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School of Mining Engineering



UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

DEVELOPING A WORK MANAGEMENT SYSTEM TO CREATE AN INTEGRATED AND OPTIMAL SHORT-TERM PLANNING PROCESS AT SOUTH DEEP MINE

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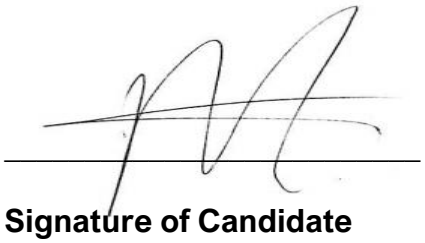
A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 2023

DECLARATION

I declare that this report is my own, unaided work. I have read the University Policy on Plagiarism and hereby confirm that no plagiarism exists in this report. I also confirm that there is no copying nor is there any copyright infringement. I willingly submit to any investigation in this regard by the School of Mining Engineering and I undertake to abide by the decision of any such investigation.



13 June 2024

Signature of Candidate **Date**

“An inspirational quote”

Imagination is everything. It is the preview of life’s coming attractions.

Albert Einstein

ABSTRACT

This research was conducted at South Deep Mine, an underground trackless gold mine located within the Modderfontein Farm in the Westonaria District, Southwest of Johannesburg. The aim of this study was to develop a work management system to create an integrated and optimal short-term planning process at South Deep Mine. The study employed both quantitative and qualitative research methods to achieve its objectives. Most of the data was obtained through an online survey which targeted individuals employed within the mine technical services department.

The problem being addressed in this research is the challenge associated with manual data capturing during planning sessions. This research is driven by a desire to improve work efficiency and mine productivity at South Deep Mine through the application of innovative planning and reporting tools. Literature review presented the importance of innovation and effective planning in mining operations, indicating the role of integrated work management systems in modernized underground mining environments.

Work Management Systems investigated were Deswik and MineRP software and Syncromine reporting system. The results reflected that Deswik and Syncromine are used throughout the industry with some benefits such as the ability to produce integrated production reports and the reliability in data handling. However, data analysis revealed shortcomings in existing work management systems, particularly in addressing real-time data and promoting automation.

The aims of this research were achieved through the development of a systemized planning protocol. The study highlighted the need for an

integrated approach to address short-term planning challenges. Future studies include the adoption of user-friendly software tailored with site specific requirements and the development of models covering all aspects of the mining value chain.

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I would also want to express my deep gratitude to both of my late parents, Dinah Maleka, and Alfred Maleka, for bringing me up in a healthy and strong manner and made sure I got the best possible education to shape my future regardless of the circumstances we encountered in life. **May their soul rest in peace…**

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LIST OF EQUATIONS

Only mean calculations were used in this research. The principle used was

- Mean Value = (sum of values / number of questions)

LIST OF ABBREVIATIONS AND SYMBOLS

The Following abbreviations were used in this study

Abbreviation	Meaning
Moz	Million Ounces
BI	Business Improvement

1 INTRODUCTION

1.1 Research Background and Context

Adoption of modernised planning and scheduling tools has optimized work efficiencies in various underground mines (Wang, 2019). Planning function continues to add a significant value to the mining industry, and it is regarded as a function that considers necessary work associated with all various activities within the entire mining value chain (Araya, et al., 2020). However, due to the challenging working conditions in an underground mine, production planning in most cases becomes very difficult (Li, et al., 2021).

The study of integrated work management systems has been in discussions since 1990s and its core value is around quality management amongst others (Souza Barbosa, et al., 2021). The primary objective of work management system is to optimize output in the organisation processes, and it is seen as a key to controlling work planned and avoiding resource, time, and management issues (Malsam, 2021). Therefore, short-term planning remains critical in addressing any operational challenges as it provides detailed methods for effective execution at operational level (Torres Toledo, et al., 2022).

South Deep Mine is an underground bulk mechanized mine, located 50km Southwest of Johannesburg, in South Africa. The operation has two underground mechanized complexes, namely Twins and South Shaft. The primary mineral being exploited is gold, and the estimated mineral reserves are around 32.2 Moz, which projects the life of mine to be over 70 years. The mine location is shown in Figure 1.

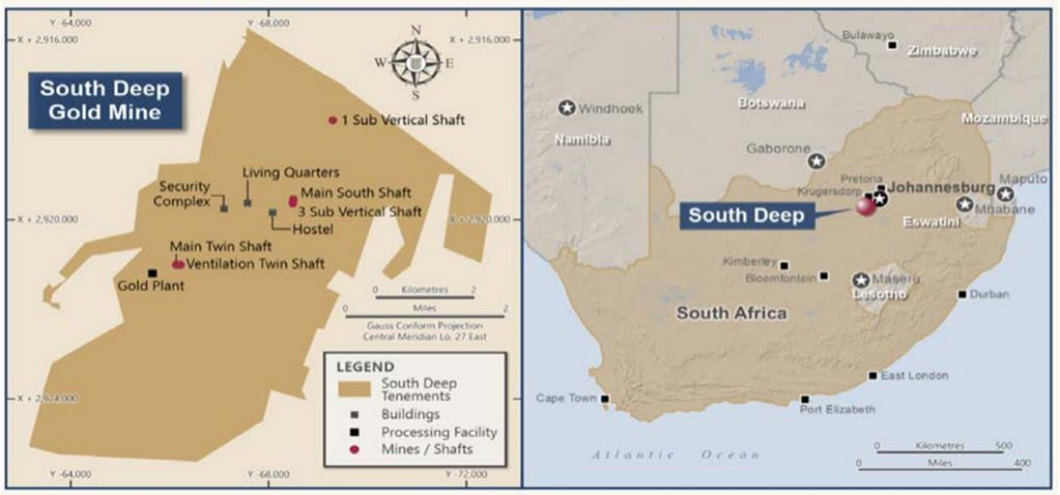


Figure 1. South Deep Mine General Location of Material Assets (Goldfields Limited, 2023)

Amongst other modern technologies, South Deep Mine employs tele-remote load haul dump truck and impact breakers, which provides live data on tonnage tipped at any given time in relation to revenue generated. The entire control room is set up to provide live communication with underground personnel. Figure 2 below shows the operation of an impact breaker as well as the tele-remote load haul dump truck in the control room, showing the tonnes profiles for year 2021 and 2022.

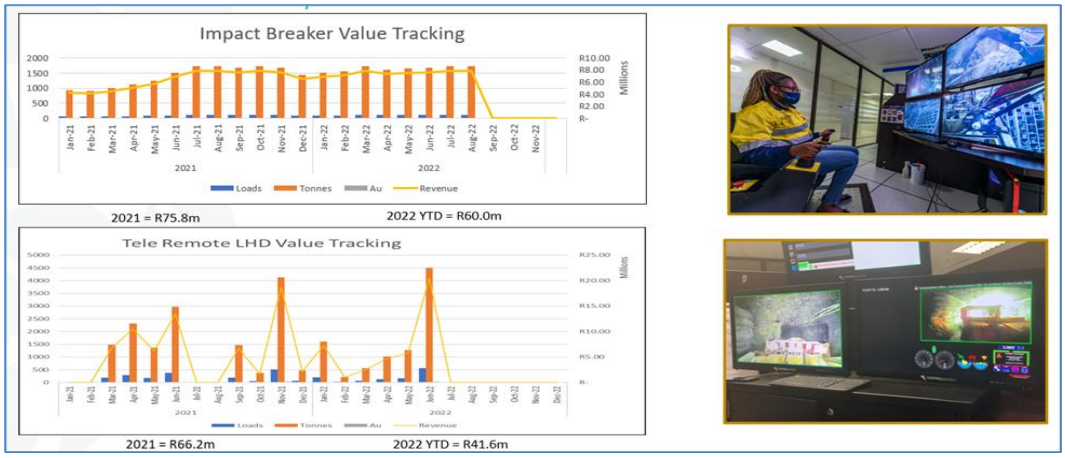


Figure 2. Tele-remote on LHD and Impact Breaker (South Deep Gold Mine, 2022)

A 10% increase in gold production between year 2021 and year 2022, was achieved at South Deep Mine. This great performance was due to the systems put in place including the operating business model, which ensured that the business operate at the acceptable standards, established process capabilities as well as process stability (Goldfields Limited, 2023). However, it was further discovered that the operation has a challenge with its work management system to integrate mining activities to optimize short-term planning process. This has impacted production negatively as well as health and safety.

To mitigate this operational challenge, this research aims to investigate and develop a reliable work management system capable of integrating mining functions to improve short-term planning process at South Deep Mine.

1.2 Problem Statement

Currently there is no planning protocol at South Deep Mine to conduct an efficient planning process. Manual data capturing during planning sessions and between systems to close-off the planning cycle is still happening to a significant extent. This creates challenges in guiding the planning process as well as to digitize and automate the reporting systems. The absence of a system to integrate mining functions, has resulted in critical issues concerning production such as engineering work, as well as health and safety not being effectively addressed during planning sessions.

In addition, the current booking system does not provide informative data, only booked meters are recorded and not lost shifts which makes it difficult to run a problem analysis. With regards to compliance to plan, current work management systems at South Deep Mine are unable to provide early warning when unplanned areas are mined. Furthermore, there were

some disorganizations of the mine's resources between different mining areas, which causes unnecessary production delays. The unavailability of effective work monitoring has resulted in areas not being planned to mine, finally being mined, which posed a significant health and safety risk to mine employees. The organisation has also experienced a reduction in production performance due to misallocation of equipment.

1.3 Justification for Research

Innovation links all spheres of humanity due to its ability to initiate economic and community growth and it is regarded as a solution for mining sector aiming to maintain global competitiveness over long term horizons (Bertayeva , et al., 2019). South Deep Gold Mine has proved to have mineral resources and reserves which could be exploited for over 70 years. This potential for mining is only possible provided every system and processes employed at South Deep Mine deliver consistent output in both the short-term and medium-term horizons.

The unavailability of work management system to address the identified problem areas at South Deep Mine as mentioned above, has been recognised by the mine management and currently there is an initiative to close the existing gap. This research is important as it will assist South Deep Gold Mine to become more efficient, by introducing a reliable work management system, capable of guiding efficient planning process, to improve mine production performance as well to enhance health and safety.

1.4 Research Objectives

This research intends to achieve the following key objectives:

a) To investigate the current work management system at South Deep Mine and find its strengths and weaknesses in integrating mining functions to improve short-term planning processes and completing planned work.
b) To develop an integrated work management system to eradicate manual data capturing, streamline short-term planning process, promote mine digitization, and automate workflows based on mining industry's best practices.
c) To develop a system that can run a problem analysis based on daily recording and reporting to assist in decision making.
d) To draw up conclusions highlighting any significances on the effectiveness of work management systems in integrating mining functions to optimise short-term planning processes and executing planned work at an underground trackless mine.

1.5 Research Methods

According to Kapoor, et al., (2022), research methods are referred to as methods employed in analysing questions related to the research. These methods are divided into either qualitative or quantitative. To achieve the objectives of this research, both qualitative and quantitative research methods were used. The aims of using both research methods, is for this research to have enough comprehensive data to enable proper data validation and analysis.

Qualitative research is research which uses word descriptions instead of numerical data (Ugwu & Eze Val, 2023). In this research, an investigation to understand key issues with current work management systems at South

Deep Mine, is conducted to make this research qualitative research. In addition, quantitative research explains phenomena according to numerical data which are examined by means of mathematically based instruments (Taherdoost, 2022). In this research, quantitative approach is applied systematically to observe and generate refined key knowledge to an existing problem.

1.6 Sources of Data

Sources of data refers to a place where any appropriate evidence, figures or facts can be found to support the research taken (Dovetail Editorial Team, 2023).This research collects data through observation of short-term planning process for various mining sections as well as through use of online survey. This process aims to identify any gaps throughout the process of planning which need to be addressed to achieve an integrated and optimized short-term planning process at South Deep Mine.

