research approach has been chosen for this research.

According to Williams (2011), there are 5 categories of methods that can be used to conduct qualitative research. Those categories include case studies, grounded theory, ethnography, content analysis and phenomenological. Each category has its strategic outline and as a result, all the different methods aim at achieving a certain objective. For example, Case studies and grounded theory will be used to analyse systems, processes, value chains, events and trends

while the ethnographic method scrutinizes groups of people looking at the common behaviours within cultures and races (Creswell, 2003).

**Figure 19** illustrates the three elements of inquiry. When designing the research framework, four questions must be considered. The first question is "What is the theory of knowledge that is part of the theoretical perspective which forms the baseline of the research", the second question is "What theoretical perspective forms part of the methodology", the third question is "What is the action plan that outlines everything until the outcome", and lastly the fourth question is about the techniques used". These questions and their answers show the interconnected phases of decisions that form part of the process when designing the research. These parameters are very crucial as they assist in the process of choosing the approach(Creswell, 2003).

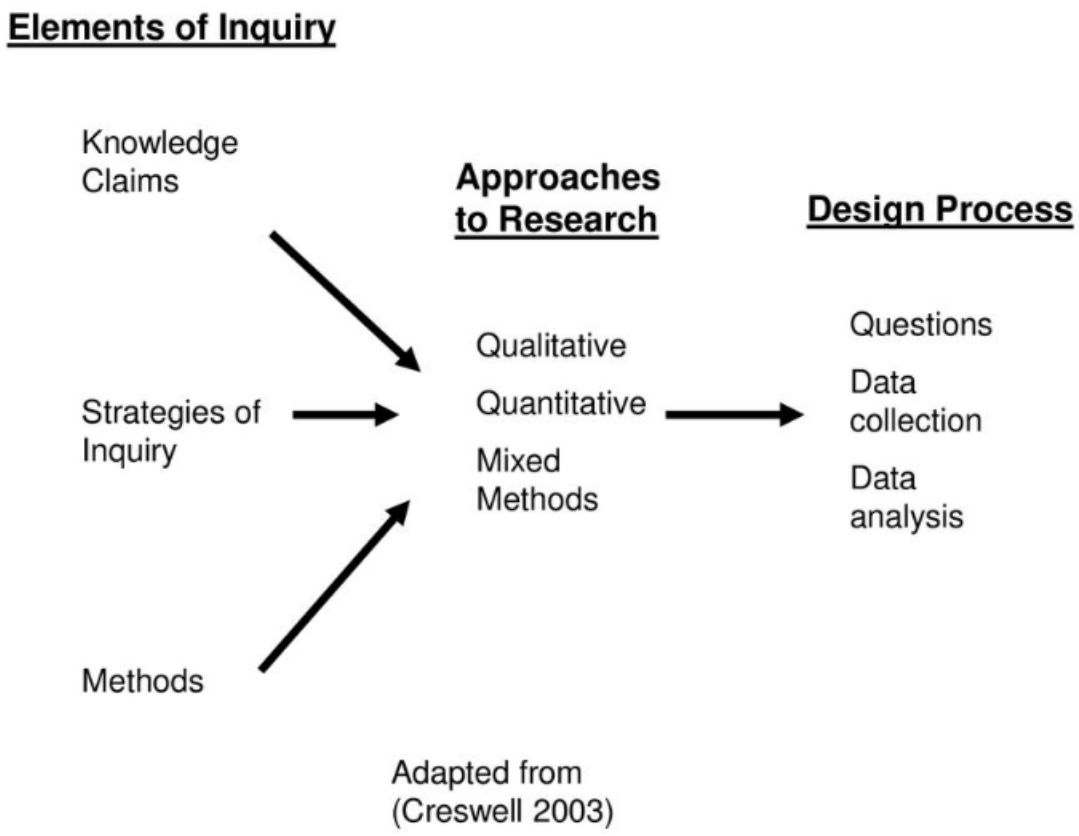



Figure 19: Elements of Inquiry (Creswell, 2003)

Taking into consideration the scope of the area and the data required to answer the question of the information flow gaps at Sishen Mine, the qualitative approach was considered best suited to this research. The collection of data was mainly done through interviews. Due to an

existing risk of information bias and other types of biases such as response bias, a semi-structured interview process was used to ensure the questioning process follows a standardized process. The process that was followed is illustrated in **Figure 20.**

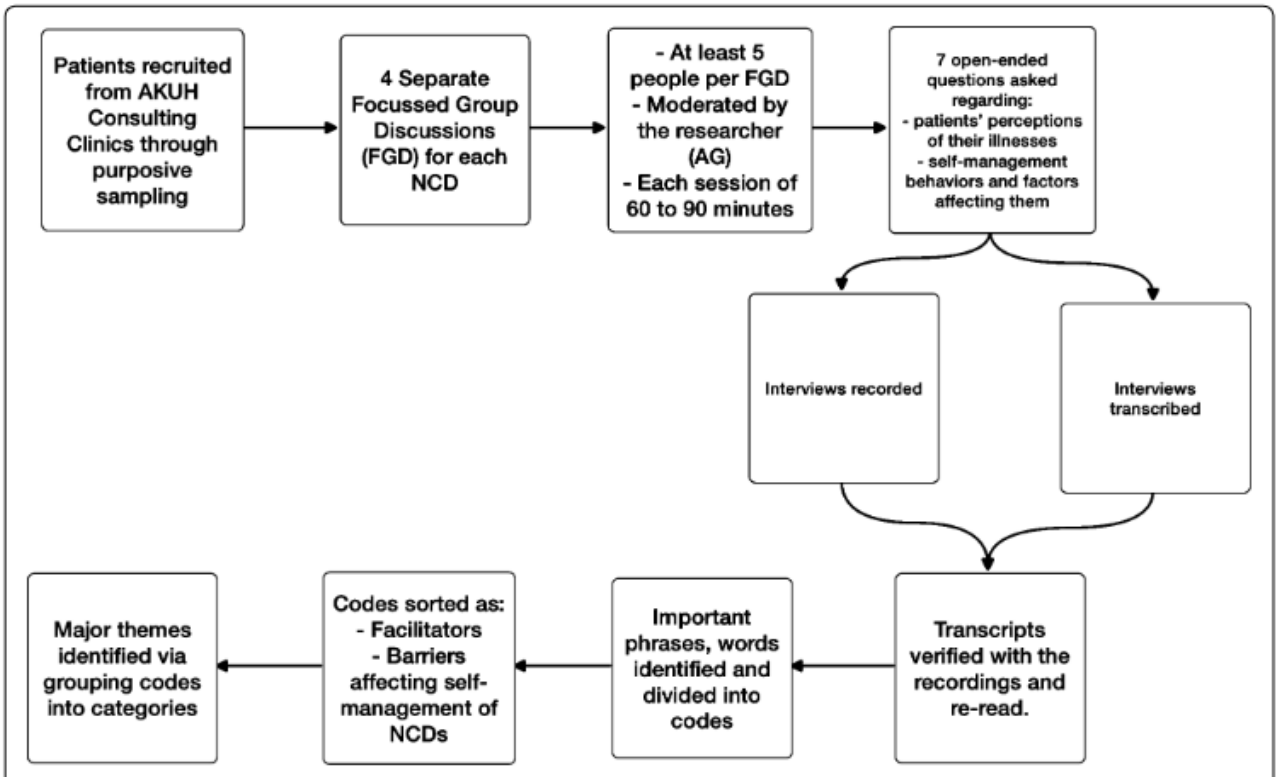



Figure 20: Qualitative study flow diagram (Gowani et al., 2016).

### 3.2. Methodological Design

The objective of the research was to identify the causes of the gaps in information inflow at Sishen Mine, determine the impact these gaps have on the Mine KPIs and finally recommend systems to close these gaps. The data collection was done through a semi-structured interview which was then transcribed to identify themes or sub-themes and prioritise them in terms of their frequency rate. According to Ryan and Bernard (2003), one of the most critical and puzzling activities in qualitative research is to identify themes. The process of theme identification has not been intensively researched and as a result, there is little information on the concept. (Opler, 1945) describes themes as "dynamic affirmations which control behaviour or stimulate activity".

It is difficult to visually observe themes as they are considered as “feelings, values, emotions, experience and perception” of the participants of the research. These themes are deeply embedded in the minds of the participants, so the questioning during the interview must be strategic in such a way as to ensure that all themes are revealed. The simplest process to extract or detect these themes is technically intensive interviews. This process of identification can be used under any form of qualitative research methods be it “phenomenology, narrative analysis, grounded theory and even thematic analysis”. Thematic analysis as an analysis method was used to identify “common patterns emerging from data”(Mishra and Dey, 2022).

Ryan and Bernard (2003) recommend that the researcher must keep an open eye during data analyses. A note must be given to (i) words or phrases that repeat or recur as they can develop into themes, (ii) native and relevant terminologies or concepts that are special to the participants, (iii) figurative speech that the participants use to describe their experience, emotions or feelings(Ryan and Bernard, 2003).

### 3.3. Interview Methodology

The main tool used to collect information in this research is Interviews. Interviews occur where the researcher asks several leading questions to collect information. Interviews include two or more people where one of them is the interviewer and the other is the interviewee. Among the three types of interviews, the semi-structured interviews which fall between structured and unstructured interviews will be used to collect the information from the sample(George, 2022). It is important to choose the right type of interview for the research(Ali and Babak, 2022).

During the semi-structured interview, the researcher has the flexibility and the freedom to structure the questions “spontaneously and explore topics in more depth”. In most of this process, the interview questions are not pre-written(IndiaScribes, 2023). Semi-structured interviews are done on a “loose structure” that is made up of open-ended questions covering the area of scope of the concepts being studied. Interviewees are first asked open-ended questions to give the interview process a direction or set up the foundation of the interview (Britten, 1995).

One major aspect that distinguishes the semi-structured interview from the unstructured interview is that the semi-structured interview is planned and organised with a set of pre-determined open-ended questions. During the interview process, other high-level questions emerge as a result of new ideas or concepts raised by the interviewee(DiCicco-Bloom and Crabtree, 2006).

