CHARACTERISATION OF INNOVATION AND IMPLEMENTATION RATES ACROSS A SOUTH AFRICAN MINING ORGANISATION

AJD Schoonbee

Student Number: 06854877

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Supervisor: Professor Francois Mulenga

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DECLARATION

I, Aidan James Dirk Schoonbee, declare that the dissertation that I herewith submit for the Master of Engineering qualification at the University of South Africa is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education.

11 February 2026

Signature: Date

University of South Africa

Johannesburg, South Africa

DEDICATION

This dissertation is dedicated to my wife, Mary-Ann, for her support and encouragement throughout my research.

To my late parents, who would be so proud of this achievement, and for passing on to me their values and the example of lives well lived.

Finally, this research is dedicated to those who innovate at Palabora Mining Company (PMC), those who seek to continually improve, and to those who believe that all of us together are cleverer than any one of us alone.

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I would also like to thank Ms Wendy Maritz, Ms Mpho Nyarela and Ms Octave Patel as well as the entire Value Improving Practices (VIP) team for making available the data generated during the first year of the corporate innovation program. Thanks are owed to Mr Kagiso Mokone and Ms Orifuna Mbengeni for assistance with graphs and charts.

I would like to thank the Executive of the Palabora Mining Company (PMC) for inspiring the vision behind the VIP program, for providing me with the opportunity to lead this workstream, and for actively supporting post-graduate technical education in collaboration with UNISA and other institutions.

Finally, I would like to thank the employees and contractors of PMC for their outstanding participation in the VIP corporate innovation program and also for the tremendous value created through their contributions. The shopfloor is where much of the knowledge is vested, and participants have demonstrated that innovation is indeed flourishing at this level.

ABSTRACT

The aim of this study was to measure shopfloor participation in a corporate innovation program within a South African mining operation. Employees were categorised according to age, gender, years of service, and job grading. The rate of innovation response was measured and analysed in terms of the type of innovation as well as the trajectory. During the first 12 months of the program, from September 2023 to August 2024, a total of 1005 submissions were registered, with 826 (82%) conforming to the criteria set for the program.

Sufficient data was obtained through which each of the five (5) research questions could be answered. The 35-45 years age group had the highest level of representation in the program at 26% of the category. A slight bias of female participants over males was noted. The >15 to <= 20 years of service category had the highest level of representation in the program, at 32%. Three Paterson grading categories contributed most to the program: Upper C (Specialists and Supervisors), Lower D (Superintendents), and Upper D (Managers), while B Band employees (unskilled & semi-skilled) reflected lower response rates. Demographic groupings that were relatively under-represented included <25 years age group, the <=5 and >20 years of service categories, as well as the contractor, student and B-band job gradings.

Approximately one in ten ideas registered during the period were implemented, showing that ideation exceeded the capacity to implement. ‘Incremental’ innovation was the dominant type, representing 94.9% ahead of ‘disruptive’ innovation at 4.3%. In terms of trajectory, most innovations (i.e., 76%) were aimed at the ‘internal’ work environment, with the ‘production’ environment at 22% as the second highest domain.

Return on innovation investment (ROII) was considered in terms of both tangible / commercial and intangible / soft benefits. The program delivered sixteen innovations with tangible financial returns of more than R100,000, while thirteen of these innovations had a return on investment above R1 million, and three had a return of over R10 million measured per calendar year. An analysis of intangible value addition by category showed that ‘operational approach’ was the most frequent intangible benefit at 38.5%, followed by ‘safety and health’ at 28.2%, and ‘maintenance approach’ at 17.0%.

Keywords: innovation program, shopfloor, rate of participation, demographics, age, gender, years of service, job grading, type of innovation, trajectory of innovation, return on innovation investment (ROII).

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List of Acronyms

AI	Artificial Intelligence
DTIC	Department of Trade, Industry and Competition
GDP	Gross Domestic Product
HSRC	Human Sciences Research Council
IDC	Industrial Development Corporation
IoT	Internet of Things
ISO	International Organisation for Standardisation
LOM	Life of Mine
METS	Mining, Equipment, Technology and Service
OECD	Organisation for Economic Co-operation and Development
OEMs	Original Equipment Manufacturers
PAYE	Pay-as-you-Earn
PMC	Palabora Mining Company
R&D	Research & Development
ROII	Return on innovation investment
SABS	South African Bureau of Standards
SANS	South African National Standards
SMEs	Subject Matter
VAT	Value added tax
VIP	Value Improving Practices Division

WIPO	World Intellectual Property Organisation
ZAR	South African Rand

CHAPTER 1 – INTRODUCTION

1.1 BACKGROUND

The word ‘Innovation’ is potentially one of the most important in business, yet it is also likely the least understood. Innovation strategy within corporations is difficult to initiate, and even harder to sustain, according to Kuratko et al. (2014), who studied the reasons why corporate innovation programs fail.