1.7 Research Validation

Research validation examines the quality of the collected data to ensure accuracy (Kakarash, 2023). Research validation aims to tell how confidently the data collected during the research process, covers the area of interest. A research validation method which makes use of both qualitative and quantitative research methods to perform data validation, is referred to as methodological triangulation (Taherdoost, 2016).

Both qualitative and quantitative research methods are used in this research, hence a methodological triangulation method is considered relevant to perform proper validation. Qualitative data and quantitative data collected in this research is compared against each other for commonality in order to achieve good validation.

1.8 Structure of the Research Report

This section provides an outline of various chapters of the research report.

Chapter 1 is the introduction and covers the background of the research, the problem statement, the justification for the research, research objectives, research methods, sources of data, and the research validation.

Chapter 2 covers the literature review on underground trackless mining environment and its operational challenges, importance of innovation to mining industry, mine planning and its divisions, work management system and integration. The chapter also provides the key debates and controversies as well as the chapter summary.

Chapter 3 describes the research methods by comprehensively outlining the design approach, data collection process, data validation process as well as the data analysis approach. At the end of this chapter, there is a summary portion which describes the overview of methodologies used in this research.

Chapter 4 presents the findings and feedback from South Deep Gold Mine. It also uses the data sourced from external participants to align with the objectives of this research, and to see how other mining companies are effectively conducting and optimising short-term planning.

Chapter 5 analyses the collected data and constructs findings to align with the objectives of this research.

Chapter 6 summarises the findings on the work management gaps and implications involved in implementing new work management system. Additionally, recommendations are also provided to act as guideline to

benchmark South Deep Mine against other mining operations in relation to work management system.

2 LITERATURE REVIEW

2.1. Introduction

This chapter covers underground trackless mining environment and its operational challenges. It also discusses criticality of short-term planning and its need to be optimized. The importance of innovation to mining industry as well as work management systems and integration is also provided. Additionally, this chapter provides the key debates and controversies related to studies conducted by various researchers in relation to this research's aims and objectives. At the end of this chapter there is summary which concludes the chapter.

2.2. Key Concepts, Theories and Studies

2.2.1. Underground Mining

Underground mining is defined as an operation below surface where numerous mining activities are conducted and its profitability depends on how well the co-ordination of mining resources is carried out (Astrand, 2018). In this type of environment, various mining methods including supported, unsupported, and caving, are employed to exploit the orebody, with diverse infrastructure and conveyance systems such as trucks and locomotives used to move the broken material (Skawina, 2019).

There are various complex problems involving mine productivity which are normally addressed during planning process and considers numerous constraints and actions that may occur throughout the life of mine (Navarro Torres, et al., 2020). However, due to the challenging working conditions in this type of operations, production planning becomes very difficult in most cases (Li, et al., 2021). The illustration of underground mining environment is well depicted in the Figure 3 below.

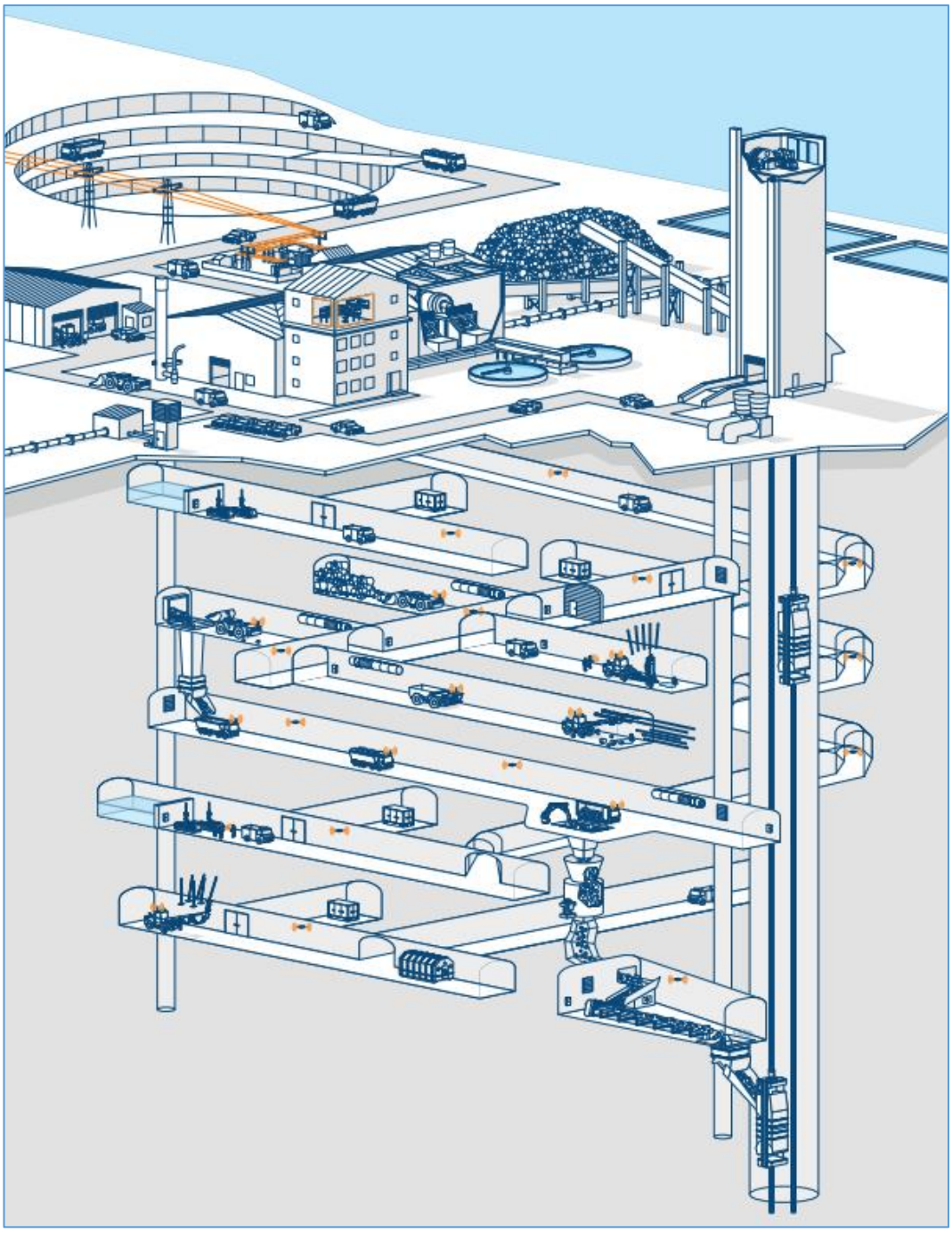


Figure 3. Underground Trackless Mining Environment (Astrand, 2018)

2.2.2. Operational Challenges

Studies in Canada depicted implementation of mine automation as a global key challenge and that is mainly due to shortage of critical skills such as engineers and scientists (Courtney, et al., 2017). Drill and blast, ore transport, mine support, mine ventilation, and backfilling activities are still

regarded as separate activities which at times make mine productivity optimization and management very challenging (Morrison, et al., 2018). Additionally, mine logistics such as material, men, and broken ore transportation, were identified amongst other ultra-deep mining challenges as factors affecting mine productivity (Oliver, 2019).

Cost reduction and improving effectiveness are some of the areas that could be improved through adoption of innovative solutions such as digitalization of mining activities. However, full implementation of mine digitalization is constrained by several factors including commitments to roll out plans, changes to organisation structures, mindset culture change about cybersecurity plans and their on-going developments (Sanchez & Hartlieb, 2020). Parallel to that, mine digitalisation appears to remain a challenge in most mining companies due to difficulty in deciding on the suitable technologies to meet organisational needs (Barnewold & Lottermoser, 2020).

In addition to mine logistics, original rock stresses existing within the rock mass before any mining commences, high temperatures, water pressure, and possible structure change due to high stresses were also identified to be challenging factors to ultra-deep mining (Li & Cai, 2021). Lastly, implementing effective wireless communication systems in an underground mining environment to enhance safety and health of miners remains a challenge due to required reliability, effectiveness, and security reasons (Sadeghi, et al., 2022)

2.2.3. Importance of Innovation to Mining Industry

As underground mines get deeper and challenging to exploit the mineral resources safely and efficiently, innovative mining layouts, mechanization, and automation, becomes important to sustain underground mining (Morrison, et al., 2018). Mine planning optimisation has been very

successful in various underground mines through the advancement and adoption of modernised planning tools (Wang, 2019).

Mine digitalization is referred to as the use of digital devices to transition the mining industry, improve business processes and reduce operational costs (Barnewold & Lottermoser, 2020). Though improvements in mining technologies have brought some good benefits including health and safety amongst others, the root causes to underperformances of some employed technologies, have not been identified in most underground mining operations (Loow, 2021).

2.2.4. Operational Mine Planning

Planning is considered an important component of the entire mining value chain, and it has been defined as the phase of problems defining, process analysing, and action plan description (Pariz, et al., 2017). Outside the mining space, Astrand (2018) defines planning as an element that describes what needs to happen and how it should be carried out. In addition to that, Otto & Musingwini (2019) defined mine planning as a function that ensures that the mineral resource is optimally exploited to deliver the final product to the market. Araya et al. (2020) further states that planning function adds significant value to mining industry in that it considers necessary work associated with all various activities within the entire mining value chain.

There are three horizons of mine planning, namely long-term, medium term, and short-term planning. Long-term planning looks into the company strategic goals and guides the medium-term planning to produce the annual budget plans, whereas short-term planning provides a detailed seasonal, monthly, weekly, and daily planning (Li, et al., 2021). Short-term planning is challenged by various aspects involving geological model data and it aims to ensure that required value and mass of broken material is

according to the long-term production schedule (Torres Toledo, et al., 2022).

2.2.5. Work Management and Systems Integration

Modernised planning tools have benefited mining engineers in moving away from manual data digitization processes to an automated process (Wang, 2019). Innovative systems and the newly adopted operating models in the mining industry continues to add great value in reducing operational cost and improving work efficiencies (Sanchez & Hartlieb, 2020). Work management systems are defined as the utilisation of instruments and methods to control time, resources, as well as management of tasks in the organisation (Malsam, 2021).

Otto & Lindeque, (2021) promotes the implementation of manufacturing type operating models known as Business Process Framework at AngloGoldAshanti. This model is depicted in Figure 4 below, and emphasises that work should be planned, scheduled, and well-resourced ahead of execution, to deliver consistent planned objectives at lower cost.