The interviews are composed of a number or series of semi-structured questions related to the critical question of the study. During the interviewing process, follow-up questions were used to elaborate on ideas raised by the interviewee(Ali and Babak, 2022). Semi-structured interviews as compared to structured interviews are more like normal conversations (Duranti, 2011). According to Mason (2002), qualitative interviews must be well-pre-planned, planned, scheduled and well-resourced. The interviewer must have a list of formal questions which will be asked first to break the ice and give the interviewing process direction. One of the benefits of semi-structured interviews is that most of the interview questions are constructed during the interview(Ali and Babak, 2022).

From the above discussion, it can be seen that qualitative research interviews are such complex process. **Figure 21,** illustrates the relationship and communication between the interviewer and the interviewee. This is shown by solid black straight lines connecting the two. Taking a closer look at the bottom right corner of the diagram, it is clear that communication between the interviewer and interviewee takes place between a “given and historically evolving social setting is stressed”. It is also, very clear this type of communication is of a certain calibre, the type with its unique “norm of what should or should not happen during and after the events”(Wengraf, 2001).

During the interview, existing power dynamics and assets may be used and at the end of the interview some additional ones might be lost and some created. One of the fascinating things about the power-balance dynamics in the interview process is that by the end of the interview, the power dynamics might have remained the same or might have extremely shifted. In some instances, it might remain the same as a result of a failed attempt by either one or both members involved in the process. So, whenever the power dimension is present during the interview it is not a case that is

always going to be a loose or win scenario but, in some cases, both interviewer and interviewee might come out with more power than they started(Wengraf, 2001).

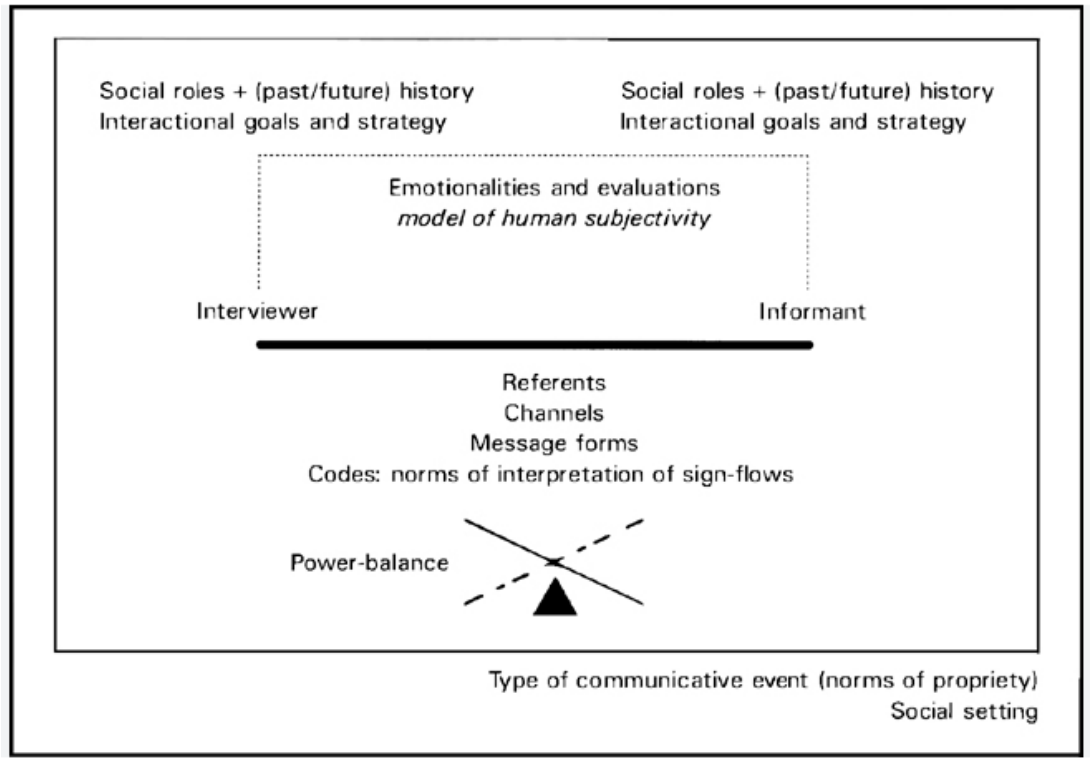



Figure 21: Briggs-Wengraf Model of Components of the Interview Situation (Wengraf, 2001)

### 3.3.1. Interview participants

As compared to quantitative research, in qualitative research, the process of selecting the interview participants is set to be purposeful, a focus is given to participants who can give critical inputs in answering the research critical question and supplement the understanding of the concepts that are under study. One of the most important parts of the process is finding the right participants. The process of choosing interview participants is based on the "research question, theoretical perspective, and evidence informing the research"(Sargeant, 2012).

The sample chosen must be able to give different angles or views, and the basis of the concept that is being studied(Sargeant, 2012). For the study of information flow at Sishen Mine participants considered were based on roles (head of the department, section managers, and

engineers), department (mining operation, mine technical services, and engineering maintenance), level of position in the organogram (senior management, and middle management), and diversity (age, gender, years of experience). All the research participants were, thus, selected using very specific criteria that allow for critical inputs on the research objectives and critical questions of the research. Sishen Mine is a multidisciplinary operation made up of 11 departments. This includes three core departments that are directly involved in safe, efficient, and effective mining of the iron ore and those are mining operations, mine technical service and engineering maintenance departments.

The sample size is the second important parameter in the selection process. A benefit when it comes to the sample size in qualitative research is that the sample size is always predetermined. The predetermined number depends on the adequate number required to give all necessary information on the concepts being studied. When the collection of data process has reached its saturation stage then it means the number of participants is adequate. Data saturation in this case means when more or additional interviews do not produce any new data or concepts(Sargeant, 2012).

Once the collection process has reached the saturation stage, the data analysis process and data collection process are done at the same time in an iterative cycle. A benefit that this brings is that the researcher continues to document any new ideas or concepts that emerge during that period(Sargeant, 2012). There are different sampling methods used to determine the right qualitative research interview participants. Different method depends on the kind of information required and how the information will be used. The most used method and the method that is chosen for this study is called purposive sampling (Dawson, Manderson and Tallo, 1993).

Creswell (1998) recommends that researchers interview from 5 to 25 individuals who have the right skills and experience in the concept. Thus, this study was composed of 10 participants who are experts in their specific technical areas. All of the 10 participants were chosen based on their area of expertise and contribution to the Sishen Mine flow of information.

### 3.3.2. Interview Questions

A set of pre-determined open-ended questions were established and used across all research participants. The first questions were just easy or introductory questions aimed at breaking

the ice with follow-up questions being more technically intensive. The interview questions were guided both by the conceptual framework and the research objectives within the Sishen information flow scope area. This can be seen in Appendix C.

The interview question formulation process followed a process as stipulated by the (Wengraf, 2001) pyramid model (Shown in **Figure 22** below). The research had three main objectives/research purposes (RP). The objectives of the research were to investigate the gaps in the information in a surface iron ore mining operation, to identify the impact of the gaps on the KPIs, and to make recommendations on how to close the gaps. The objectives are then used to formulate the central research question. The central research question (CRQ) was then divided into three main theory questions.

The three theory questions were, establishing the context of the Sishen Mine flow of information, investigating the causes of gaps in the information flow, and identifying the impact of these gaps on the mine KPIs. The theory questions are then broken down into interview questions. Theory question 1(TQ1) was able to formulate interview questions 1 and 2. Theory question 2 (TQ2) was able to formulate interview questions 3 to 8 while theory question 3(TQ3) was able to formulate interview 9.

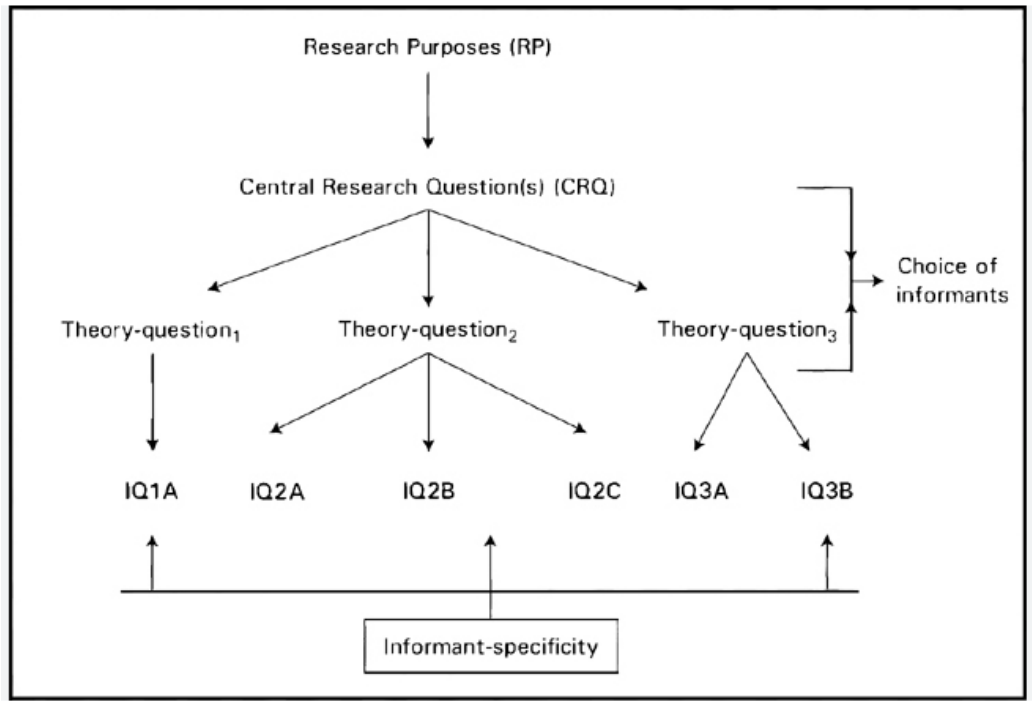



Figure 22: Pyramid Model (Wengraf, 2001)

### 3.3.3. Data Collection

The data collection for this study was collected by a semi-structured interview which was done through a team's platform and face to face. Each interview took between 30 – 45 minutes. One of the key principles that was part of the interview process was the ethical standards. Human worthiness and dignity were maintained by ensuring that the interview process was transparent and non-judgemental. All interviewees were treated with the utmost respect, fairness and impartiality regardless of race, religion, beliefs, socioeconomic status, and physical appearance (Jones and Bartlett, no date).