Many researchers have concluded that the study of innovation within resource-intensive industries remains relatively unexplored (Bartos, 2007; Crawford, 2018; Hossein et al., 2021; Ranestad, 2018; Reichet and O'Brien, 2023; Valacchi et al., 2023). These authors highlight the need for new and tailored innovation metrics in resource-intensive sectors because the standard metrics tend to focus on high-technology industries where research, development, patenting, and new product development are common practice.

As a result of under-reporting on innovation metrics, mining, along with other resource-intensive industries such as forestry, agriculture, and fisheries, is often considered to be an industry that is conservative, resistant to change, and of low-technology intensity (Crawford, 2018).

This study challenges negative perceptions regarding the rate of innovation in mines. It demonstrates practical metrics that allow for a data-driven approach to innovation management.

If the mining industry is to prosper, innovation will need to be embraced by organisations within it. As highlighted in the ISO standard 56000:2020, *“The capacity of an organisation to innovate has been identified as a key element of its sustainability, economic viability and overall well-being.”* (SABS, 2020).

1.2 CONTEXT OF THE STUDY

1.2.1 The Palabora Mining Company

Palabora Mining Company (PMC) is located in the Limpopo Province of South Africa. The mine shares a border with the Kruger National Park.

PMC owes its origin to a unique rock formation known as the Palabora Igneous Complex. The Phalaborwa region, although blessed with abundant mineral wealth, suffered from an early confusion over the spelling of place names. Early explorers spelt the name Palabora, which then evolved in the 1950s to become Phalaborwa. However, before this happened, the registration of a new venture was done under the name of Palabora Mining Company (Pottinger, 1990).

Today, the primary product of the company is copper, although by-products which make a significant contribution to net profit, such as magnetite, nickel sulphate, anode slimes, sulphuric acid, and vermiculite are also produced.

The mine runs underground operations accessed through the shafts shown in Figure 1.1 while Figure 1.2 shows the old surface operations. PMC enjoys a staff complement of approximately 5,000 employees including contractors (Forbes, 2023).

Figure 1.1 – Aerial view of the PMC Ventilation Shaft with Service and Production Shafts in the background (Source: PMC, 2024)

Figure 1.2 - PMC Open Pit (Source: PMC, 2024)

1.2.2 The Value Improving Practices Division

In September 2023, a new Division was launched at PMC with the three strategic objectives, which had direct application to the corporate innovation program considered within this research (PMC Policy, 2023):

i. To adopt value-improving processes in order to facilitate continuous technical transformation that results in year-on-year business enhancement and outperform our competitors.

ii. To recognise, incentivise, and motivate employees with specific reference to our ability to implement and execute ideas generated on the shopfloor.

iii. Create a culture where innovation and technical excellence is supported and recognised.

Figure 1:3 illustrates one poster that was shared across the various divisions and units of PMC as a business leading up to the official launch of the new division known as Value Improving Practices (VIP) Division.

Figure 1.3 – Example of a VIP Launch Poster (Source: PMC, 2023)

The VIP Division was also tasked with executing Life of Mine (LOM) Extension Studies and the implementation of various Capital Expansion Projects. These two workstreams, however, fall outside of the scope of the innovation program underpinning this research study.

1.2.3 The VIP Corporate Innovation Program

In their paper on corporate innovation and corporate entrepreneurship, Ghura and Erket (2021) point out that there is no one-size-fits-all innovation program that works for every organisation and occasion. They note that different organisations use a wide variety of innovation definitions and metrics; therefore, benchmarking is problematic because of the lack of a basis of comparison.

In accordance with their findings, a bespoke approach was adopted for PMC's VIP corporate innovation program. The Corporate Innovation Program is open to all employees and contractors working on the mine. It is intended to support workers on the shopfloor. Its focus, therefore, is primarily, but not exclusively, aimed at unskilled, semi-skilled and artisanal workers.

The VIP program was set up using a decentralised model vested in the operating divisions rather than in the core VIP team. According to Kuratko et al. (2014), a decentralised operating system can help establish roles and responsibilities within the organisation by specifying innovation activities and incentives at the correct level and within relevant boundaries. Decentralisation places control and responsibility at the level of decision makers working at the coal face. This is where the most operational knowledge resides.