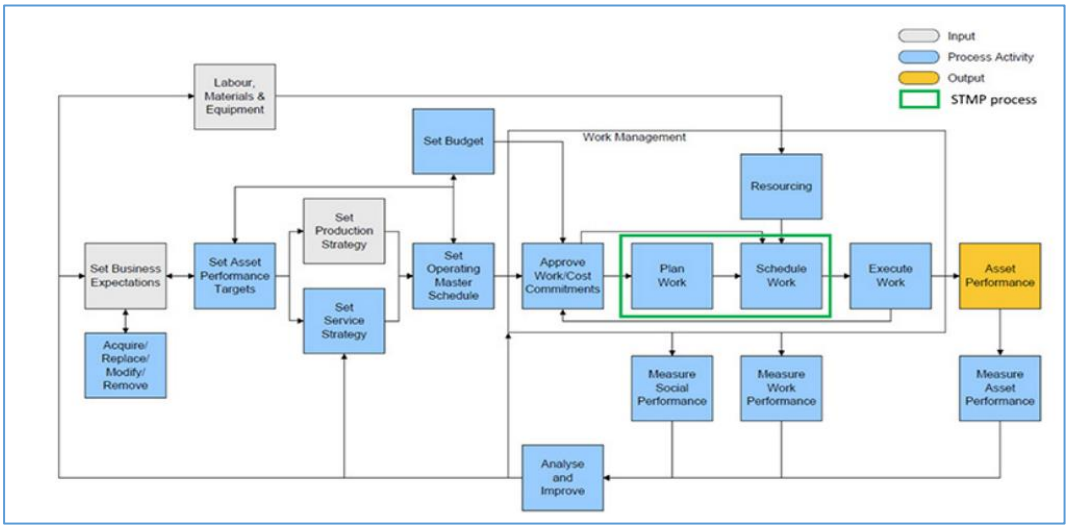


Figure 4. Business Process Framework (BPF) Major Elements (Otto & Lindeque, 2021)

2.3. Key Debates and Controversies

Study by Morrison et al. (2018) highlighted that, isolated technologies are unlikely to be effective in a high tonnage underground operation unless they are incorporated into a mine production system designed to address available constraints. High rising mining costs remain one of the issues constraining the mineral sector in various ways. The necessity to innovate mining processes, becomes imperative to the mining industry as the future of mining will be shaped by costs determined by global competition (Loow, et al., 2019). According to Wang, (2019), modernized planning tools brought in by various researchers and software developers, have improved underground mine planning function very well as well as the optimization of processes.

In general terms innovation is referred to as a process of change through which an impression is usefully applied to generate value and achieve new customer requirements (Sanchez & Hartlieb, 2020). In addition, Sanchez & Hartlieb, (2020) highlight that innovation has a potential to bring drastic changes in terms of improving working efficiencies and reducing operational costs to the mining industry, as well as achieving societal and environmental needs. However, Barnewold & Lottermoser, (2020) indicate that deciding on the appropriate technologies for a specific mining operation remains a challenge.

The development and the implementation of digital systems such as Internet of Things in various mining operations, have drastically transformed the mining processes which increased profits, improved working efficiencies, and achieved the ability to comply with applicable laws and regulation (Olvera, 2021). However, as underground mining progress to deeper levels, it remains challenging to optimally and safely exploit the mineral reserves (Janiszewski, et al., 2022). Therefore, to effectively address any of the operational challenges, short-term planning

remains critical, as it provides detailed methods for effective execution (Torres Toledo, et al., 2022).

2.4. Chapter Summary

This chapter has provided operational challenges in underground mining environment, providing the significance of innovation and optimising short-term planning. The chapter also highlighted the importance of effective planning in mitigating the identified operational challenges. Furthermore, the importance of an integrated work management is also discussed. The following chapter discusses the methods employed in achieving the objectives of this research.

3 RESEARCH APPROACH

3.1. Introduction

This chapter defines the approach employed in making this research successful. There are three research approaches available, namely inductive, deductive, and abductive research. Inductive research approach begins with addressing a question asked in the research as well as its aims and objectives needed to be accomplished throughout the research (Patel & Patel, 2019). Deductive research approach begins with stating the general research statement and the conclusion is derived through a logic debate. (William , 2022). Abductive research can be either a data or hypothesis driven, and it is aimed at finding a central ground amongst deductive and inductive research (Thompson, 2022).

This study employs an inductive approach because it is considered relevant in addressing the research questions as well as achieving aims and objectives of this study.

3.2. Research Design

Research design is defined as a structure in which a research project is carried out (Bhome, et al., 2013). According to Kapoor, et at., (2022), there are two categories defining research design, namely quantitative and qualitative research design. Quantitative research is considered a formal research technique which uses numbers such as statistical methods to achieve perfect results (Haradhan, 2020). Xiong, (2022), emphasized the advantages associated with quantitative research, these include:

- elimination of researcher's biasness when interpreting and analysing data collected,

- data collected can be comprehensive and scientifically analysed, lastly,
- data can be effectively analysed with less amount of time.

Ugwu & Eze Val, (2023), defines qualitative research as a research approach which involves use of non-numerical data to answer the research question and to justify why research is important. Additionally, Ugwu & Eze Val, (2023), emphasized on number of great benefits which comes with qualitative research, these include:

- true reflection of the real world since data is collected from actual participants within the real-world,
- achieved results are closely related to the collected data,
- used in discovering new findings,
- a structured analysis technique can be adopted throughout the research approach, and
- simplified data collection and analysis can be achieved.

To source reliable data for this study, a population group was identified and requested to participate in this research. A population group is referred to as a group of individuals or units on which the research findings are based (Shukla, 2020). A selected group will include mining engineering professionals within the mine technical services and the mine management at South Deep Mine as well as in other mining houses. For the success of this research, both qualitative and quantitative research methods will be used to collect and analyse the data. This is to ensure that sufficient data is available to make an informed decision.

3.3. Data Collection Process

According to Bhome. et at., (2013) data has a low level of value until it is well organized to make meaningful sense, until then, it is of no use.

Kapoor, et al., (2022), indicates that data can be collected either as a primary data or as secondary data. Primary data refers to the raw data in which surveys, observations or experiments are collected from first hand source (Kapoor, et al., 2022). Whereas secondary data refers to a data made available in the public domains (Patel & Patel, 2019).

To achieve the objectives of this study, primary data will be collected in two ways, which include observation of the entire short-term planning process at South Deep Mine using an existing planning guide, to see how current short-term planning process complies with the available planning guideline. The planning guideline outlines the planning calendar, roles and responsibilities of relevant stakeholders during planning session, requirements for the plans, process for plan review and approval, as well as rules concerning re-planning work (South Deep Mine, 2013).

Additional primary data will be obtained through online surveys issued to South Deep Mine participants as well as participants at other mining operations. External participants will be included as part of this study, to achieve industry's best practices data, which might be helpful to South Deep Mine in achieving an integrated work management system to optimise short-term planning process. A total of 20 participants from South Deep Mine will participate in the study and 10 external participants will be issued with the online surveys.

3.4. Data Validation Process

Data validation tells how the collected data effectively address the problem investigated in the research (Taherdoost, 2016). It is important that research data validation be effectively carried out to ensure research findings are well interpreted and utilized to make proper decisions (Bans-Akutey & Timub, 2021). Data validation is also important to eliminate

existing data errors, to clean-up data not relevant to the study and highlight errors with the collected data to increased accuracy of the outcomes amongst others (Kakarash, 2023).

The current problems faced by South Deep Mine during planning process involves manual data capturing, which creates a challenge to digitise and automate the reporting systems. For achieving the aims and objectives of this research, methodological triangulation is used to validate the collected data. Methodological triangulation is explained by Taherdoost, (2016), as a validation technique which allows mixed method such as qualitative and quantitative methods to be used in the research to enhance data validation.

3.5. Data Analysis Approach

According to Taherdoost, (2020), data analysis refers to processes employed to convert collected data into a useful information. In addition to that, Alem (2020), indicated that statistical method has delivered a useful outcome in data analysis. Statistical methods provide meaning to worthless data by performing necessary numerical analyses (Ali & Bhaskar, 2016).

The two mostly used statistical tools are descriptive and inferential methods. Descriptive statistics provides an overview summary of surveyed population in a form of either a mean, median or mode. Inferential statistics uses a random data sample on the selected population to describe and make interferes about the population sampled (Ali & Bhaskar, 2016). Mean provides an average figure of the selected data, whereas the median is middle number of the selected data (Babayo & Garba, 2022). To achieve good data analysis, this research uses a mean to obtain an average value of data collected.

3.6. Chapter Summary

This chapter dealt with the research methods necessary to obtain useful data for interpretation. Research design, data collection process, data validation process and data analysis approach were discussed to ensure relevant protocols are followed to make this research a success. In the following chapter, the researcher uses the research methods discussed in this chapter to clearly present the data significantly.

4. DATA FOR THE STUDY

4.1. Introduction

To align with the objectives of this research, this chapter deals with representation of data collected during the research. The process employed in collecting the data for this study included use of online surveys which were issued to both South Deep Mine Participants as well as mining professionals in other mining houses. In addition, live observations of entire short-term planning process were done using a digitalised sheet which was guided by the current short-term planning policy. The short-term policy outlines the roles and responsibilities of relevant stakeholders during the planning process amongst other things. To justify the production bookings concerns as stated in the problem statement section in Chapter 1, a specific production profile data was sourced from the reporting system to reflect the current bookings overview.

4.2. Data Representation

Data representation refers to a format in which collected data is presented, it can be as text, tabular or graphical form (In & Lee, 2017). The collected data for this study is presented in two cases, which include data from the South Deep Mine Participants as well as participants from other mining houses. Observations of short-term planning process at South Deep Mine is also presented in this section. For easy representation, the collected data is presented in graphical form as well as in tabular format.

Graphical format is a method of data representation which clearly shows collected data in manner that is easy to remember and understand, whereas tabular format refers to a data representation method which deals

with huge amount of data which might be confusing to be described in textual format (Bavdekar, 2015). Additionally, Kabir (2018), emphasized that graphs are considered good at conveying data relations, and they include bar graph, line graph, pie graph, pictorial graphs, and scatter plots. For clear illustration of data in this research, bar graphs, tables and pie chart are used.

4.2.1. South Deep Participants

The collected data from South Deep Mine on current work management system is presented in the Table 1 below. This data was sourced from a developed questionnaire which aimed at understanding the current work management system's capabilities, concerns, as well as shortcomings.

Table 1: South Deep Mine Work Management Systems Reflection

Questions	Responses	Deswik	Syncromine	No system used
What do you think could be the benefits and limitations when planning process is conducted systematically using specialized software?	Great benefit, which could improve integrity of the month plan	9	7	4
What could be the major concerns associated with current work management system at south deep mine?	The system is not automatically linked to other operating systems to avoid manual data inputs	8	7	5
How do you see the implementation of a new work management system improving the integration of mining functions and optimizing the short-term planning process at South Deep Gold Mine?	Positive impact, but depends on the core activities build into the proposed work management system and the training provided	7	7	6
What could be some potential barriers to the implementation of an effective work management system?	Technical skills and competencies to those applying the system	4	4	12
How can the above barriers to implement effective work management system be addressed?	Provide comprehensive training to ensure all users understand how effectively to use the system	5	6	9
In your opinion, what are the strengths of the current work management system at South Deep Gold Mine?	Mine performance report could be accessed (Integrated Production Reports)	4	5	11
In your opinion, what are the weaknesses of the current work management system at South Deep Gold Mine?	Manual data capturing which has potential for personal errors	4	3	13
Mean Values		5.9	5.6	8.6

A total of twenty participants within the mine technical services department and mine management responded well to the questionnaire. Out of the twenty participants, four indicated to be utilizing Deswik planning and scheduling software as well as Syncromine Reporting System, whereas twelve respondents indicated that none of the two systems are used in their daily, weekly, and monthly routine. The representation of system utilization is shown in Figure 5 below.