The participant consent form attached in **Appendix B**, was used at the start of the data collection phase to recruit and inform the participants of the type of study they were about to be involved in. The participant information sheet attached in **Appendix A** was also sent to the participants together with a consent form to give them a description of what the study is about and what is it trying to achieve.

### 3.3.4. Thematic analysis

Once data is collected and stored safely it is then analysed using categorising, ordering, manipulating, and summarising to get answers to the research question. The main objective of the data analysis process is to filter out irrelevant and unusable data leaving only the relevant or crucial data that can be used to satisfy the research objectives. The analysis process is iterating as more information is collected, or classified and more additional supporting question arises to verify, validate and produce conclusions(Uprety, 1970).

Qualitative research data analysis can be done by using two main approaches namely deductive and inductive approaches. The deductive approach uses a very strict or predetermined structure to analyse data. The researcher has a certain predetermined framework or concepts and uses them to analyse the "interview transcript". The structure of this approach is only applicable in studies where the researcher has an idea of the potential responses of the participants(Burnard et al., 2008).

Thematic Analysis was used in this research to analyse the interview data. Thematic Analysis (TA) is the most used method to analyse data in qualitative research. Even though this method can be used with other approaches such as ethnography and phenomenology, it mostly aligns with the grounded theory approach. The TA process mainly involves analysing transcripts, determining themes within the data, and collecting additional examples of themes from the

work. The basic principle of the thematic analysis process is the same regardless if the data is analysed by software or by hand(Burnard et al., 2008). The data is then grouped in a thematic classification under specific themes or sub-themes. When organising the data, the researcher must take cognisance of "commonalities and differences" in the data(Uprety, 1970).

According to Braun and Clarke (2006), thematic analysis is a method used to identify, analyse and report themes or patterns. It is mostly used due to its ability to organise and describe the data set in detail. The method does go on another advanced level "interpreting various aspects of the research topic". Even though thematic analysis is used it does not have a distinct definition of what it is and how it is done. A code is a critical concept or parameter used to explain or measure something. A code deduced from the text can represent a certain theme or themes. As these different types of codes are deduced from the text different themes are born and from that one can determine the frequency or pattern of each theme(Braun and Clarke, 2006).

**Figure 23,** Illustrates the general process that is followed during thematic analysis. The first step is when the entire data is analysed and broader themes are formulated. In the second step, the researcher goes into detail to determine the themes or sub-themes within a text. The third step is then to review the themes identified and verify or validate if such themes exist in the text. Once the themes have been reviewed and refined the fourth step is to explain them in full detail. The most important part of this step is also to ensure that the final themes align with the research question. The alignment between the research question and themes will ensure that the report or the research meets the overall research objectives(Villegas, 2023).




Figure 23: Thematic Analysis Steps (Villegas, 2023)

### 3.4. Data Presentation

When it comes to qualitative data presentation there are two fundamental approaches to use namely the traditional approach and the combination of the finding and discussions approach. The traditional approach is where the key findings are reported under each main theme or category. Once key findings are noted the following step is to relate or link the research findings to the existing research, ideas and concepts. The second approach is to combine both the findings and the discussions in one chapter(Burnard *et al.*, 2008). The raw data does not give the necessary information as required and as a result, the researcher must develop their ideas(analysis) about what is happening, raise and note those ideas down and support them with the relevant information from the interviewee(Uprety, 1970).

Another basic and simple way of presenting data to others is by using visual displays such as tables, flow charts or maps(Uprety, 1970). **Figure 24,** illustrates the flow diagram of how the researcher interacts with the raw and the different types of means to collect, store, present and analyse data.

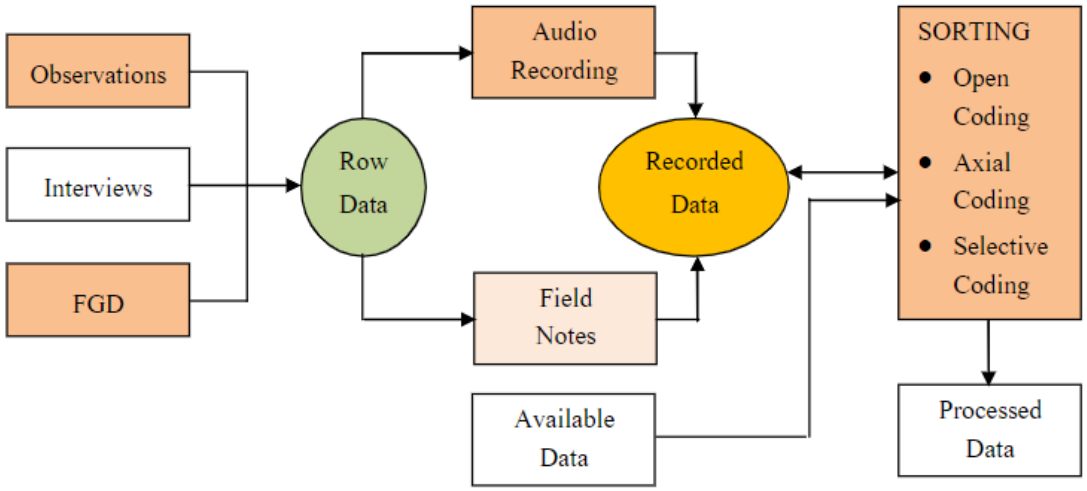



Figure 24: Steps in data presentation/analysis (Uprety, 1970)

## 3.5. Validity and repeatability of results

Validity and reliability in qualitative research are two very important concepts that can assure scientists and other researchers that the research findings are “credible and trustworthy”. This is very crucial in instances where the researcher’s subjectivity and biases can influence the results or the interpretation of the data. Validity is mainly related to the “accuracy and truthfulness” of the research findings while reliability is much more concerned with the “consistency, stability, and repeatability” of the data from the participants(Brink, 1993).

The validity concept was achieved by involving professional experts’ participants from different sectors of the value chain and as a result, everything was able to come together and form a bigger picture illustrating the accuracy and truthfulness of the information(Bashir, Afzal and Azeem, 2008). Repeatability was addressed through the continuous checking and reassessing of the data during the collection and analysis phase of the research to ensure that the results produced could be repeated by others. The data from the interviews and transcriptions was continuously rechecked. The data was highly reliable because the responses from different participants were consistent. A moderator who was an expert in mining reconciliation was chosen to look at the results and ensure that the was bi personal bias influence on the data and results.

## 3.6. Ethical Consideration

One key risk was identified during the literature review phase and that was the researcher's biases during the collection, access and analysis of data. This was mainly a result of the researcher being part of the research process. It is very important to protect participants, especially women and follow appropriate ethical principles during this research study (Mohd Arifin, 2018). All the participants were chosen based on their position on the mine organogram enabling the flow of information. This selection process was free from bias in terms of race, age, gender and any other biases.

As part of the postgraduate research which uses interviewing people as the main source of collecting information the "Guidelines for Human Research Clearance Application(non-medical) from the University of the Witwatersrand" was followed. Due to the high number of people participating in this research, a well-structured participant information sheet (Appendix A) and letter of consent (Appendix B) were attached.

A very discreet and transparent participation structure was developed which informed the participants of their rights, and safety and a clear message that every one of them has the right to withdraw from the research at any time. A very well-mannered and structured process was followed during the interview process. Participants were very aware of their involvement and the need for their significant contribution. Taking into consideration the safety and security of the company data, all measures were taken to ensure that the employee's data was maintained anonymous and very confidential. All the processes and activities during this process were aligned with the "ethics guidelines of the University of the Witwatersrand (**Ethics Clearance Number MIAEC 080/23**)".

# CHAPTER 4

# 4. INTERVIEW FINDINGS AND ANALYSIS

This chapter is made up of the transcribed interview audio recorded during the interviews that were conducted from October 2023 to January 2024. The data is then presented in the form of tables, figures and schematics to enable the intensive analysis process.

## 4.1. Sample profiles

All 10 participants were chosen based on their specific department and position which were very important in both intra and inter-departmental communication. A full detailed introduction of the participants is included below.

Table 1: Summary of the participants

| Date of the Interviews | Participants | Departments | Sections | Positions | Years of experience |
|---|---|---|---|---|---|
| 31-Oct-23 | Participant 1 | Mine Technical Service | Geotechnical Engineering | Geotechnical Engineer | 6 |
| 07-Nov-23 | Participant 2 | Mining Operations | MIOC | Load and Haul Coordinator | 17 |
| 15-Nov-23 | Participant 3 | Mine Technical Service | Production Geology | Production Geologist | 5 |
| 20-Nov-23 | Participant 4 | Mine Technical Service | Drill and Blast Technical | Drill and Blast Technician | 6 |
| 05-Dec-23 | Participant 5 | Mine Technical Service | Drill and Blast Technical | Drill and Blast Engineer | 9 |

| | | | | | |
|---|---|---|---|---|---|
| 12-Dec-23 | Participant 6 | Mining Operations | Contractor Management | Section Mining Manager | 11 |
| 28-Dec-23 | Participant 7 | Engineering Maintenance | Hydraulic Shovels | Section Engineer Manager | 11 |
| 05-Jan-23 | Participant 8 | Engineering Maintenance | Trucks | Feedback Specialist | 10 |
| 08-Jan-23 | Participant 9 | Engineering Maintenance | Secondary Equipment | Feedback Specialist | 10 |
| 11-Jan-23 | Participant 10 | Mining Operations | Drill and Blast | Line Advisor | 12 |

As illustrated in **Table 1**, all the participants had 5 years plus the number of experiences in their area of expertise. This was crucial to ensure the participant's views and insights into the studied topic were reliable.