The intent behind the establishment of the VIP corporate innovation program was to foster continuous improvement on the mine by promoting creativity and encouraging employee-initiated enhancements to processes, facilities, systems and services.

The following internal definition of an innovation was adopted (VIP Operating Procedure, 2024): "VIP Innovations are defined as new solutions to existing problems that improve value by better using the resources we already have".

1.3 PURPOSE OF THE STUDY

This section considers the motivating factors behind the design of this study. It begins with the research problem, then considers the research aim at a higher level and the specific objectives in more detail. Five research questions are posed in accordance with the study objectives.

1.3.1 Research Problem

‘How can a mining company use data to measure, manage, and promote shopfloor innovation in order to fundamentally improve business performance?’ This is the research problem statement.

One of the problems facing organisations is how they can use data to measure, manage, and promote shopfloor innovation in order to fundamentally improve business performance.

A survey by Accenture was conducted on vice presidents, directors, and managers of companies in the United States of America, the United Kingdom, and France (Koertzier and Alon, 2013). Companies with a turnover greater than US$100 million were selected as part of the survey. Of all the 519 executives interviewed, 93% indicated the long-term success of their company depended on the corporate ability to innovate. However, only 18% considered that innovation management in their organisations was delivering a competitive advantage. Furthermore, most executives went so far as to rate their own innovation program as ‘poor’.

Kuratko et al. (2014) mirrored the Accenture survey by concluding that innovation strategy within corporations is very difficult to initiate, and even harder to sustain. And the passage of time has hardly yielded research to improve our knowledge of corporate innovation strategies. Ghura and Erkut (2021) found that little is understood about how corporations approach innovation, which aspects of innovation they focus on, and what benefits they receive in return.

It is in this context that it has become important to develop means of measuring innovation in the PMC mining company in order to deliver data that might be used to leverage the benefits of the VIP program

1.3.2 Research Aim

The aim of this research is to measure and categorise employee participation in a value-improving innovation program within the South African mining industry in order to facilitate the management of shopfloor innovation.

Using a tailored definition of innovation, and customised metrics, the research tests the innovation response of demographic sub-groups and analyses the characteristics of employee participation. This information can be used to improve the management of innovation in the mine and to determine return on investment from innovation.

The study aims to develop commercially relevant recommendations for managing innovation at PMC and potentially for the broader mining industry.

1.3.3 Research Motivation

This study looks at innovation in the mining industry because it is an under-studied topic (Bartos, 2007; Crawford, 2018; Hossein et al., 2021; Ranestad, 2018; Reichet and O'Brien, 2023; Valacchi et al., 2023) that has the potential to improve the viability of the industry. It proposes practical indicators for the measurement and classification of shopfloor innovation. The research attempts to demonstrate that workers in the mine can actively participate in meaningful business transformation through innovation.

“The mining sector plays a vital role in job creation and economic growth, particularly by reducing unemployment through the employment of unskilled workers” (Labour Research Service, 2023, p. 3).

Regrettably, the contribution of the mining industry is reducing relative to other sectors. The Minerals Council (2024) explained that most of the sector’s recent growth appears to be value-related (a combination of mineral prices and rand exchange rate) rather than performance-based. In real terms, the industry has faced stagnant to declining production volumes over many years.

Within this challenging operating context, an increase in employee participation, measured by the rate of innovation engagement, would likely benefit not just individual mining organisations but the industry at large. Stagnant and declining production volumes with associated job losses would appear to be fertile ground for a study that motivates corporate growth via shopfloor innovation.

1.3.4 Research Objectives

Research objectives were developed in accordance with the research aim. Through an analysis of primary historical data, the research methodology and subsequent data analysis were designed in order to satisfy the following research objectives.

- **To measure** rate of employee participation in a corporate innovation program.
- **To categorise** innovation participation by employee demographic.
- **To categorise** the most prevalent types of innovation using a four-quadrant model.
- **To categorise** the most prevalent trajectory, or target domain, of shopfloor innovation using a researcher-defined model.
- **To measure** the return on investment, or value contribution of shopfloor innovation.

1.3.5 Research Questions

The study was designed to answer the following five research questions stemming from the objectives presented in the previous paragraph:

i. What is the rate of shopfloor innovation?

ii. How does employee participation differ by demographic (age, gender, years of service, job grading)?

iii. What is the distribution of innovation by type, using a four-quadrant model?

iv. What is the distribution of innovation by trajectory, using a four-domain model?

v. What is the return on innovation investment?