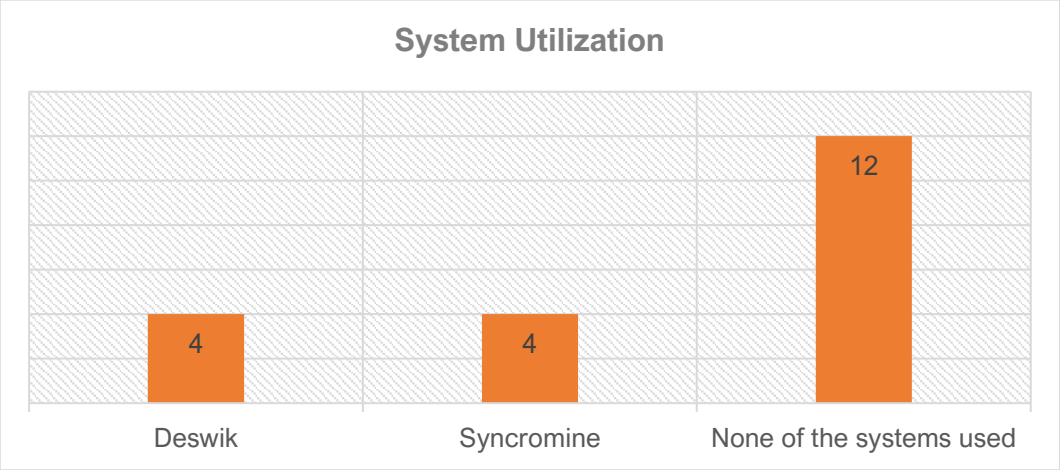


Figure 5: Current Work Management System

The process employed in conducting short-term planning came out to be very traditional in a sense that, manual word documents are used to capture the planning minutes and the coloured hard copies of the mining plans are still in use to illustrate the proposed planned areas. The time taken to complete the planning process for the three observed mining sections was around five hours on average depending on the scale of mining section. To address the manual data capturing operational challenge, which came out to be the cause of long planning sessions, a systemised integrated planning protocol was introduced to ensure work efficiencies are improved during the planning process. Use of power BI tools was also adopted to automate reports.

The proposed integrated planning protocol allows mining department reports to be sourced from the current reporting system and pulled into the planning protocol database. This process is done prior to the planning session to provide guidance to the execution team, and the planning summary is generated and signed-off to close the planning session. The process flow of activities required to happen in order to close of the month plan cycle, is presented in Figure 6 below.

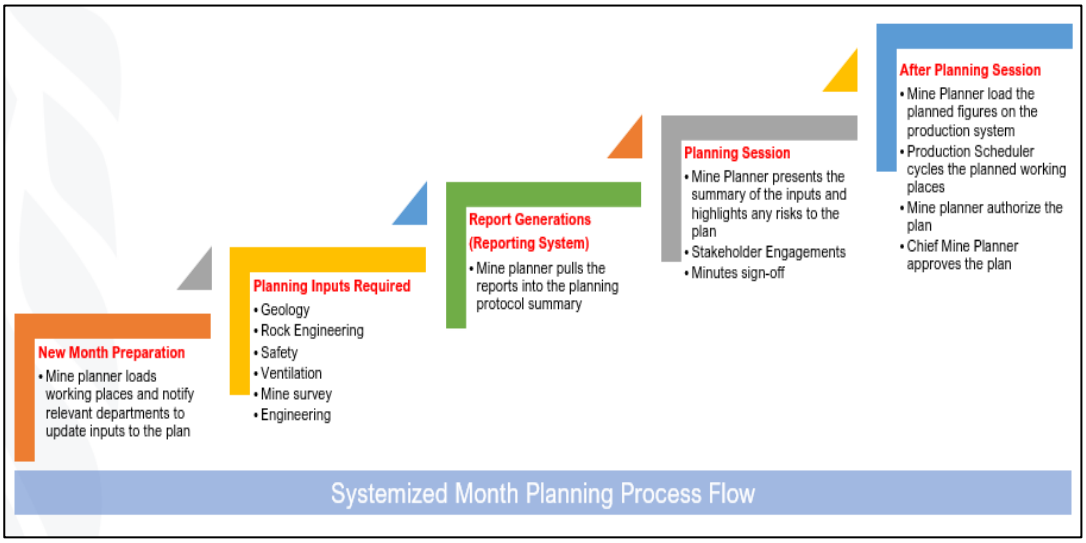


Figure 6: Planning Activities Process Flow

To enhance qualitative data collected, the researcher observed three production sections' short-term planning processes. South Deep Mine short-term planning policy was used as a guideline to establish the observation sheet. The planning policy put emphasis on inputs required from each stakeholder during the planning session to contribute to the production of an achievable mine plan. The observation sheet looked at contribution made by each stakeholder and simply needed a Yes or No response as well as open general comments. Table 2 below shows the used observation sheet.

Table 2: Observation Sheet

Planning Process/Inputs				
Item		**Yes**	**No**	**Comments**
Short-Term	Did the End achieve previous month planned target?			
	Was the end mined on grade and at required dimensions?			
	Any reason for failure to achieve planned targets?			
	Is there an action plan to address production failures?			
	Is there any posible design changes where mining will take place?			
	Was the grade report provided and analysed for value optmisation?			
	Is the plan for the new month, ready for execution?			
	Miner/Shift Supervisor and crew participated in planning?			
General Comments/Instructions				
Safety Officer	Is the current risk rating within the benchmark?			
	Is there any A hazards identified?			
	Any outstanding actions?			
	Number of accidents reported to date			
	Is there any outstanding accident report?			
	Waiting place and Notice Board to standard?			
	Logbook compliance %			
	Workplace files %			
General Comments/Instructions				
Legals	Competent A Person appointed?			
	Health and Safety Representative appointed?			
	Miner/Developer appointed?			
	Shift Supervisor appointed?			
	All Equipment operators appointed?			
	Any Special Instructions			
General Comments/Instructions				
Medium-Term	Is the plan following critical path to align operational and build up plans			
General Comments/Instructions				

Item		Yes	No	Comments
Mine Geology	Was the end mapped for any new geological structures?			
	Is the structures well depicted on the new mining plans?			
General Comments/Instructions				
Mine Survey	Does the end require start/ stop/ normal survey note (including any holing note)			
	Was there any deviation to plan in terms of direction, grade, or dimension observed?			
General Comments/Instructions				
Rock Engineer	Do we have existing seismic data?			
	Is the end mined within required standard and recommendation?			
	Is the current mining support strategy still applicable for the new month?			
General Comments/Instructions				
Environmental	Dust suppression in place and working?			
	Wet bulb temperature			
	Dry bulb temperature			
	Specific cooling power			
	Force columns distance to face (m)			
	Force columns leakage (& per 100m)			
	Face Velocity (m/s)			
	Refuge Bay distance from working face (m)			
	Is the ventilation requirements installed as per the given layout?			
General Comments/Instructions				

The illustration in Table 3 below, highlights the feedback results from the observations of the planning process, are. From the feedback obtained, mean values were used to quantify the results. Diagram next to each department indicates the percentage contribution based on the positive and negative mean values.

Table 3: Short-Term Planning Process Observed Responses

		Yes	No
Mine Planning	Did the section achieve previous month planned targets?	3	0
	Is there an action plan to address production failures?	2	1
	Is there any possible design changes where mining will take place?	2	1
	Was the grade report provided and analysed for value optmisation?	3	0
	Is the plan for the new month, ready for execution?	3	0
	Miner/Shift Supervisor and crew participated in the planning process?	0	3
	Is the plan following critical path to align operational and build up plans	3	0
	Mean	**2.29**	**0.71**



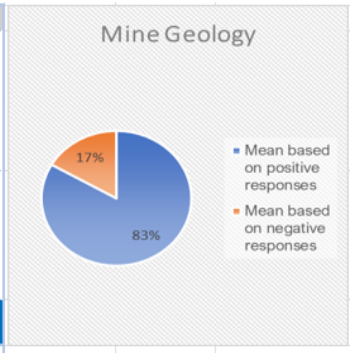
		Yes	No
Safety	Is the current risk rating within the benchmark?	3	0
	Is there any A hazards identified?	3	0
	Any outstanding actions?	2	1
	Number of accidents reported to date	3	0
	Is there any outstanding accident report?	3	0
	Waiting place and Notice Board to standard?	2	1
	Logbook compliance %	3	0
	Workplace files %	3	0
	Mean	**2.75**	**0.25**



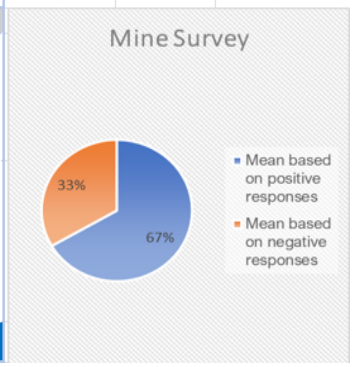
		Yes	No
Legals	Competent A Person appointed?	3	0
	Health and Safety Representative appointed?	3	0
	Miner/Developer appointed?	3	0
	Shift Supervisor appointed?	3	0
	All Equipment operators appointed?	3	0
	Mean	**3.00**	**0.00**



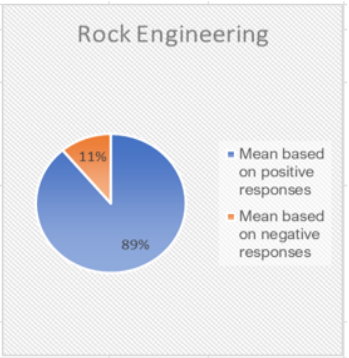
		Yes	No
Mine Geology	All ends mapped for any new geological structures?	3	0
	Is the structures well depicted on the new mining plans?	2	1
	Mean	2.50	0.50



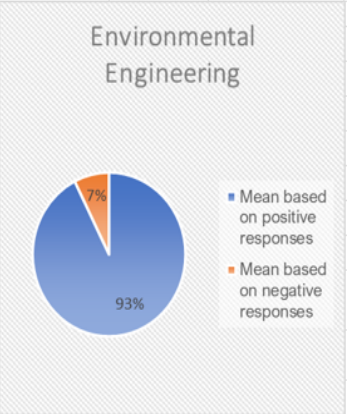
		Yes	No
Mine Survey	Does the end require start/ stop/ normal survey note (including any holing note)	2	1
	Was there any deviation to plan in terms of direction, grade, or dimension observed?	2	1
	Mean	2.00	1.00



		Yes	No
Rock Engineering	Do we have existing seismic data?	3	0
	Ends mined within required standard and recommendation?	2	1
	Is the current mining support strategy still applicable for the new month?	3	0
	Mean	2.67	0.33



		Standard	off-Standard
Mine Ventilation/ Environmental	Dust suppression in place and working?	2	1
	Wet bulb temperature	3	0
	Dry bulb temperature	3	0
	Specific cooling power	3	0
	Force column distance to face (m)	3	0
	Force column leakage (per 100m)	3	0
	Face Velocity (m/s)	3	0
	Refuge Bay distance from working face (m)	2	1
	Is the ventilation requirements installed as per the given layout?	3	0
	Mean	2.78	0.22



In addition, Table 4 illustrates the process used in obtaining the mean values for each department. The use of mean values in data analysis

assists in data comparison and generating easily readable reports which could be presented in a graphical form.

Table 4: Mean values calculation process

'Yes' Responses	'No' Responses
Mine Planning	
Number of questions = 7 Sum of values = 16 Mean Value = (sum of values / (number of questions) = 2.3	Number of questions= 7 Sum of values = 5 Mean Value = (sum of values / (number of questions) = 0.7
Safety	
Number of questions = 8 Sum of values = 22 Mean Value = (sum of values / (number of questions) = 2.8	Number of questions = 8 Sum of values = 2 Mean Value = (sum of values / (number of questions) = 0.3
Legal	
Number of questions = 5 Sum of values = 15 Mean Value = (sum of values / (number of questions) = 3	Number of questions = 5 Sum of values = 0 Mean Value = (sum of values / (number of questions) = 0
Mine Geology	
Number of questions = 2 Sum of values = 5 Mean Value = (sum of values / (number of questions) = 2.5	Number of questions = 2 Sum of values = 1 Mean Value = (sum of values / (number of questions) = 0.5

Mine Survey	
Number of questions = 2 Sum of values = 4 Mean Value = (sum of values / (number of questions) = 2	Number of questions = 2 Sum of values = 2 Mean Value = (sum of values / (number of questions) = 1
Rock Engineering	
Number of questions = 3 Sum of values = 8 Mean Value = (sum of values / (number of questions) = 2.7	Number of questions = 3 Sum of values = 1 Mean Value = (sum of values / (number of questions) = 0.3
Mine Environmental (standard)	**Substandard**
Number of questions = 9 Sum of values = 25 Mean Value = (sum of values / (number of questions) = 2.8	Number of questions = 9 Sum of values = 2 Mean Value = (sum of values / (number of questions) = 0.2

A concern which came out of the observation was that front line supervisors are not part of the planning session. This indicates that there is potentially a huge possibility that team members across all levels of work do not effectively collaborate towards a common objective. This act has a potential to cause poor performance or non-compliance to plan.