## 4.2. Interview Analysis Context

Once the data was collected using the semi-structured interview the long interview recordings are saved in a password-protected company laptop. These recordings were then stored again in the Anglo-American cloud SharePoint for extra safety and security until transcribed. The last interview was held on 11 January 2024 and this concluded the data collection through interviews. During the data analysis process, the researcher went through the recordings a few times to fully understand and get a deeper understanding of the type of data sets that exist within the text. A full understanding was useful when outlining all the themes that exist within the text. These data sets were attached with a specific “closed code”.

The set of questions was structured in such a way to satisfy the objectives of the research and as a result, they were clustered into three key ideas.

**1st key idea:** Establish the context of Sishen Mine Flow of Information.

**2nd key idea:** Investigating the causes of gaps in the information flow.

**3rd key idea**: To identify the impact of these gaps on the mine KPIs.

Because of the type of interview that was used the interview questions allowed the flexibility to ask follow-up or additional questions to get more details. This was a very crucial benefit as emergent themes came to light during the questioning. Illustrated below in **Figure 25** are the "codes" that were deduced from recording transcriptions.

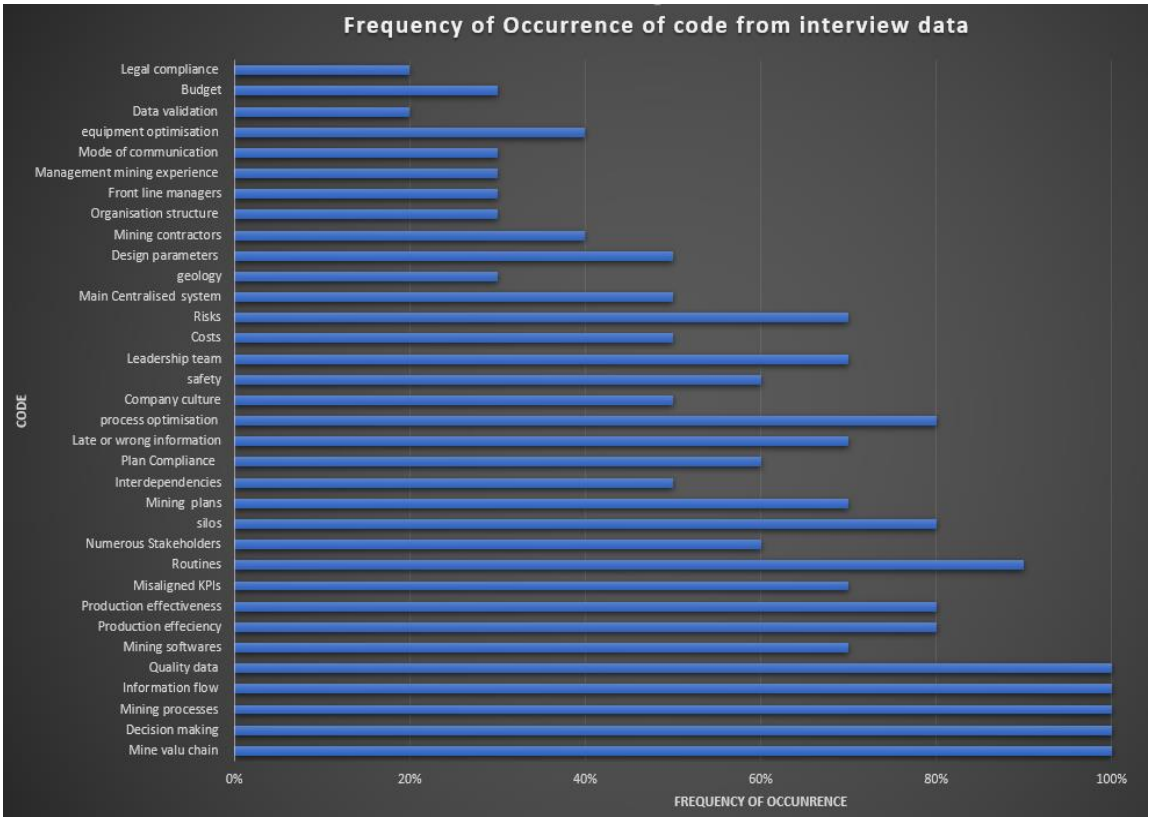



Figure 25: Frequency of occurrence of code from interview data

### 4.2.1. 1st key Idea: Establishing the context of Sishen Mine flow of information (Q1 &Q2)

The objective of this idea was to give full details of the operating environment within which the flow of information operates at Sishen Mine.

All interviews started by asking the participants to give more details about what their responsibilities are, what they do on a day-to-day basis and how they fit into the Sishen Mine structure.

**Participant 1** is a geotechnical engineer which is a middle management position within the geotechnical engineering section under the geology department. As a geotechnical engineer,

Participant 1 is responsible for ensuring that all parameters that are used for pit design all correct, practical and up to date. Those include but are not limited to structure and core logging. Geotechnical engineers are also responsible for ensuring pit design compliance. Then in terms of strata control, geotechnical engineers are responsible for continuous monitoring of the pit walls' stability to assess any potential rock-related incident such as fall of ground (FOG) and give recommendations where necessary. The geotechnical recommendation may include the construction of safety catchment berms, installation of a specific type of support, catch fence and pit design optimisation. The section closely works with several sections across the mine including but not limited to the mining operation block preparation section, mine activity design section, planning section, production geology section, drill and blast technical and survey section.

**Participant 2** is a load and haul coordinator within the MIOC section in a mining operation department. Participant 2 is responsible for ensuring all equipment especially primary equipment's optimised to maximum capacity. This is achieved by prioritising in terms of demand. On a day-to-day basis, the coordinator oversees all load and haul activities of iron ore from the mine to the plant, stockpiles and dumps. As a coordinator, continuous engagement with relevant departments and sections such as engineering maintenance, grade control, plant, planning, and survey is crucial to ensure fully optimised load and haul activities.

**Participant 3** is a production geologist within the production geology section under the geology department. As a production geologist, participant 3 is responsible for providing the mine with in situ rock properties including the ore quality of the reserves. The section achieves this by drilling cores. The cores are sent to the lab for evaluation and once the information comes through the production geologists can use this information to demarcate blocks on the ground depending on the rock type, density, quality and other factors. The production geology section works closely with sections such as grade control, survey, planning, geotechnical engineering, mining operations and contractors such as ROSOND. Participants 4 and 5 are drill and blast technicians and engineers respectively. Both work within the drill and blast technical section under the Mine Technical Service department.

**Participants 4 and 5** are mainly responsible for designing the drilling, charging and blasting patterns, and sequence. They oversee the correct drilling and blasting of the production block while also doing compliance, production and quality reconciliation. On a day-to-day basis, they also do past drilling data validation and check if any rework needs to be done either for

short holes or collapsed holes. The drill and blast technical section is also responsible for executing secondary drilling and blasting on areas that did not blast well such as boulders, toes and ridges. During blasting time, the team closely monitors the seismograph to ensure that the right vibration and air blast are produced.

**Participant 6** is a section manager within the contractor management section under the mining operation department. As a section manager of mining, participant 6 is responsible for mining service providers which are two contractors responsible for loading and hauling of pre-strip portion of the mine. The core responsibility of the contractor manager is to ensure that all parties involved meet their commitment and obligations and ensure that all the parties are compliant with the conditions of the contracts. As an appointed 2.6.1 legal appointee, they are also responsible for ensuring adherence and compliance with the Mine Health Safety Act (MHSA).

**Participant 7** is a section engineering manager within the hydraulic shovel section under the engineering maintenance department. As a section engineering manager, participant 7 is legally appointed in terms of section 2.13.3.1(section engineer appointment) of the MHSA responsible for the safe maintenance of the hydraulic shovels. The core functional responsibility includes servicing and maintaining the hydraulic shovels to ensure high availability.

**Participant 8** is a feedback specialist under the trucks section within the engineering maintenance department. As a feedback specialist, participant 8 is responsible for advising middle and senior management in terms of where to add value or where improvement is needed across the value chain. Thus, ensuring continuous improvement in all stages and phases of the mine value chain.

**Participant 9** is also a feedback specialist within the secondary equipment section under the engineering maintenance department. As a feedback specialist, participant 9 is responsible for ensuring that the measurement system from various departments is standard and working as per the business structure processes. Formulate weekly, monthly, and quarterly critical reports to both senior and executive management. The section is also responsible for operational readiness for all technology projects that must implemented at the mine. They also oversee continuous improvement projects aimed at improving the business.

**Participant 10** is a line advisor within the drilling and blasting section of the mining operation department. As a line advisor, participant 10 is responsible for supporting the drilling and blasting section with necessary improvement initiatives. Overseeing and assisting in the implementation of the operating model through project 82 aimed at improving the equipment availability to 82%. All interviewees described their roles and from this, it was clear that all roles and sections are interconnected and fully depend on each other with information, support, and technical advice or recommendations. There were some mixed responses both positive and negative with an overall idea that Sishen Mine is a very huge and complex operation with abundant information moving or stagnant all across different levels of work.

All participants described how their roles require them to have sufficient information and inputs from different members of the Sishen Mine team and vice versa and how they must provide advice, support and provide significant information contributions to other teams, sections and departments to enable them to do their work and make quality timeous decisions. The overall sentiments were that there is an extremely large amount of information flowing horizontally and vertically in all directions and across all levels of work and that everyone had a significant role and responsibility to ensure swift flow and cooperation.