The answers to these research questions hold potential to provide management with the information needed to sustain and improve the recently launched VIP innovation program.

1.4. ORGANISATION OF THE DISSERTATION

The dissertation includes the following chapters:

Chapter 1: Introduction – This chapter includes the background and context of the research. Research aims and objectives are explained. The significance and scope of the study are introduced.

Chapter 2: Literature Review – This includes a critical analysis of innovation literature. The topic is considered first with reference to the South African Mining industry, thereafter, the mining sector is placed within the context of other ‘primary’, or ‘resource-intensive’ industries. Various themes applicable to this research are examined in order to identify knowledge gaps, contextualise the research problem and confirm the significance of this research.

Chapter 3: Methodology and Data Collection – This chapter describes the procedure followed to collect data in line with the research objectives set out for the study. Selection of variables, research design and research methodology are considered.

Chapter 4: Categorical Analysis of Innovation Participation at PMC - In this chapter, the raw data collected and pre-processed in Chapter 3 are analysed. Details are provided in terms of how the sample population contained in the raw data was cleaned. The results are then presented in the form of tables, graphs and charts.

Chapter 5: Discussion of Innovation Participation at PMC – This chapter provides a discussion of pertinent findings revealed by the data analysis done in the previous chapter. Findings are interpreted within the context of existing literature on innovation as referenced in Chapter 2.

Chapter 6: Conclusions and Recommendations – This chapter revisits the purpose of the research before contextualising the key findings. Recommendations for future academic research as well as industry practice are listed.

CHAPTER 2 – LITERATURE REVIEW

2.1 INTRODUCTION

The mining industry, often thought of as conservative with respect to innovation, is at a crossroads due to the increasing constraints such as a tighter regulatory environment, declining head grades, low productivity, and increased global competition for scarce resources. These challenges are creating an imperative to embrace creative innovation. According to Calzada Olvera (2021), the mining industry is unlike high-technology industries such as information technology or pharmaceutical industries. In mining, innovation is mainly through its processes because there is minimal opportunity for product innovation – miners do not control market prices, which has resulted in innovation being driven mostly by cost-cutting and regulation compliance.

Researchers have observed that the study of innovation within resource-intensive industries, such as mining, remains relatively unexplored (Bartos, 2007; Crawford, 2018; Hossein et al., 2021; Ranestad, 2018; Reichet and O'Brien, 2023; Valacchi et al., 2023). These authors highlight the need for new and tailored innovation metrics in resource-intensive sectors because the standard metrics tend to focus on high-technology industries where research, development, patenting, and new product development are common practice.

This chapter includes a critical analysis of innovation literature to identify knowledge gaps that could be addressed in this research.

The topic of innovation is considered first with reference to the South African Mining industry; thereafter, fundamental concepts of innovation are explored. This is followed by innovation as a strategy for sustainability, and finally, a review of factors influencing innovation in mining

The chapter concludes with a short summary.

2.2 THE SOUTH AFRICAN MINING INDUSTRY

This section considers the role of the South African mining industry as a major employer and core economic contributor. Significant challenges facing the industry are identified. And the need for and dynamics related to innovation in this critical sector are reviewed.

2.2.1 Role of the South African Mining Industry

"The mining sector plays a vital role in job creation and economic growth, particularly by reducing unemployment through the employment of unskilled workers" (Labour Research Service, 2023, p. 3).

The mining industry is important to the employees who work in the sector, their dependents, and to all the vendors, consultants, and contractors that service the industry.

According to the Minerals Council of South Africa (2024), the economy of South Africa has historically been centred on the mining sector. Today, the South African mining industry remains a major component of the country's economy, despite having receded in both importance and volumes in recent times. To emphasise the positive impact of employment, the Minerals Council South Africa (2024) reported that each employee in the mining sector supports close to nine dependents, meaning almost 5 million people are financially dependent on this sector.

The important role of the sector to the overall South African economy is reinforced by the Department of Trade, Industry and Competition (DTIC), which records that mining and metallurgical activities play a key role in South Africa's economy (DTIC, 2024). The sector's mineral reserves are top tier, with South Africa's mining industry being the fifth largest in the world in terms of gross domestic product (GDP).

Skills composition within the South African mining industry is made up of almost equal proportions of those without secondary education and those with secondary schooling completed. Workers with tertiary education make up a small proportion of the total mining workforce as shown in Figure 2.1. This is according to the Department of Research and Information, a department under the South African Industrial Development Corporation (IDC).