In addition to South Deep Mine data collection process, a specific production section bookings were obtained to reflect production profile as well as lost blast shifts. The data for the specific mining section is illustrated in Table 5 below which indicates only booked meters and not lost shifts. This reflection shows the lack of a problem analysis system

which makes it difficult to understand production issues which contribute to poor performances.

Table 5: Development Section's Production Bookings (Syncromine Data)

Main Activity	Description	Month Plan	Prog Book	Diff	Production Shifts																													
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Development Section	End 1	9	15	6.0			3							3					3					3								3			
	End 2	6	15	9.0			3					3															3							3	
	End 3	12	12	0.0													3								3			3			3			
	End 4	9	12	3.0																	3			3			3	3				3			
	End 5	9	12	3.0													3											3	3					3	
	End 6	6	3	-3.0															3																
	End 7	6	3	-3.0															3																
	End 8	0	6	-3.0																								3	3						
	End 9	9	27	18.0		3						3		3					3					3			3		3				3	3		
	End 10	9	3	-6.0						3																									
	End 11	9	6	-3.0																								3	3						
	End 12	2	0	-2.0																															
	End 13	18	15	-3.0							3						3							3								3	3		
	End 14	6	9	3.0		3																				3								3	
	End 15	6	3	-3.0																															3
	End 16	15	30	15.0		3				3		3					3		3		3			3				3				3	3		
	End 17	15	3	-12.0		3																													
	End 18	12	33	21.0			3			3	3			3			3		3		3			3				3				3		3	
	End 19	18	9	-9.0																						3						3	3		
Total		176	216	31	0	12	9	0	0	9	6	9	0	9	0	0	15	0	18	0	9	0	0	18	0	9	9	15	15	0	0	24	15	15	0

A.	Support	B.	Idle
C.	Service	D.	No Operator
E.	Breakdown		

4.2.2. External Participants

The aim of sourcing external data was to understand how other mining companies conduct their short-term planning process as well as management of planned work. The population group were mining professionals with two years minimum industry experience and some with well over ten years. The reason for this selected population group was to get more practical inputs from experienced individuals across the industry so that conclusions derived from this study could be of benefit to the mining industry. A total of twenty participants were issued with an online survey and only sixteen responded to the survey.

Figure 7 below represents the number of operations which make use of Deswik, Syncromine and MineRP to conduct planning processes as well as to manage planned work. It appeared that four operations are still without a digital work management system and two operations are using other systems not discussed in this study.

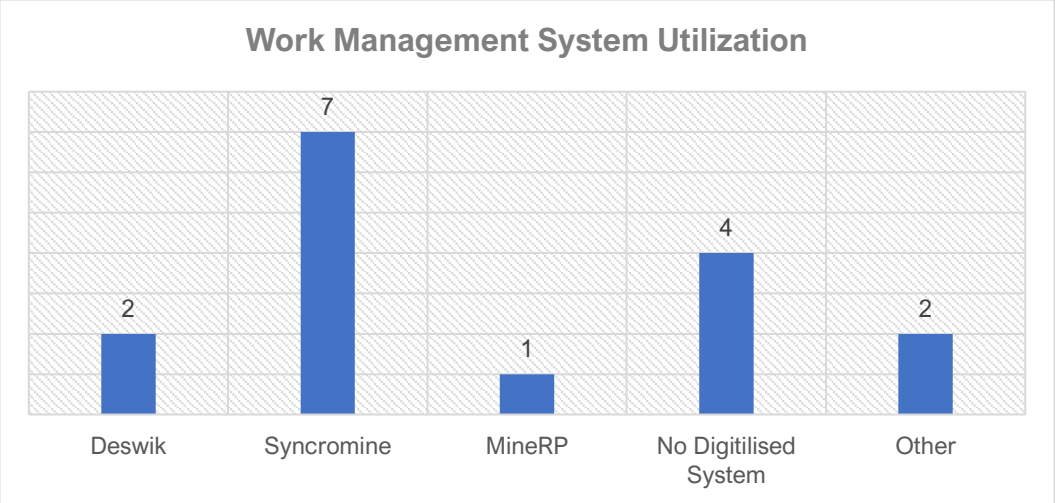


Figure 7: System used to Co-ordinate Planning Process

The population group that participated in this research consisted of different skills within the mining as well as the technical services. The Figure 8 below shows the breakdown of skills that participated in this study.

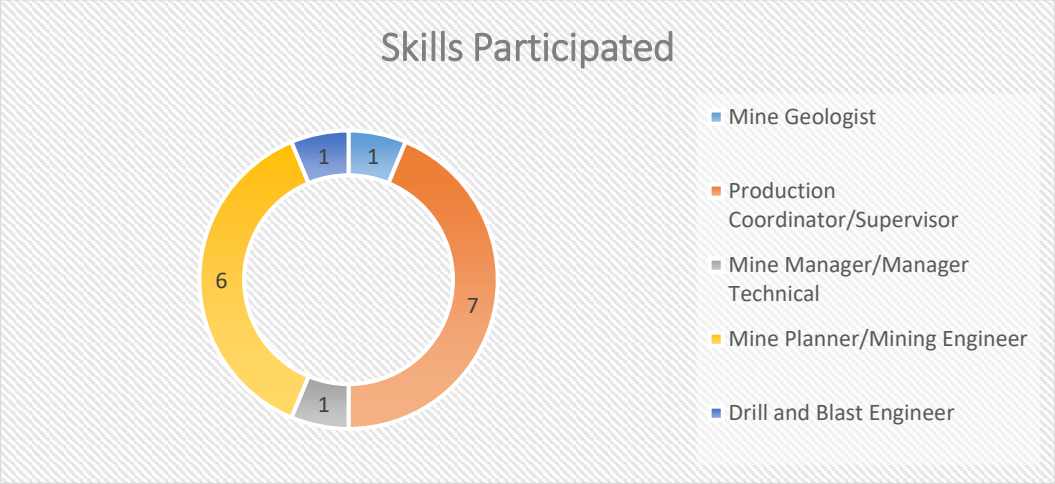


Figure 8: Participants skills outlook

Deswik, MineRP and Syncromine Work Management systems appeared to be the systems used. They have a common benefit but tend to differ with operational challenges. In addition, Table 6 below outlines the responses to questions asked which contributed to industry's best practices in terms of work management system utilization. The benefits as well as existing gaps were also highlighted. The mean values were used to quantify the contributions.

Table 6: Current Work Management System Benefits and Gaps

Question	Responses	Deswik	Syncromine	MineRP	Other	No Digitilised System	Mean per Response
What are the greater benefits with your current work management system?	Planning process follows a required protocol and produces a well summarized report	0	1	0	0	0	0,2
	Planning process is well optimized, mining functions/reports are well integrated and can be used to make informed decision related to health and safety as well as production	1	3	1	1	4	2,0
	The system can produce a detail work report for analyzing production related issues (problem analysis)	1	3	0	0	0	0,8
	None of the above	0	0	0	1	0	0,2
Mean Value		**0,5**	**1,8**	**0,3**	**0,5**	**1,0**	**0,8**
What are the things you would like to see which you are currently not achieving with your work management system?	System should be User-friendly and only address production related issues	1	2	0	1	1	1,0
	Summarized integrated standard reports	1	2	0	0	2	1,0
	System should provide early warning when workplaces are mined out of plan	1	3	1	0	1	1,2
Mean Value		**1,0**	**2,3**	**0,3**	**0,3**	**1,3**	**1,1**

The data collection process was successfully carried out, however, there were some few challenges encountered with external participants. These included late responses as well as other individuals not attempting to respond to the issued questionnaire. However, to ensure that a reasonable conclusion is arrived at, additional participants were sourced through the linkedin platform, and the participation rate came to 80% of the total issued.

4.3. Chapter Summary

This chapter presented survey results obtained from both South Deep Mine participants as well as participants in other mining houses. The data collection for this study was done in three ways, firstly a specific mining section's data reflecting the production bookings was sourced from the reporting system, secondly, online surveys were issued to South Deep Mine participants as well as external participants and lastly short-term planning process was observed to understand the process employed in making contributions to the month plan.

South Deep Mine responded with a 100% participation rate, whereas for the external participants only 80% participated. The challenge experienced during the data collection and selection process was the lower participation rate than expected, especially with external participants. This necessitated the need to source new participants through social media platforms such as LinkedIn, but also to continue reminding individuals to participate.

The other challenge involved the selection of quality data for achieving good representation. To deal with this challenge, a thorough evaluation of data was carried out to identify the data with the most useful insights. Lastly, the researcher had a challenge of deciding on the relevant data to achieve the research objectives. To overcome this challenge, preliminary data was assessed for quality and consistency and data which indicated to contribute to the research questions in hand, was used to achieve the objectives of this research.

The following chapter deals with the interpretation and analysis of data collected in order to achieve a general overview of South Deep Mine's current work management systems benefits as well as challenges in integrating and executing planned work. The external participant's data is

also analysed to understand differences in processes and systems used in other mining houses, which could be beneficial to South Deep Mine in optimizing short-term planning process where possible.

5. ANALYSIS AND FINDINGS

5.1. Introduction

Taherdoost, (2020), defined data analysis as a process employed to convert collected data into a useful information. Chapter 4 has presented the collected data in simpler formats using graphs and tables to translate information obtained from online surveys as well as from the observations of short-term planning process. This chapter aims to provide a detailed analysis of data presented in chapter 4 and uses statistical methods to achieve proper data analysis.

5.2. Data Analysis

Data analysis is completed in numerous ways depending on the area of the study and the evidence is used to address the research problem (Ashirwadam, 2014). To achieve the objectives of this research, qualitative research methods as well as quantitative research methods were used. The idea for using the two research methods was to enhance data collection for proper data analysis. The steps followed in ensuring good data analysis for the two research methods are defined below.

5.2.1. Qualitative Data Analysis

To achieve the integrity of the data collected and to perform proper data analysis, data collected from the online surveys as well as from the observations of short-term planning sessions was handled in five steps, namely, data lodging, anecdotes, vignettes, data coding and thematic network. According to Ashirwadam (2014), data lodging is about documenting the collected data and anecdotes refer to the streamlining of data collected using available evidence such as photographs. Vignettes focuses on comprehensive description of the situation, participants, and

subjects to establish the research credibility, and data coding is mainly about sorting and reducing amount of data to a manageable size. Whereas the purpose of thematic network is to dig into a deeper understanding of the subject or the emergence of an idea. Process employed in performing qualitative data analysis using the five steps mentioned above is presented in the Figure 9 below.