Besides Participant 2, the rest of the participants were very direct and open to sharing the fact that Sishen Mine is interconnected and as a result, they depend on each other for more than just information. Participant 5 stated that “they work with several departments and sections on a day-to-day basis and do hold information that is very critical to colleagues to execute their work and vice versa”. For that participant 5 believes that all “Sishen employees need each other”. As a drill and blast engineer, Participant 5 requires “geology outlines of rock mass including all geological features such as faults or dykes and other properties of the rock mass to design drill and blast patterns and sequencing”. They also require a “survey coordinator and collar elevation to publish designs”. Participant 5 concluded by stating that “this indeed does show how interdependent we are on each other”.

Participant 8,9 and 10 also stated that because their main functions are around developing and implementing improvement initiatives for the mine they require almost 100% of the information from other sections or departments.” We depend on the accuracy or the data that we get from different sections across the mine, to development and implement initiatives to improve Sishen Mine performance”. To improve the operation performance, one must collect the data for a specific period and from that data one can identify where the process is lacking and therefore recommend mitigating or control measures. Participant 2 believes that all the

MIOC systems and processes within the section scope area are automated and people-independent and as a result do not believe in the interdependencies of people, sections and departments.

Participant 1 reaffirmed that without technical geological scans from the survey and pit design parameters from the mine design team, geotechnical engineers are unable to do their legal appointment functions. “I fully depend on the information given to me by all other sections or departments (survey, mine design, rehabilitation, and mine operations) to give my operation department recommendations or guidelines on matters related to health and safety”

### 4.2.2. 2nd key Idea: Investigating the causes of information flow gaps (Q3-Q8).

The objective of this idea was to identify factors or parameters that prevent quality, and timeous flow of information.

The main objective behind implementing processes, systems and culture that enable the flow of information is to ensure that the flow of information across all sectors, branches and levels of Sishen Mine is accurate, relevant and timely. The information flow from any specific area to another across Sishen Mine must indeed be timely, accurate and relevant to assist everyone in making data-based decisions and building well-informed ideas or designs. Participants 1, 4 and 5 are fully involved in matters that impact the health and safety of the employees. As a result, they all believe “that critical information must be timely and accurate because this is what people’s life depends on”. “If information is wrong or arrives late people's lives and stability of the major infrastructure remain at stake”.

Senior managers such as participants 6 and 7 both reiterated the above statement. Participant 6 stated that “as a contract management senior manager my decisions must be data-based, accurate and timeous and as a result, I need all the information I need to make such decisions”. Any gaps that prevent “my section from receiving quality information is detrimental to the resources and life of this mine”. “Such information must also be relevant, accurate and timely”, Participant 6 repeated. Participant 7 also stated, “Any wrong information or information that arrives late impacts the quality of maintenance and servicing of the equipment”.

According to Participant 6, even though Sishen Mine is one of the largest operations with a significant number of people, sections, systems, and processes it is doing fairly well when it

comes to managing the flow of information. For the last 10 years, Sishen Mine has restructured its organisational structure 4 times. Every time there was a restructuring there were main bigger sections and departments broken into smaller “manageable” sections and departments. The Mine moved from 8 departments with 43 sections to 11 departments and 66 sections with the total number of employees increasing from 7 265 to 11 986. The contractor’s headcount has also increased over the years from 3259 to 6119 employees. So, “this shows how Sishen Mine's headcount has exceptionally increased over the years”. Participant 2 reiterated “Having more people focusing on specific area results in information being dispersed all over the mine and that causes information underload”.

The final outlook of the structure was smaller sections and a high number of people with a smaller scope of area. This meant each employee focuses on their small area of scope and as a result, there is too much information scattered across a large number of people. According to Participants 8 and 9 “The side impact of this was not being able to find or get adequate information from one person and as such for every design and decision, a person must get in contact with a great number of people to get a fair amount of information”. Sishen Mine is 24 hours run operation so to be able to find all relevant people on time is almost impossible. Participants 1, 2,3 and 5 have described instances where they couldn’t find all the right information on time because people were not reachable and as a result, they made decisions based on what they felt was right not based on data.

Sishen Mine produces 2.05 Million tonnes a year and for it to produce these many tonnages it requires a significant number of systems, processes, and performance measures or indicators. Participant 10 stated that “another major factor that enables the gaps in information flow is the fact that Sishen Mine has many systems and processes that do not talk to each other”. Different sections have different systems they use to gather, store, analyse and share information. Due to the security and sensitivity of specific information, most personnel from other sections do not have access to another system in other sections which makes it even more difficult to get information on time. Participant 7 further explained “Planning engineers do not have access to Blast logic and Rockma, systems that are being used by drill and blast engineers” and load and haul coordinators do not have access to execute, or deswik software, these are the systems that are used by planning engineers”.

Production geologists do not have access to the haulsim and fleet management system that is being used by load and haul coordinators. Besides the named systems there are still a huge number of other systems with section-restricted access. The negative impact of this is that

other professionals cannot access other systems with information that is relevant to their scope of area and this makes it difficult to get needed information and make necessary decisions. E.g. “If a planning engineer is sick, off on public holidays or not available and the drilling and blasting engineer needs information on which block must blast”. “Since only the planning engineer can provide such information and the drill and blast engineer does not have access to the planning system it makes it difficult for a drill and blast engineer to execute or make decisions on such matters”. So, in conclusion, it is clear that Sishen Mine has a huge number of these systems and processes that are not linked or integrated.

The third enabler of gaps in the information flow is the non-integrated performance measurement units used to measure the performance of individuals and sections, systems, processes or departments. The Key Performance Indicators (KPI) are role, section and department based and as a result, everyone is measured differently. The mining operation is measured on safety and productivity while the engineering department is measured on availability and mean time between failures of the types of equipment. Mine technical service is measured on compliance and quality of the mining sequence and plans. On a day to day, mining operation personnel (section mining manager and mine overseers) execute their activities at the highest quality possible ensuring the highest productivity with zero harm. The KPIs are very crucial to determine performance track record which is used as a factor to calculate bonuses and for potential promotions. Participant 1 reiterated that “this idea forces everyone to focus on their own KPI taking no consideration of other parties KPI’s and this is mainly because different sections, departments or individual KPIs are not integrated and this results in non-cooperation or silos mentality between all members of the Sishen Team”.

Sishen Mine has had a very unbalanced number of systems and processes in terms of manual and autonomous systems or processes. Autonomous systems are those systems that do not require human interventions throughout their operation, they can record, store, analyse or interpret data and execute their recommendations or measures. Most of the critical systems and processes are mainly manually operated systems and those tend to be “people dependent” and as a result are not productive or useful if the system owner is not available (sick or family responsibility leave or annual leave). Participate 4 notes that “one of the factors that motivate the existence of gaps in the flow of information is making most of the critical systems or processes to be human dependent while limiting the number of systems owners or people who can access or operate them”.

Participant 6 was frustrated when it came to different groups of people making different decisions on several platforms and it does not filter to the other mediums. There are plenty of mediums both formal and informal that are being used to communicate different types of matter across different levels of work. In support of this, Participant 3 also outlined that "one of the reasons that the right information does not flow to the right people at the right time is because there is no clear line of communication (vertically and horizontally) and there are a substantial number of unintegrated mediums (meetings, emails, WhatsApp, and the team platform) being used to collect, store and share information". From this, it was clear that the communication structure is not centralised.

According to Participant 4, Sishen Mine is 90 years old (in 2023) and most people have been working for Sishen Mine for more than 30 years. The side effect of having a certain group of people working for one organization for a long period is the fear of change. Those managers, engineers and front-line managers prefer doing things the way they have always been doing them and as a result, they will always resist change. How this impacts the flow of information is that they (long-serving employees) tend to be self-centred with information and not willing to cooperate and sharing of information. Participant 8 has reiterated "how some of the employees do not understand and appreciate their importance in the value chain". If one individual continuously holds information from other people the entire value chain suffers. These types of behaviour do spread across the mine and generate over wide silo mentality or culture across the entire organisation.

Some of the positions are specialized roles and that means they specialize in a certain discipline or area in the mine value chain. Production geologist for example specialises in rock properties such as grade, rock strength and type. Some of the information that production geologist needs to execute the work has nothing to do with rock properties. The production geologist might need maps and survey notes from the survey section. The entire research has been about quality information getting to the right people timeously. An overlooked fact that contributes to the gaps in the flow of information is when there is too much unreadable data. Sending too much data or sending the data that the receiver cannot interpret or use can also be regarded as no information received. Participant 10 argued that "a simple dashboard giving just enough useable data to the receiver rather than a big file spreadsheet or report can improve the efficiency of the upstream sections and departments".

Participant 1 raised concerns about the type of leadership team Sishen Mine has. Leaders and managers must lead by example and that has been the area of concern. Most senior managers

are motivating and encouraging silo culture. As a result, it becomes easier for sub-ordinate to also work in silos. Silo culture drastically impacts the flow of information. So, at the end of the day there are several pockets of information across the whole mine and this results in a "non-centralised information flow system". Participant 9 also supported the statement above and continued to add that "for information to be used to make critical decisions it must be accessible timeously". To ensure that data is available timeously it must be collected and stored in a central platform where everyone has access.

### 4.2.3. 3rd key idea: To identify the impact of these gaps on the mine KPIs(Q9).

The objective of this idea was to determine the impacts that the gaps in information flows have on Sishen Mine KPIs such as safety, production, costs and sustainability.

Sishen Mine has about 5 main key performance indicators (KPI) and those are safety, finance, safety, productivity and compliance, equipment availability and utilisation. These are parameters that are used to measure the performance of the operation. The main vision and mission of Sishen Mine has always been a high-producing, cost-effective mine with zero harm. Due to iron ore market price fluctuation over the years Sishen Mine has had to better manage its operational costs if it wanted to stay operating and making profits. In the 2023 financial year, Sishen Mine exceeded its budget by almost 4 billion rand. Most of the factors that contributed to the 4 billion rand extra were mainly re-works in construction (ramps and infrastructure), damages to equipment (R18 Million drill fell from the bench) and many more.

Poor or wrong data communication of design parameters from geotechnical engineering to mining operations may result in wrong pit design. In such cases, the operation needs to redesign the pit wall boundaries which require additional support or a different design. Resources and time required for redesigning the pit and improving the stability of the pit with additional support will require additional capital which then increases the costs. If the wrong design parameters are realized late there might be an incident such as a fall of the ground damaging the equipment, slowing down production or resulting in injuries or fatality of employees.

Every month a compliance scan is done on the pit walls to calculate compliance of the pit to the design. Any wrong deviation from the design impacts the pit design compliance. Participant 1 stated that "when it comes geotechnical engineering responsibilities any gaps in

the information flow will have a detrimental impact to the extent of multiple fatalities or loss of billion or infrastructure worth of billions of Rands".

MIOC department uses a system such as a fleet management system (FMS) to control and direct haul trucks between the loading units, dumps, stockpiles and crusher. The FMS is a semi-automated system so it only needs human intervention half of the time. The FMS monitors and directs the load haul cycle time of the shovel and trucks which are queuing, dumping, hauling, and loading time. When information such as equipment status and location does not flow or wrong information flows to mining operations for them to "man up" equipment then the "manning up" of equipment is compromised and this negatively impacts the equipment utilization time.

Depending on the requirements of the plant the shovel and truck alignment must be balanced to ensure that the queuing of trucks and hanging of the shovel are eliminated. So, any miscommunication between grade control and crusher may result in long truck queuing or shovel hangings and this negatively impacts productivity. Diesel consumed when the trucks are queueing is regarded as waste because no tonnages were moved during that period. Participant 2 affirmed that "costs related to diesel consumption was found to be the highest operational costs in 2023 FY, so any gaps in information flow either from the plant team, ore control or operation team can result to a cost waste of over 100 of millions of Rands"

In a production geologist space, most of the wastage costs are a result of re-drills. Most of these re-drills are caused by a shortage of information from previous drilling operations or exploration geology. The re-drills increase the operational costs while slowing down production and this is because for re-drills to happen the production geology must stay longer in production blocks and as a result the actual production drilling is delayed. The basis of re-drills was found to be wrong or incomplete information or miscommunication of the rock properties on that certain block.

An operation of the production geology drills requires 9 people (operators, samplers and assistants) at the same time. Because of several moving parts in the drills miscommunication or no thorough communication between operators, samplers and assistants can result in a serious incident (e.g. fatality of one of the assistants took place in Kolomela Mine on 13 February 2023). Participant 3 argued that "production geology drilling is always suffering as a result of limited to no geology information on blocks and not been giving enough time to acquire enough core drills by the production drilling team". Participant 3 continued to reiterate

that “most of the grade or rock properties demarcation of the blocks is 100% and that impacts the quality of the ore that is fed into the crusher and plant”.

The drill and Blast technical team are responsible for generating drilling, charging and blasting plans or patterns. To produce these patterns, drill and blast engineers require a significant amount of information such as rock properties and types from geology, explosive properties from BME, tonnages and collar coordinates from the survey, and planned drilling diameter from short-term planning. Any of the information mentioned above is very critical to producing a good fragmentation blasted block. Any shortage or wrong or miscommunication of rock and explosive properties may result in a wrong drilling and charging plan which then will produce fly rocks, excessive dust, excessive vibration, misfired holes, uneven floors, toes and ridges, boulders, over mining and undermining.

Any secondary blasting required to treat toes, ridges and boulders requires additional resources and thereby increases the operational cost. Excessive fly rock, dust and vibration may cause a safety hazard (injuries or fatality), or damage equipment or infrastructures. If a piece of equipment like a shovel is damaged by fly rocks then production is negatively impacted up until the shovel can be fixed. It is very crucial not to overcharge the holes and to adequately stem the holes to prevent the noise and vibration from exceeding the legal limit of 85 dB and 12.7 mm/s respectively. If the seismograph detects a noise that is above 85 dB then compliance is impacted. Participants 4 and 5 raised their concern regarding the “inadequate information on rock properties which has been a major concern resulting in poor blasting practices causing toes, ridges and boulders”.

Many contractors within the mine have complained to the senior management that they do not get enough timeous information from the mine contractor management team. There have been records of instances where contractors were overcharging the mines and this was a result of poor over-inspection by the mine contractor management team. Miscommunication and inadequate inspection of contractors result in poor safety records, poor productivity, and poor compliance with very low equipment availability and utilisation while the contractual payout remains the same. Over the years it became worse to the point where contractors work in silos. At the end of the day, the mine is losing significant capital. Participant 6 also reaffirmed that “the current existing contractor management structure and policy do not motivate for easier flow of information and effective over inspection of contractors and as a result, we have seen contractors exceeding their budgets while the equipment utilization drops”.

The engineering maintenance department is measured by one specific KPI and its sub-element. The main KPI is the equipment availability of 85% and the sub-element is the mean time to repair and the mean time before failure. For financial year 2023 engineering maintenance was the highest spender. This was mainly due to equipment damages, high breakdowns, delays in parts arrivals, and several changes in vendors. Both delays in part arrival, high breakdown and damages impact both the costs and productivity. Any work less than the planned and scheduled such as damages and breakdowns requires additional resources which then increases costs. Engineering work is high-risk work done by technicians, artisans and boiler makers.

Any miscommunication between the engineering team and the equipment part supplier can delay the process. When the repair process is delayed the equipment is off production for longer and all the KPIs are negatively impacted. Early in December 2023, two technicians were injured (second-degree burns) and it was found that the main cause was the lack of communication between the technician who was responsible for locking out or insulating and the technician who was responsible for replacing winding in the transformer. According to Participant 7, "This gives a clear picture in terms of how crucial is quality, relevant and timeous information flow and how deeply it negatively impacts the Sishen Mine KPIs **(Table 2)".** It also shows how it will be important and beneficial to prevent a silo mentality and promote a "centralised and integrated operation".

Table 2: Impacts on the KPIs as discussed by participants

| KPIs<br><br>Participants | Costs | Safety | Productivity | Compliance | Equipment utilization and availability |
|---|---|---|---|---|---|
| Participant 1 | X | X | X | X | |
| Participant 2 | X | | X | | X |
| Participant 3 | X | X | X | | |
| Participant 4 | X | X | X | X | |
| Participant 5 | X | X | X | X | |
| Participant 6 | X | X | X | X | X |
| Participant 7 | X | X | | | X |

| | | | | | |
|---|---|---|---|---|---|
| Participant 8 | X | X | X | | X |
| Participant 9 | X | X | X | | X |
| Participant 10 | X | X | X | X | X |

### 4.3. Summary of the Analysis

Chapter 4 analysed the responses from 10 mining professional's data from the interview transcripts. Thus, 3 key ideas or themes, and 35 codes were developed from the analysis.

The context of how information flows in Sishen Mine, the factors and parameters that cause the gaps in the information flow and the impact of these gaps on Sishen Mine KPIs were analysed and discussed in detail. From this analysis, it was clear that there were both people, process and system-based factors that motivated or caused the gaps in information flow at Sishen Mine. People-based reasons included employee fear of change and self-centred individuals who like to gatekeep information, while system or/and process-based factors include unintegrated systems and people-dependent systems. The last part of the chapter showed how these different factors or parameters negatively impact the Sishen Mine KPIs.

# CHAPTER 5

# 5. DISCUSSION\S

## 5.1. Research aims revisited

This research was aimed at investigating the causes of the gaps in information flow at Sishen Mine. This was done by understanding how the information flows between different individuals, sections and departments, from these the research was able to determine the impact of these information gaps on the Mine KPIs. The current literature on the information flow concepts and how Sishen Mine operates was reviewed and it provided a great insight. This however also showed that there is limited previous research done on Sishen Mine and the flow of information in mining operations.

To get more details on the research topic semi-structured interviews were done with different engineers and section managers from different sections and departments. The data collected from the literature review and interviews was able to give more insights into the information flow gaps and their impact on the critical KPIs and most importantly provided the foundation for the development of a "Central and Integrated Information System (CAIS)" to assist close these gaps. This research was guided by three main objectives:

- To investigate the gaps in the flow of information in a surface iron mining operation.
- To identify the impacts of the gaps on KPIs.
- Make recommendations on how to close the gaps.

The first objective was to investigate the gaps in the flow of information in a surface iron mining operation which in this case is Sishen Mine. The objective was fully addressed in Chapter 4 (section 4.2.2) where analysis of the data from the interview transcription was done. The second category of the interview included several interview questions (Q3-8) aimed at finding what are some of the factors or parameters that cause the gaps in information flow. From the analysis, it was explicit that there were several factors or parameters causing gaps in information flow at Sishen Mine. These factors were categorised into two categories namely-people-based factors and system or process-based factors.

The second objective was to identify the impacts that the gaps in information flow have on the mine's key performance indicators (KPIs). This objective was also addressed in Chapter 4(section 4.2.3) where analyses of the data from the interview transcription were done. The third category of the interview included interview questions (Q9) that were aimed at

determining the impacts of the information flow gaps on the KPIs. From this analysis, it was very clear that both people-based factors and systems-based ones have a tremendous impact on the 5 KPIs as illustrated in **Table 2**. Wrong, late, and irrelevant information that moves from one individual, section or department to the other was found to have put an employee's life at risk either in terms of falling off the ground or other high-potential incidents. High-potential incidents have the potential to cause mass destruction that might cause damage to equipment or major infrastructure and negatively the costs, safety and productivity. Miscommunication of the execution plans and sequence negatively impacts compliance.

The last objective was to make recommendations on how to close the gaps in information flow. The recommendation on how to close the gaps is fully detailed in Chapter 6 (section 7.1). From the literature review, interview discussions and data analysis it was already clear that the Sishen Mine needed a system that has two main objectives, which are to centralise and integrate both organisation and data platform.

The literature review revealed the importance of core departments such as engineering, production and technical service in an industrial sector. It showed how these departments are important both individually and together as to some extent depend on each other. These departments are managed through a structure that includes critical parameters crucial for managing the technical processes and systems. This structure is known as a business process framework and it mainly focuses on breaking down an organisation's strategy to operational level teams to continuously monitor the execution of the strategy and finally respond to the performance.