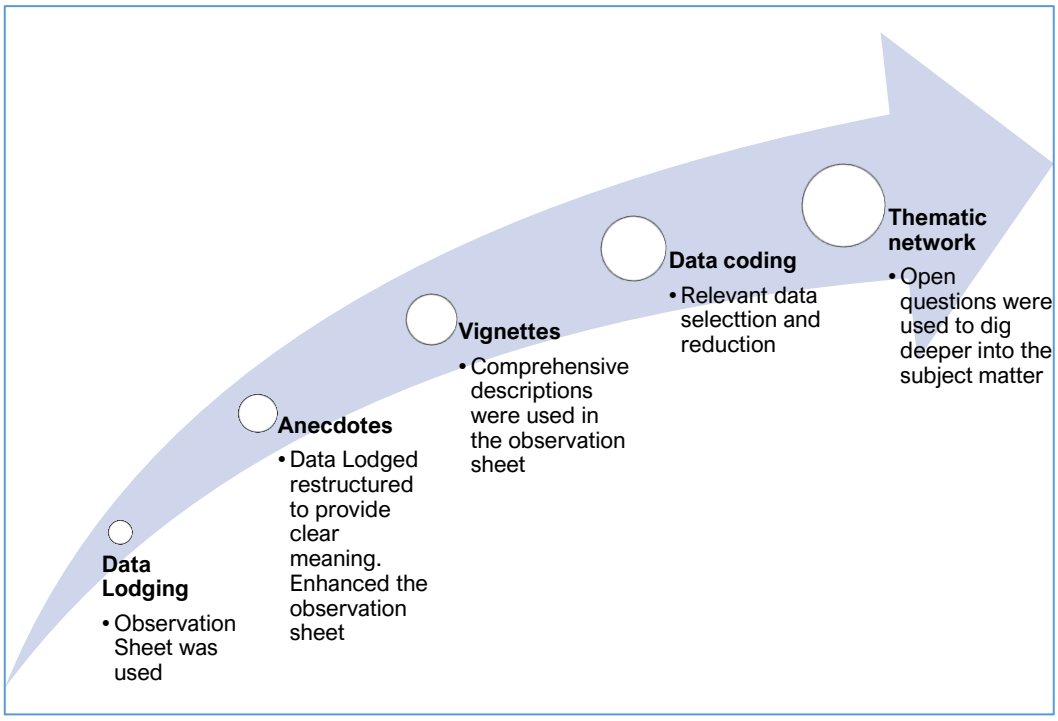


Figure 9: Steps in Performing Qualitative Data Analysis

5.2.2. Quantitative Data Analysis

According to Alem (2020), quantitative data uses numerical values to present the data collected and the results are statistically reliable. Ameer (2021), elaborates that quantitative data analysis applies an organized process to collect the research data, evaluate the data, and to perform data verification. Statistical methods have a reliable history in providing meaning to worthless data by performing necessary numerical analyses (Ali & Bhaskar, 2016).

For clear data analysis, this study has adopted a descriptive statistical analysis approach to perform an analysis of the data collected and presented.

5.3. Findings

The data analysed in this research is presented in two stages. Stage one concerns work done at South Deep Mine which included online surveys completed, short-term planning process observations, production report analysis as well as process followed in building a systemised planning protocol. The other stage includes concerning participants in other mining companies excluding South Deep Mine.

5.3.1. South Deep Mine Data Analysis

Deswik planning and scheduling software and Syncromine production reporting software are the two identified work management systems used within the mine technical service department, particularly the mine planning department. The total number of participants were twenty and all responded well to the questionnaire. The number of participants utilizing these work management systems was four for both Deswik and Syncromine. This data confirmed that only a few mining departments within the mine technical services make use of Deswik and Syncromine, whereas twelve individuals indicated not to be using any of the two systems at all.

The collected data was analysed using statistical descriptive methods and the mean values were used to quantify the results. The achieved mean values for the work management systems being investigated are presented in Figure 10 below.

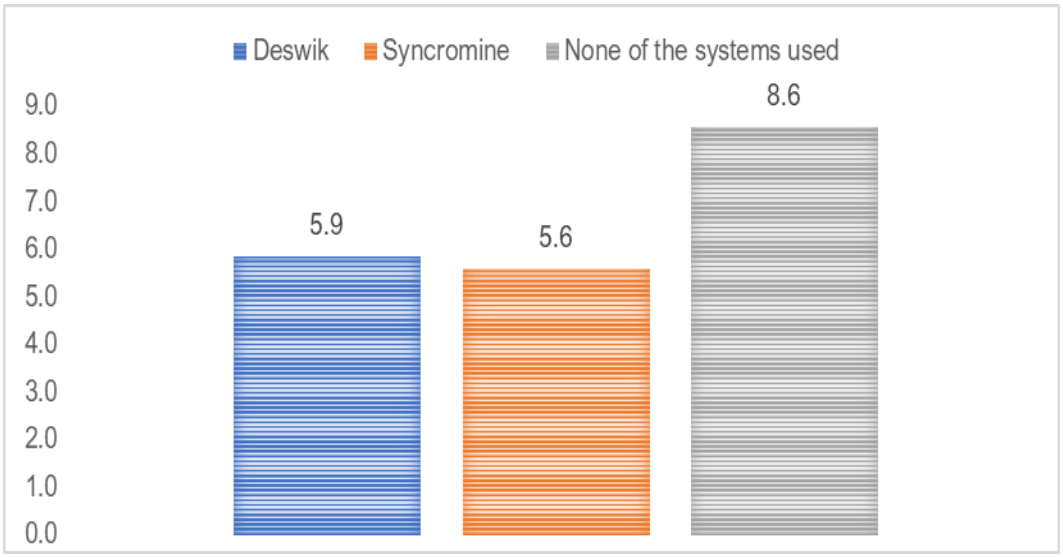


Figure 10: Mean Values of the Efficiency of Work Management Systems

As depicted in Figure 10 above, 8.6 mean value for individuals not utilising either Deswik or Syncromine is higher than those individuals exposed to Deswik or Syncromine. This is evidence of the fact that not all individuals within the mine technical services are exposed to these two systems. There were two benefits which came with utilisation of Deswik and Syncromine. These included access to integrated production reports and reliability in data handling. However, there were two areas of concern which included manual data capturing due to the two systems not being automatically linked and the lack of ability to produce problem data analysis report for scrutinizing mine performance.

The short-term planning process observation results were analyzed, and each mining department mean values were used to make a clear justification. The achieved mean values for number of positive responses during planning, were higher than the negative responses. Figure 11 below indicates mean values achieved by each mining department. Based on the mean values presented, it can be confirmed that relevant stakeholders do contribute to the generation of the month plan. However,

a few issues from each department except for the legal department, need to be ironed out in order to achieve better inputs. Legal department inputs were positively covered without any reflection of negative input.

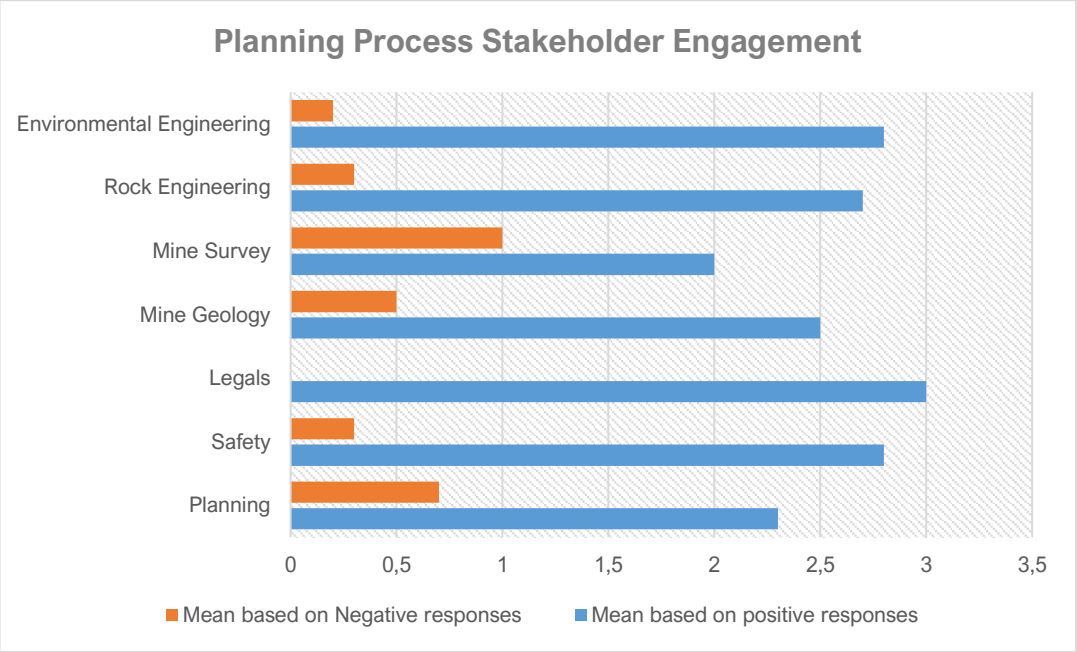


Figure 11: Mining Departments' Achieved Mean Values

Additionally, there were two areas of concern which came out of the planning sessions namely:

- The planning process is conducted by senior mining personnel and cascaded to front line supervisors and their respective team members. There was no evidence to prove that proper collaboration had occurred amongst other team members in all the other levels of work.
- The planning process is still manually conducted, with mine planners expected to capture the planned figures between various systems as well as to update planning minutes on a work document.

Further on, the analysed production bookings report for the mining sections indicated that no production issues were booked when there is a

lost shift, which makes it difficult to run a weekly or monthly problem analysis. It was found that the current production booking system, being Syncromine, does have a problem booking function. The system is not configured to demand production personnel to book production issues, instead only advanced meters are accepted.

In addition to the above, it was discovered during the study that the current work management systems at South Deep Mine, are not integrated to promote automation of activities. This has impacted on health and safety, where in some instances risk assessments were not done prior to mining taking place. Failing to comply to plan also remained an ongoing issue month on month. It was observed that some areas were mined way ahead of plan, others were mined out of plan, and some were planned but there was absolutely no attempt to mine them.

Mining out of plan was due to planned working places not being prepared and ready for execution. Planned work is effectively monitored weekly, and the data required for monitoring is only available ones the survey department has completed the actual scans on the blasted ends. This process has a shortcoming of allowing unplanned work to occur due to relying on survey department's actual scans to recognise what is happening underground.

Equipment performance remained a major contributor in failing to execute as planned. The Figure 12 below shows the three months production rig achieved mean values for a specific development section.

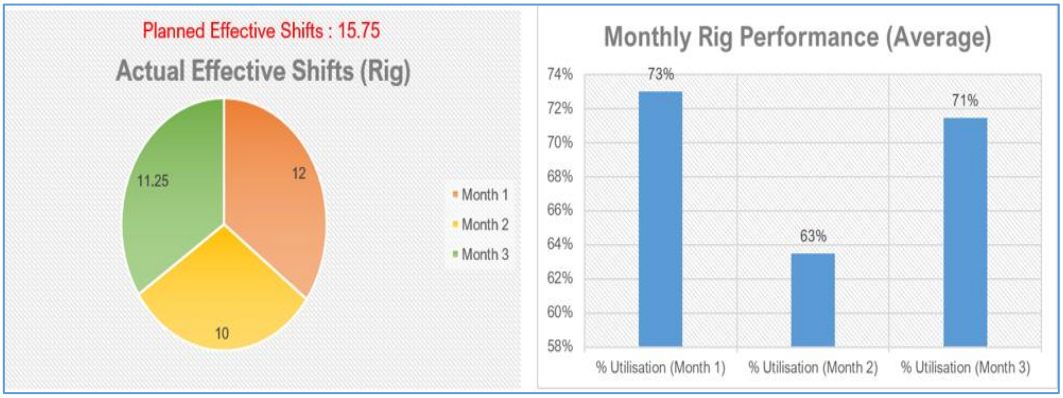


Figure 12: Mining Section's Equipment Utilization Overview

The above graph shows low utilisation of production equipment to perform production activities which was caused by shortage of skill to urgently attend to engineering breakdowns.

As part of the month planning, Deswik Time Usage Model, is used to allocate engineering team with shifts to perform planned equipment maintenance on monthly basis. Time Usage Model is an established excel sheet build to assist mine planners to populate available times for scheduled maintenances throughout the month. The sheet is then allowed to be uploaded into the Deswik planning and scheduling software to produce the required equipment maintenances. To avoid low utilization due to units being unutilised, two rigs are planned per level to perform production drilling as well as mining support activities.