Performance is tracked using measuring indicators known as Key Performance Indicators. There are several different KPIs used to measure a certain area of an organisation, system or process. The different category of the KPIs covers areas such as safety, finance, compliance, and productivity. Visual dashboards are then used to illustrate the trend of these KPIs.

To improve and better manage an organisation it is very clear the cruciality of having a good and practical structure in place to maximise the efficiency of the organisation. This structure allows easy flow of information across different levels of work both vertically and horizontally. Once information is available to all relevant stakeholders it is then easier for such stakeholders to be aligned with the mission and vision of the organisation. As more people start sharing information through systems and processes then coordination and integration of systems, processes and people become a lot easier.

So far there has been a great alignment between the data collected from the literature review and the data from the interviews. The results outlined that from the cost overrun in FY 2023, costs related to fuel or diesel were the highest contributor. Participant 7 confirmed and highlighted that the equipment availability and utilisation of 85% was necessary to ensure efficient and effective load and haul operation. In alignment with the results, the literature review was able to make the following highlights: a keynote is that one of the highest capital costs in open-cast mining operations is related to transportation equipment while the highest operational costs are related to fuel and diesel costs. Equipment availability and utilization were also noted as the two main KPIs that are very crucial for optimizing the equipment operation in an open-cast mine.

One of the issues that were fully and explicitly detailed as one of the enablers for gaps in the information flow was unlinked KPIs. 70% of the participants as illustrated in Figure 25 mentioned this as a key enabler. Unlinked KPIs motivate individuals to focus on their sole KPIs not giving regard to how that impacts others or their KPIs and the overall Sishen Mine KPIs. The fact that everyone is solely focusing on their KPIs enables a silo working culture. Participant 1 gave details of the scenario where certain people blindly decided to focus on their KPIs only and how this resulted in a near-miss incident that had the potential to be a fatality. So according to the literature review, the main objective behind KPIs implementation is to enable management and leaders to be aware of trends or patterns as they will assist them in making overall strategic decisions. The key word from this is “making an overall strategic decision” meaning the manager or the leader must make a decision that will improve all KPIs but the issue remains that most of the KPIs are not linked as a result they cannot show an overall picture or performance of the organisation.

Sishen Mine is one of the biggest operations managed by Kumba Iron Ore and as a flagship operation of the Anglo-American Group, it has implemented several systems and processes to improve its efficiency and effectiveness. For the past 10 years, the Sishen Mine production target has exponentially increased and currently amounting to 183 Million tons in FY 2024. The high production has required Sishen Mine to also increase its systems, processes and employees. The company went through a restructuring process 4 times over the last 10 years and the results were an increased number of employees and contractors. The total outlook of the organisation structure changed with more departments and sections. Some of the departments and sections were broken down into smaller manageable departments and sections.

From analysis, it was very clear that the current Sishen Mine's organisational structure does not motivate and enables the quality, and timely flow of information. The organisational structure has been structured in such a way that information only circulates within a certain area, level, section or department. A certain department collects, stores or shares information within themselves and only allows information to flow to another department on the head of department level. The sections collect, store and share information only to allow it to other sections on the section manager level. So, all these departments or sections do not enable inter and intra-departmental collaboration. Each section and department works on silos and motivate their team members to work on silos. There is a huge gap when it comes to information flowing horizontally between sections or departments.

Silo mentality or culture refers to a culture where employees are reluctant to share information with other employees from other sections, departments or another organisation. If a geotechnical engineer holds information relating to pit wall stability from a mining operation engineer this might result in an incident that might cause equipment damage or even result in an injury\fatal. The act by the geotechnical engineer to hold information from other relevant stakeholders causes gaps in the information flow and does hurt the mine KPIs such as safety, productivity and costs.

According to the literature review, the organisational structure is the framework or build-up of an organisation. The structure outlines everything about an organisation including how the organisation must be managed or controlled, what are the roles and responsibilities of every role, section and department, how the organisation operate, what is the chain of command and how the information must flow within the structure or outside, and lastly the structure details how different roles, section and department must work together and what information must they provide to each other. From this, it is very clear that there is a huge contradiction between the results and literature in terms of how the current Sishen Mine's organisation structure is structured and how it operates as compared to how the organisation structure is supposed to be structured and operated.

Being one of the most advanced mining operations Sishen Mine has quite a significant number of systems and processes which are fully automated, semi-automated and some are manual. All these different systems or processes operate within their area or platform and that means most of them are not linked or integrated and thereby do not talk to each other. The fact that these systems and processes are not integrated is the enabler for miscommunication or gaps in the information flow. Other factors were related to having too many processes or systems that are people-dependent. Once the systems or processes owners are not available or

reachable then the system is retendered useless or inactive. This mainly becomes possible if an organization does not have a well-established or mature flow of information or communication structure. Hickethier, Tommelein and Lostuvali (2013) stated that the more people, systems and processes are integrated into one main system coordination, and allocation of resources becomes easier and more efficient.

The research question was “How can the flow of information be improved among the different sections and departments at Sishen Mine”. The first step in answering the research question was to first analyse the current state of the information flow at Sishen Mine. This was achieved in Chapter 4 section 4.2.1. were systems and structures on how information flows were discussed. The second step was to determine the factors that impact the information flows or rather factors that cause the gaps in the information flow and this was also achieved in Chapter 4 section 4.2.2. From this analysis, it was clear that to improve Sishen Mine's information flow, the mine had to invest in developing and implementing a system that would allow information and the organisation to be both centralised and integrated. Centralised in a way everything is operated, controlled or managed or everyone is managed from a central basis within the organisation. Integrated in such a way that everything is linked or everyone is linked in a way that relationships or links between them are clear in terms of the requirements for existence and the impact they have on each other.

## 5.2. Reliability and validity

The research mainly used Google Scholar, different universities' websites and reports, corporate reports and presentations, and other trusted research institutions to collect information to do the literature review. All the used data sources both formal and informal showed similarities in the information shared showing a great deal of “triangulation approach”. The researcher interviewed 10 participants from different sections and departments of the Sishen Mine operation. Those included feedback specialists, line advisors, drill and blast technicians, drill and blast engineers, load and haul coordinators, contractors section managers, and section engineering managers.

The chosen participants were very diverse in terms of gender, area of expertise, number of years of experience and qualifications. This was beneficial to provide quality data with little to no bias. The congruency of the information from the participants was very clear as different engineers and section managers from different parts of the mine shared the same sentiments, ideas, and frustrations. The intensive long interviews and literature reviews done in a space of 3 months between 31st October 2023 to 11th January 2024 were able to give very crucial

insight into the scope of research. The information received answered the research critical question and satisfied all the research objectives.

# CHAPTER 6

## 6. CONCLUSION

The overall objective of the research was to improve the information flow between systems, processes, sections, individuals and departments in Sishen Mine. The overall objective was broken down into 3 main objectives which were used to guide literature review, research design and methodology.

A semi-structured interview of the 10 mining professionals from different sections and departments within Sishen Mine was done as the primary source of information. A qualitative research method using thematic analysis was used for the analysis process to identify codes and themes\key ideas.

Sishen Mine is one of the largest iron ore mining operations in South Africa and a major contributor to Kumba Iron Ore revenues, so if Sishen Mine is not doing well then automatically the company would not do well. Thus, there is a high appetite to continuously improve systems and processes at Sishen Mine. One of the major issues that has been at the top was the impact on costs, safety and productivity KPIs. This is motivated by the lack of poor communication between individuals, sections, systems, processes and departments to enable a safe, efficient and effective operation.

It was clear from the analysis and discussions that the gaps in the information flow have had a major impact on the efficiency and effectiveness of the operations. The main objectives of the research were to investigate the gaps in the information flow, determine the impacts of these gaps on the KPIs and recommend a system to close them. Several people-based factors and system-based factors were identified to be the cause of these gaps and a clear impact in terms of how they impact the KPIs was realized.

All the research objectives were achieved and a system to mitigate these gaps was also outlined. The system recommended will be able to improve the information flow across all levels of work and as a result, answer the research critical question. The analysis of the data and discussions were found to support the literature review. The semi-structured interviews were used as the main medium to collect primary data from

the 10 mining professionals. Thematic analysis was used to transcribe and analyse the interview data.

Taking into consideration that all of the interviews were done during office hours, there was a limitation when it came to the availability of the participants. Kumba Iron Ore is a member of the Anglo-American Group and for that confidentiality is one of their main principle. Due to privacy and confidentiality of some of the information participants could not share some of the information that was relevant for the research scope due to its sensitivity. Sensitivity information such as actual revenues, targets, headcount and so on.

## 6.1. Recommendations

### 6.1.1. Centralised and Integrated System (CAIS)

From the literature review and interview data analysis, the researcher was able to conclude that the best recommendation to eliminate the gaps in the information flow was a mega system that is both centralised and integrated called a "Centralised and Integrated System (CAIS)". The system will have two major benefits which are to centralise and integrate the organisation and the data platform. CAIS will be the main central system throughout the entire mine and value chain integrating all different operating systems, information systems, people and processes. This system will create the structure for information flow and any details about how, why, what and when must the information flow and to whom(Spike Team, 2024).

One of the factors that resulted in the gaps in the flow of information was the unintegrated systems and processes. All the systems across the value chain will be integrated into this one mega system that all relevant personnel will have access to and those include Engineering, MTS and Mining operation departments and all other supporting department systems. All relevant performance and progress reports, Gantt charts and trend diagrams will be accessible to all relevant personnel through this one mega system. The system will be real-time updating any information that comes through from the site-specific systems(nqa, 2021). E.g. When a drill and blast engineer updates drilling and charging progress on the blast logic software (only drill and blast engineers have access to this software) such information can also be accessed through CAIS by anyone including planners, maintenance engineers, mining engineers, surveyors and all other relevant personnel.