5.3.2. External Participants Data Analysis

This analysis is based on the 16 responses received from the external participants. The results indicated that the systems used within the planning space are, Deswik, Syncromine and MineRP. Number of participants utilising these systems was 2, 7, and 1 respectively. Four mining operations appeared to be relying on manual systems and the other two use systems not covered in this study. Benefits which came with utilisation of Deswik, Syncromine and MineRP included:

- Planning process follows a required protocol and produces a well summarized report.
- Planning process is well optimized, mining functions/reports are well integrated and can be used to make informed decision related to health and safety as well as production issues.
- The system can produce a detailed work report for analyzing production related issues (problem analysis)

However, there were two preferences which the users would have preferred to have within the three systems which are:

- the system should be user-friendly and only address production related issues.
- the system should provide early warning when workplaces are mined out of plan.

To ensure that the short-term planning process is optimized at South Deep Mine, a dedicated team within the mine technical services department was selected and worked with Mineware team to build a systemised planning protocol into the current Syncromine reporting system. The planning protocol development process was tracked regularly for progress. The project milestone was well achieved, and the system was put into test to check its viability. This development was justified by the need to have an innovative platform that will be managed electronically and could eliminate extensive manual data capturing during planning session. Recommendation to adopt the new platform was discussed with mine technical services management prior to its development.

The developed planning protocol offers advanced features and capabilities to optimise the planning cycle. The system integrates current reporting systems used in other mining departments and produce a summary report which can provide stakeholders with insights for decision making during

planning session. The process followed during the development of the protocol is presented in Figure 13 below.

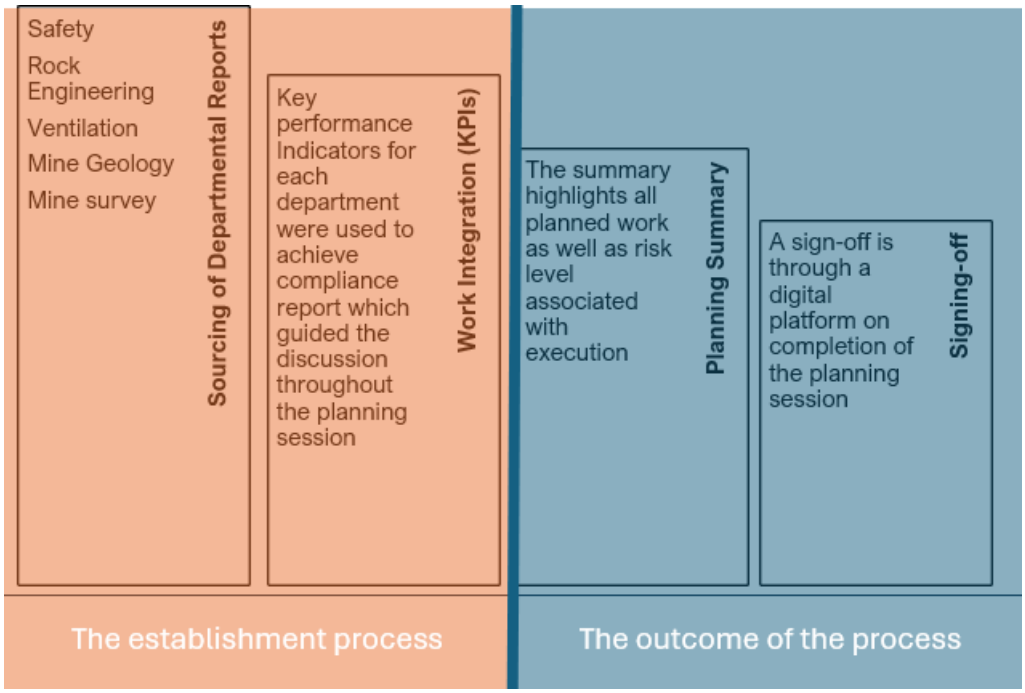


Figure 13: Process Employed to Develop a Systemised Planning Protocol

5.4. Chapter Summary

The purpose of this chapter was to perform a data analysis and to present the findings of the analysis. The work done in this chapter highlighted that South Deep Mine utilises Deswik program to conduct the planning process. Two benefits which came with the use of Deswik were reliable data handling and production of an integrated report. However, it was noticed that Deswik is not automated and linked with the reporting system namely Syncromine. This shortcoming resulted in mine planners performing extensive manual data capturing work to close off the planning cycle.

In terms of the observed short-term planning process at South Deep Mine, the process appeared to be well conducted with relevant stakeholders contributing to the production of the month plan. However, the achieved mean values for each department, indicated that inputs made to the monthly planning were not fully compliant to conclude the month plan with positive feedback. There were a few outstanding items not closed during planning session which could risk the month plan.

In addition, production booking system have a shortcoming which prevents problem analysis to be carried out. The system allows production supervisors to only book advanced meters and not the problems encountered during the shift. Even though the engineering maintenance schedule is part of the monthly planning, the equipment performance data still indicated that engineering equipment availability remains a huge contributor of production loss at South Deep Mine.

Deswik, Syncromine and MineRP appeared to be the current work management systems used in other mining operations. Out of the sixteen responses received, utilisation of the three systems were 2, 7 and 1 respectively. Four mining operations have no digital system and two use other work management systems not covered in this study. The personnel with critical skills that participated in this study included mine geologist, production supervisors, mine managers, mining engineers and drill and blast engineers. The following chapter is the last chapter of this research study which discusses the research conclusion and recommendations.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This research has applied necessary methods to investigate and to achieve the industry's best practices regarding work management systems. Malsam (2021), emphasized that the study of work management systems has been in existence since 1990s and its primary focus is to optimise organisation's output. South Deep Mine was used as a case study to identify existing operational challenges related to short-term planning process which could be effectively addressed with proper application of work management system. Other mining houses were also used to collect data relevant in achieving objectives of this research.

6.2. Summary of Chapters

This report has presented six chapters which covered the introduction, literature review, research methods, data representation, data analysis and findings, and lastly conclusions and recommendations. The summary of each chapter is clearly described below.

Introduction Chapter: Outlined the research background, problem statement, objectives of the study, the justification of the research, research methods and the validation processes for establishing a reliable work management system at South Deep Mine to enhance short-term planning process. Additionally, the chapter provided a brief discussion about the current technologies and operational challenges regarding the work integration at South Deep Mine.

Literature Review: Defined underground mining and its operational challenges. The significance of adopting modernised tools to enhance mine planning process was also highlighted. Three levels of mine planning processes namely: long-term, medium, and short-term planning, were discussed to provide clarity and how they are all related to the objectives of this research. Challenges associated with short-term planning were also discussed since this study focused mainly on the short-term planning process.

Additionally, the chapter included the challenges experienced by mining engineers after the adoption of newly recognised planning tools. The primary functions of work management system in ensuring that every work to be carried is well planned, resourced and scheduled ahead of execution were all discussed. The aim of this chapter was to gather existing knowledge about the research topic as well as key debates and controversies between various researchers. The source of information was obtained from published journals, reports, and articles. This chapter has successfully accomplished its aims with a clear understanding of underground mining environment, short-term planning process and challenges associated with work integration.

Research Methods: This chapter covered research design, data collection process, data validation and data analysis. Research design covered two research methods, namely: qualitative and quantitative research methods. Both qualitative and quantitative data was sourced from individuals employed within the mine technical services department at South Deep Mine as well as from other external mining operations. The application of the two research methods was motivated by the need to obtain as much data as possible to make an informed decision on this research.

Data collection process in this study involved use of primary data from South Deep Mine and other mining houses. Data sourced from South Deep Mine participants was through online surveys, observations of short-term planning process, and production data interpretations. Data obtained from other mining houses excluding South Deep Mine was through online surveys. The researcher issued twenty participants with an online questionnaire at South Deep Mine as well as in other mining houses. Collected data was analysed using descriptive statistical methods such as mean values to quantify findings. The processes followed ensured that reliable methods are employed to deliver the research objectives.

Data Representations: Dealt with representation of data collected. Three formats of data representation namely textual, graphical, and tabular, were discussed and used to present the data. Work management systems used at South Deep Mine and in other mining houses, to conduct short-term planning process and reporting of mine performances were presented. Deswik and Syncromine work management systems were found to be the two systems used at South Deep Mine to perform planning functions and production reporting, respectively.

Data sourced from other mining houses indicated that the systems used are Deswik, Syncromine and MineRP. Deswik was utilised by two participants while Syncromine was used by seven participants and MineRP was used by one participant. Four mining operations still rely on manual systems and the two other mining operations use other systems not covered in this study. The disciplines which participated in this study included mining engineers, mine geologists, mine surveyors, mine managers, drill and blast engineers and production supervisors.

There were also some few concerns raised by external participants regarding the work management system in order for it to achieve common

goals. These concerns include the system's need to be user-friendly and only address production related issues, its ability to provide summarised integrated reports, and its function to offer early warning when working places are mined out of plan.

The aim of this chapter was to present data collected during this research using the selected formats but encountered few challenges such as lower participation rate than expected, especially with external participants, selection of quality data to achieve good representation, and lastly deciding on the relevant data that will assist in achieving the objectives of this study.

Analysis and Findings: This chapter presented the analysis and findings derived from the data collected in the previous chapter. The importance of data analysis in translating collected data into useful information, was emphasised. The analysis of qualitative data was carried out following the five steps, namely: data lodging, anecdotes, vignettes, data coding and thematic network. These steps allow the researcher to examine and better understand the data collected. As for quantitative analysis, descriptive statistical method was effectively applied, with mean values being used to calculate the results.

The data from South Deep Mine and from external participants was used to present the research findings. It was found that South Deep Mine uses Deswik and Sycromine to plan and manage the work at hand. The observed month planning sessions indicated that various mining department representatives do make relevant contributions which assist with concluding the planning process. However, an expected mean value of 80% is not achieved in each mining department to achieve a full compliance plan.

Manual data capturing and lack of problem analysis reporting, are the two areas of concern associated with these two work management systems. It also came out that the entire short-term planning process is a top-bottom process, meaning it is only carried out by senior mine personnel and cascaded to lower-level personnel for execution. Front-line supervisors are not involved in the planning session. This has somehow created a culture that a month plan, is a middle management plan and not front-line supervisor's plan. Equipment breakdown and a skills shortage came out to be the root causes of low equipment utilization.

Data from external participants, shows similar work management systems to be in use. However, the users prefer the systems to be user-friendly with ability to address production related issues as well as providing early warning for deviations from the original plan. In conclusion, the analysis has indicated that for both South Deep Mine and external participants, shortcomings do exist within the current work management systems which need improvement to achieve efficient planning processes.

Conclusions and Recommendations: The section presents the research summary by providing details of each chapter in this research.

6.3. Research Observations

This research observed application of current work management systems as applied at South Deep Mine to create an integrated and optimal short-term planning process. Structured observation sheet was used to collect relevant information during the planning process.

6.3.1. Initial and complimentary studies

The study covered the application of work management systems as well as short-term planning process at South Deep Mine. Other mining operations

excluding South Deep Mine, were also investigated to understand the application of current work management systems in conducting an effective short-term planning process. The study is complemented by the desire to investigate the current work management systems shortcoming so that efficient work approach to improve work management process within the mine technical services can be achieved. Work integration remained a major drive in this study with automation of production reports being the end goal to be achieved. The management of this work management system integration in the industry remains critical in achieving the objectives laid out in this study.

6.3.2. Key findings and observations

South Deep Mine

Work management systems used at South Deep Mine to conduct short-term planning process and to manage planned work are Deswik planning and scheduling software and Syncromine production reporting system. The short-term planning process was found to be time consuming due to extensive manual data capturing taking place during the planning session. The session is well arranged and effectively conducted, however not all stakeholders contribute optimally towards the generation of the month plan. The development of the planning protocol improved work efficiencies by eliminating extensive manual data capturing and streamlining the entire planning session.