CAIS will use dashboards to illustrate the entire key performance indicators trends across the mine value chain. This will show how each indicator performs daily, weekly, and monthly. The benefit that this brings is the integration of all the measuring indicators across the mine value chain and shows how every one of them impacts the other. The integration of KPIs creates teamwork between individuals, sections and departments and as a result, eliminates a silo mentality culture(ACCA, 2013).

The CAIS will have its operating manual called information management structure which will determine all relevant routines(meetings) and sub-routines (feedback sessions) necessary to feed information into CAIS. The routine structure will give full details in terms of the importance and need for that routine. The detailed structure will clarify when the routine is held and how often (daily, weekly, monthly or quarterly). It will also give more details on who is expected to be in routines and what type of information must they bring. There will be different types of routines with different objectives held by different sections and departments(Lucidchart, 2024).

E.g. A planning team will have a planning meeting on Monday morning and this routine will be attended by all planning and mining operation teams. The meeting will aim to align on the work to be done throughout the week and the mining operation team must commit to the work to be done. The dream behind CAIS implementation is that any relevant team member can log in on CAIS and from there one can find any information from any department across the mine. Those include but are not limited to operational data, technical data, KPI performance and reporting, strategy and tactical plans, procedures, change of management reports, and all other communications.

This centralised and integrated system provides the following benefits: Since it is centralised which means quality information flows to a central point and as a result, this reduces any miscommunication or flow of wrong information. It ensures that there is only one viable information, instruction, guidelines, designs and plans at a certain point in time accessible to all relevant stakeholders. Because it enables integrated operation which means everyone and every KPI is linked to each other and the Sishen Mine KPIs. People are aware and clear of their roles and responsibilities in the main Sishen vision and how their work impacts others. Everyone is clear about which routines they are expected to attend and which information must they bring. They are also clear about which information must they give to whom, when and how and vice versa where can they find any information relevant to the work. At the end of the day, everyone is happy and willing to work together with others because everyone understands how they either as an individual or as a group impact Sishen Mine KPIs.

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# 8. APPENDICES

## 8.1. Appendix A: Participant information sheet

***01 October 2023***

Dear Section Manager/Engineer

Re: Participation in Research on "Investigating the flow of information in a surface iron ore mining operation

Thank you for offering, via your response to the recent formal request to participate in the interviews.

I am a part-time MSc student in the School of Mechanical, Industrial and Aeronautical Engineering at the University of the Witwatersrand, under the supervision of Dr Bernadette Sunjka. My MSc title is: Investigating the flow of information in a surface iron ore mining operation. My studies are sponsored by the Mining Qualification Authority. My belief is that there is a lot of gaps in information flow that exists between individuals', sections, and departments. I would specifically like to understand the impact that these gaps are having on the mine KPI's such as costs, productivity and safety. I would like to formally invite you to participate in this study.

The interviews will be conducted between October 2023 and January 2024. Involvement in the study would entail two (2) face-to-face and teams interviews with you, as the Section Manager/Engineer, at your convenience. During these interviews I would like to understand how your company operates, and understand more about the information flow. Participation in the study is voluntary, and you may withdraw at any time. Anonymity (regarding company name and any owner/manager/employee names) and confidentiality of information provided will be assured and respected. I would like to record the interviews, so I can later transcribe them. Your consent at the time of the interview will be requested. If you do not wish the interviews to be recorded this will be respected.

The results of the study will form part of my MSc dissertation report, and may also be reported in academic papers and at conferences. A summary of the results of the research will be made available to you on request.

Please contact me if you have any questions regarding the research and participation in the study.

I look forward to hearing from you.

Yours faithfully
Loeto Levious Sekwati
E: 1433284@students.wits.ac.za
T: 0670385661

Supervisor: Dr Bernadette Sunjka
Contact details: Bernadette.Sunjka@wits.ac.za

## 8.2. Appendix B: Participant Consent Form

Dear Participant,

Thank you for accepting to participate in this study. Please complete this consent form as you see appropriate. By signing this consent form, you are indicating that you have read and understood the description of this study and that you agree to the terms as described below:

| | Mark with X | |
|---|---|---|
| | YES | NO |
| I confirm that I have read and understood the information about this study as provided in the participant's information sheet. | | |
| I understand that my participation is voluntary and that I am free to withdraw at any time without any penalties or negative consequences against me. | | |
| I grant permission for the interview to be audio recorded. | | |
| I agree that the information I provide may be treated as strictly confidential and anonymous and only the research team will have access to the interview data. | | |
| I understand that the information acquired from the interview will not be recorded in excess of what is required for this study. | | |
| I agree that the results of this study may be recorded in academic journals and at conferences. | | |
| I have had the opportunity to ask any questions related to this study and I have had all my questions answered to my satisfaction. | | |
| I may request a report summary, which will come as a result of this study. | | |

With full knowledge of all above-mentioned terms, I agree to participate in this study.

| Participant | | Consent taken by (Researcher) | |
|---|---|---|---|
| Name | | Name | |
| Signature | | Signature | |
| Date | | Date | |

## 8.3. Appendix C: Research interview questions

**Semi-Structured Interview:**

1. What is your current role, responsibility and where do you fit within the Sishen Structure?
2. What is your responsibility when it comes to information flow at Sishen Mine?
3. What's your view on the structure (Organogram) of information flow at Sishen Mine?
4. How and What systems do you use to provide information to other stakeholders (upstream section)?
5. How and what systems do you use to get information from other stakeholders (downstream section)?
6. How does information flow from one process to another in the mining value chain?
7. How do you measure the risks of information flow?
8. What causes the gaps in information flow at Sishen Mine?
9. How does the information flow gaps impact Sishen Mine KPI's (Safety, Productivity, and Finance)?
10. What will you propose or recommend to close the information flow gaps in your view?

[OFFICIAL]

## 8.4. Appendix D: Participants interview transcript.

| Participant | Text | Codes |
|---|---|---|
| All Participants | Thus, ensuring continuous improvement in all stages and phases of the mine value chain. | Mine Value Chain |
| All Participants | For information to be used to make critical decisions it must be accessible timeously | Decision making |
| All Participants | The information flow from any specific area to another across Sishen Mine must indeed be timeous, accurate and relevant | Information flow |
| All Participants | They oversee the correct drilling and blasting of the production block while also doing compliance, production and quality reconciliation | Quality data |
| Participants 1,2,3,6,7,8,9 & 10 | Load and haul coordinators do not have access to execute, or deswik software, these are the systems that are used by planning engineers | Mining softwares |
| Participants 2,3,5,6,7,8,9 & 10 | Spreadsheet or report can improve the efficiency of the upstream sections and departments | Production efficiency |
| Participants 2,3,5,6,7,8,9 & 10 | The main vision and mission of Sishen Mine has always been a high-producing, cost-effective mine with zero harm | Production effectiveness |
| Participants 2,4,5,6,7,8, & 9 | This idea forces everyone to focus on their own KPI taking no consideration of other parties KPI's. | Misaligned KPIs |
| Participants 1,2,4,5,6,7,8, 9 & 10 | There is no clear line of communication (vertically and horizontally) and there is a lot of unintegrated mediums (meetings, emails, what's app, and the team platform) | Routines |
| Participants 1,2,3,6,7,8,9 & 10 | This is mainly because different sections, departments or individual KPIs are not integrated and this results in non-cooperation or silos working between all members of the Sishen Team | silos |
| Participants 9,2,4,5,6,7 & 10 | The drill and Blast technical team are responsible for generating drilling, charging and blasting plans or patterns. | Mining plans |
| Participants 1,2,4,5,6,7,8, & 9 | Those include but are not limited to structure and core logging. Geotechnical engineers are also responsible for ensuring pit design compliance | Plan Compliance |
| Participants 1,2,3,6,7,8,9 & 10 | Poor or wrong data communication of design parameters from geotechnical engineering to mining operations may result in wrong pit design | Late or wrong information |
| Participants 3,2,4,5,6,7,8, & 9 | The geotechnical recommendation may include the construction of safety catchment berms, installation of a specific type of support, catch fence and pit design optimisation | process optimisation |
| Participants 1, 2,8,9 & 10 | These types of behaviour do spread across the mine and generate over wide silo mentality or culture across the entire organization. | Company culture |
| Participants 1,2 4,5,6 & 7 | Miscommunication and inadequate inspection of contractors result in poor safety records, poor productivity | safety |
| Participants 2, 6,7,8,9 &10 | Participant 1 raised concerns about the type of leadership team Sishen Mine has | Leadership team |
| Participants 1, 2,3,5 & 6 | In a production geologist space, most of the wastage costs are as result of re-drills. | Costs |
| Participants 2, 8,9, &10 | From this, it was clear that the communication structure is not centralised. | Main Centralised system |
| Participants 1,3,4 & 5 | Most of these re-drills are caused by a shortage of information from previous drilling operations or exploration geology. | geology |
| Participants 1, 4, & 5 | The data from the continual monitoring software such as radar is used to recommend design parameters | Design parameters |
| Participants 3, 4, 5 & 6 | The production geology section works closely with sections such as grade control, survey, planning, geotechnical engineering, mining operations and contractors | Mining contractors |
| Participants 8,9 & 10 | For the last 10 years, Sishen Mine has restructured its organisational structure 4 times | Organisation structure |
| Participants 6, 7 & 2 | Those managers, engineers and front-line managers prefer doing things the way they have always been doing them and as a result, they will always resist change. | Front line managers |
| Participants 2, 6 & 7 | All the participants had 5 years plus the number of experiences in their area of expertise | Management mining experience |
| Participants 1, 3 & 10 | There are a lot of mediums both formal and informal that are being used to communicate different types of matter across different levels of work. | Medium of communication |
| Participants 4 & 5 | On a day-to-day basis, they also do past drilling data validation and check if any rework needs to be done either for short holes or collapsed holes. | Data validation |
| Participants 6, 8 & 9 | Sishen Mine exceeded its budget by almost 4 billion rand | Budget |
| Participants 6 & 7 | Any wrong deviation from the design impacts the pit design compliance. | Legal compliance |