To monitor planned work, data from Syncromine booking system was sourced and analysed. It was found that the bookings system does not provide informative data such as lost shifts to allow effective problem analysis to happen. Compliance to plan remains a huge concern in that actual measured meters were observed to be more than planned meters in

some areas. Certain areas were over performing while other planned areas were not mined at all throughout the month cycle.

The deviation to plan was caused by the constraints associated with getting blasted ends cleaned as scheduled to prepare for the next production cycle. Amongst other day-to-day production issues, failure of water pumps to effectively manage water accumulation and constant equipment breakdowns, hinder the achievement of cleaned blasted ends. The current work management systems do not provide real-time data which can assist in alerting relevant parties when the monthly plan goes off the in advance.

In addition, most of the underground existing conditions that could affect the safe execution of work are sometimes not covered during planning sessions. Consequently, issues such as ventilation requirements and substandard conditions affecting health and safety emerge during the execution process, leading to production delays and ultimately loss of planned production. This is due to the absence of front-line supervisors not being part of the planning session. Moreover, the achieved equipment availability consistently falls below the target set in the plan due to frequent breakdowns.

To address the challenges associated with equipment, a detailed equipment availability report indicating planned utilisation against the actual utilization, as well as action plan to address the low utilization, was proposed to be part of the planning phase. This proposed report will highlight the planned equipment performances on average and use the data to plan and predict the new monthly availability and utilisation. This will assist in making informed decision and plan with confidence.

Other Mining Houses

Work management systems applied in other mining houses, were Deswik, Syncromine and MineRP. Syncromine is widely adopted in the mining industry as opposed to Deswik and MineRP. It was also found that these systems do share common benefits which included:13/06/2024

- planning process follows a required protocol and produces a well summarized report,
- planning process is well optimized, mining functions/reports are well integrated and can be used to make informed decision related to health and safety as well as production, and
- the system can produce a detail work report for analysing production related issues (problem analysis).

6.4. Research Contributions

This study has highlighted challenges associated with work management systems, short-term planning process effectiveness, development of systemised planning protocol as well as the production booking system shortcomings. Most importantly, the study illustrated that current work management systems at South Deep Mine are not integrated to promote automation of activities. The lack of work integration system at South Deep Mine has impacted on health and safety, where in some instances risk assessments were not done prior to mining taking place.

Duplicates of reports on production figures were also observed which resulted due to different individuals using their own reporting templates instead of the standardised templates. The work management systems investigated in this research has optimally contributed to the creation of a planning protocol for South Deep Mine which aimed at improving the entire planning process.

6.5. Research Limitations

This research was limited to underground mining operations and the sample group in the study had to be employed in the mine technical services department to give better feedback on the system.

6.6. Recommendations for Future Research Work

Based on the arrived conclusions, this study has addressed its core objectives. However, to achieve the mining industry's best practices in relation to optimization of planning process, additional work including development of models that involves every aspect in the mining value chain should be considered. The aspects to be included in the establishment of the model should cover planning of mining activities such as labour planning, equipment allocations, maintenance work, reliable tracking, and monitoring systems as well as problem solving techniques amongst others. Additionally, use of power BI in automating reports could also be adopted to improve information sharing.

A need for proper problem defining techniques to solving, preventing, and eliminating similar incidents from re-occurring remain a critical aspect. The model should further promote effective collaboration amongst different stakeholders involved in the execution, to enable reliable contributions to the month planning sessions. In addition, reliable software programs should be developed as per specific site requirements with same principles being applied throughout the industry. This is necessitated by the existing gap in data handling in some mine planning and scheduling software.

In some instances, it was found that MineRP software is unable to handle huge amount of data at a given time, especially when performing data export from one system to other. Some files end up crashing and causing

re-work of project files. Therefore, it is imperative that software developers keep this fact in mind and to regularly invest in continuous research and development studies.

REFERENCES

Alem, D. D. (2020). An Overview of Data Analysis and Interpretations in Research. *The International Journal of Academic Research in Education and Review, 8*(1), 1.

Ali, Z., & Bhaskar, S. B. (2016). Basic Statistical Tools in Research and Data Analysis. *Indian Journal of Anaesthesia, 60*(9), 662.

Ameer, A. (2021). Quantitative Data Analysis. Pakistan: ResearchGate.

Araya, A. S., Nehring, M., Vega, E. T., & Miranda, N. S. (2020). The Impact of Equipment Productivity and Pushback width on the Mine Planning Process. *The Southern African Institute of Mining and Metallurgy, 120*(10), 599-600.

Ashirwadam, J. (2014). Communication Research Methods. India: Rawat Publications.

Astrand, M. (2018). *Short-Term Underground Mine Scheduling.* Sweden: KTH Royal Institute of Technology.

Babayo, M. A., & Garba, G. U. (2022). Mean and Median Varieties of the Bull-Eye Magic Square: A Case Study of 5 by 5. *The Journal of Equational Algebras, 1*(1), 28.

Bans-Akutey, A., & Timub, B. M. (2021, August). Triangulation in Research. *Academia Letters*, p. 1.

Barnewold, L., & Lottermoser, B. G. (2020). Identification of Digital Technologies and Digitalisation Trends in the Mining Industry. *International Journal of Mining Science and Technology*(30), 747.

Bavdekar, S. B. (2015). Using Tables and Graphs for Reporting Data. *Journal of the Association of Physicians of India, 63*, 61.

Bertayeva , K., Panaedova, G., Natocheeva, N., Kulagovskaya, T., & Belyachikova, T. (2019). Industry 4.0 in the Mining Industry: Global Trends and Inoovative Development. Russia: EDP Sciences.

Bhome, S., Jha, N., Chandwani, V., Iyer, S., Prabhudesai, A., Desai, S., & Koshti, D. (2013). *Research Methodology.* HimalayaPublishing House Pvt. Ltd.

Courtney, D. B., Collette, E., Martineau, S., Khadr, A., Neville, M., & Bhagat, M. (2017). Innovation in the Canadian Mining Sector. Canada: Cambridge University Press.

Dovetail Editorial Team. (2023). *Dovetail*. Retrieved 04 06, 2024, from https://www.dovetail.com

Goldfields Limited. (2023). *Integrated Annual Report.* Johannesburg: Goldfields.

Haradhan, M. (2020). Quantitative Research: A Successful Investigation in Natural and Social Sciences. *Journal of Economic Development, Envrionmnetal and People, 9*(4), 3.

In, J., & Lee, S. (2017). Statistical Data Presentation. *Korean Journal of Anesthesiology, 70*(3), 268.

Janiszewski, M., Pontow, S., & Rinne, M. (2022). Industry Survey on the Current State of Stope Design Methods in the Underground Mining Sector. *MDPI*, 1.

Kabir, S. M. (2018). Data Presentation: Table and Figure Design. In *Basic Guidelines for Research* (p. 496). Perth: ResearchGate.

Kakarash, Z. A. (2023). Why is Data Validation Important in Research? Kurdistan Region Iraq: ResearchGate.

Kapoor, R., Mahamuni, R. R., Bhowmick, M., & Qureshi, Y. (2022). *Research Methodology and Methods.* India: AGPH Books.

Li, N; Feng, S; Ye, H; Wang, Q; Jia, M; Wang, L; Zhao, S; Chen, D. (2021). Dispatch Optimization Model for Haulage Equipment between Stope based on Mine Short-Term Resource Planning. *MDPI*, 2.

Li, P., & Cai, M. (2021). Challenges and New Insights for Exploitation of Deep Underground Metal Mineral Resources. *Science Direct*, 3478.

Loow, J. (2021). Understanding Technology in Mining and its Effect on the Work Environment. *Springer*, 143.

Loow, J., Abrahamsson, L., & Johansson, J. (2019). Mining 4.0 - The Impact of New Technology from a Work Place Perspective . *Springer*, 701.

Malsam, W. (2021). *Project Manager*. Retrieved February 24, 2023, from https://www.projectmanager.com

Morrison, D. M., Drylie, V., & Labrecque, P. O. (2018). A System Approach to Mining Innovation. *Australian Centre for Geomechanics, 10*(39), 511.

Navarro Torres, V. F., Mateus, G. R., Martins, A. G., Carneiro, W., & Chaves, L. S. (2020). Integrated Optimization and Simulation Models for

Short-Term Open Pit Mine Planning. *The Journal of the South African Institute of Mining and Metallurgy, 120*, 617.

Oliver, M. E. (2019). *Quantification of Logistic Performance in Ultra-Deep Mining - A South Deep Gold Mine Case study.* Potchefstroom : North West University.

Olvera, B. C. (2021). Innovation in Mining: What are the Challenges and Opportunities along the Value Chain for Latin American Suppliers? *Springer*.

Otto, T. J., & Lindeque, G. C. (2021). Improving Productivity at an Open-pit Mine through enhanced Short-Term Mine Planning. *The Journal of the South African Institute of Mining and Metallurgy , 121*, 591.

Otto, T. J., & Musingwini, C. (2019). A Spatial Mine-To-Plan Compliance Approach to Improve Alignment of Short-Term and Long-Term Mine Planning at Open Pit Mines. *The Journal of the South African Institute of Mining and Metallurgy, 119*, 253.

Pariz, C. M., Cotrim, L. M., Leal, G. C., Barbosa, H. D., & Galdamez, E. V. (2017). Work Routine Management in Operational Units of an Agro-Industry Cooperative. *Independent Journal o Management and Production (IJM&P), 8*(4), 1416.

Patel, M., & Patel, N. (2019). Exploring Research Methodology: Review Article. *International Journal of Research & Review, 6*(3), 53.

Sadeghi, S., Soltanmohammadlou, N., & Nasirzadeh, F. (2022). Applications of Wireless Sensor Networks to Improve Occupational Safety and Health in Underground Mines. *The Journal of Safety Research, 83*, 8-25.

Sanchez, F., & Hartlieb, F. (2020). Innovation in the Mining Industry: Technological Trends and a Case Study of the Challenges of the Disruptive Innovation. *Springer*, 1385.

Shukla, S. (2020). Concept of Population and Sample. India: ResearchGate.

Skawina, B. (2019). *Load-Haul-Dump Operations in Uniderground Mines.* Lulea University of Technology .

South Deep Gold Mine. (2022). Business Review. Johannesburg: Goldfields.

South Deep Mine. (2013). Short-Term Planning Policy. Johannesburg: South Deep Mine.

Souza Barbosa, A., da Silva, L. B., de Souza, V. F., & Morioka, S. N. (2021). Integrated Management Systems: Their Organizational Impacts. *Taylor & Francis Group*, 1.

Taherdoost, H. (2022). What are Different Research Approaches? Comprehensive Review of Qualitative, Quatitative, and Mixed Method Research, Thier Application Types, and Limitations. *Journal of Management Science & Engineering Research, 05*(01), 54.

Taherdoost, M. (2016). Validity and Reliability of Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research. *International Journal of Academic Reseaarch in Management (IJARM), 5*(3), 28.

Thompson, J. (2022). A Guide to Abductive Thematic Analysis. *The Qualitative Report, 27*(5), 1411.

Torres Toledo, A. A., Marques, D. M., Coimbra Leite Costa, J. F., & Capponi, L. N. (2022). Short-Term Mine Scheduling Targeting Stationary Grades. *Mining Mineracao*, 73.

Ugwu, C., & Eze Val, H. U. (2023). Qualitative Research. *IDOSR Journal of Computer and Applied Sciences, 8*(1), 20.

Wang, H. (2019). Underground Mine Planning Optimization Process to Improve Values and Reduce Risks. *Taylor and Francis Group*, 335.

Xiong, X. (2022). Critical Review of Quantitative and Qualitative Research. China: Atlantis Press SARL.