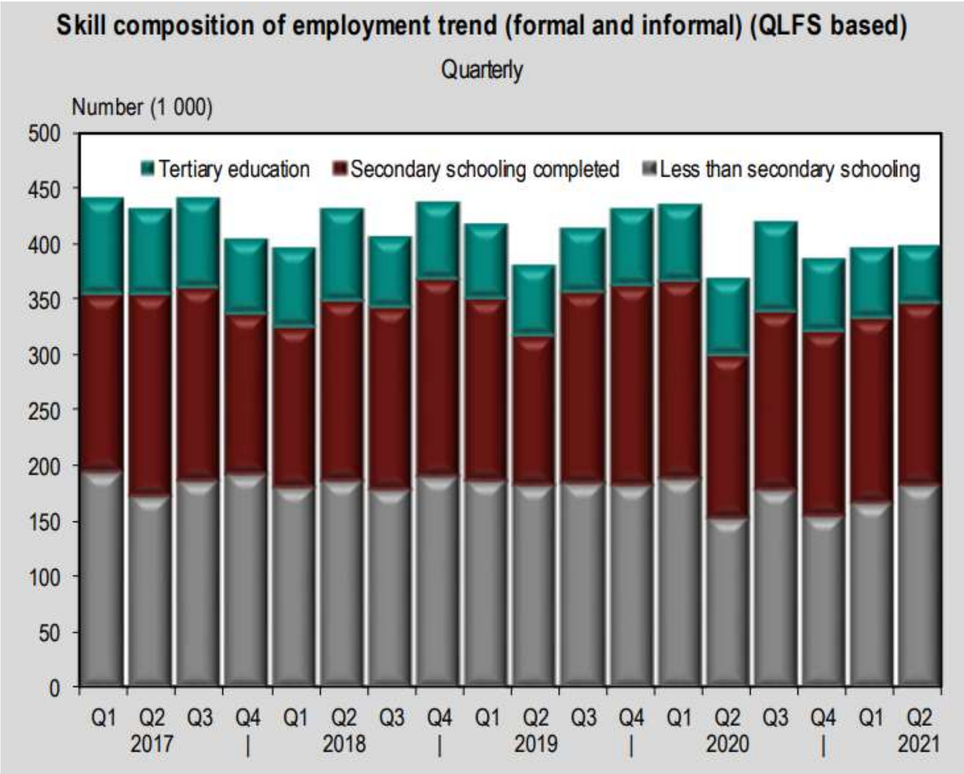


Figure 2.1 - Skills composition on South African Mines (IDC, 2021)

The industry presents on the one hand, relatively few highly skilled employees and consultants, and, on the other, a large majority of low-skilled workers performing low technology tasks.

The mining industry employed 474,876 persons in 2024 on its way to making a 6% gross domestic product (GDP) contribution of ZAR432.7 billion (Minerals Council of South Africa, 2025). The industry's contribution towards employee earnings was ZAR195.3 billion, resulting in an employee pay-as-you-earn (PAYE) tax contribution of R36.1 billion for the calendar year. Value-added tax (VAT), company tax, and royalty contributions were ZAR21.5 billion, ZAR43.6 billion, and ZAR16.0 billion, respectively. Note here that ZAR stands for South African Rand, the currency used in South Africa.

2.2.2 Challenges facing the South African Mining Industry

Mining production in 2024 was below the pre-COVID levels, according to the Facts and Figures Pocketbook by the Minerals Council. The Council notes there are numerous challenges that restrict growth. The competitiveness of the sector is constrained by "high levels of crime, regulatory hurdles, continued above-inflation electricity tariff increases, as well as worsening water provision in parts of the country that go together with weak local government capacity to deploy capital budgets" (Minerals Council of South Africa, 2025, p. 4).

Regrettably, the contribution of the mining industry is reducing relative to other sectors. The Minerals Council of South Africa (2024) explained that most of the sector's recent growth appears to be value-related (a combination of mineral prices and rand exchange rate) rather than performance-based. In real terms, the industry has faced stagnant to declining production volumes over many years.

South Africa's mining industry has unfortunately been in the media for many of the wrong reasons recently: warring unions, hostage situations, deadly incidents, illegal mining (commonly referred to in South Africa as 'zama-zama'), and gang-related activities (Arends, 2023).

Libera (2025) reported a reduction in the workforce of more than 10,000 personnel industry-wide throughout 2024 as a result of increasing challenges facing the industry.

In their South Africa Mining Report, Fitch Solutions (2025) forecast further contractions in the industry in 2025 related to high operating costs, unstable power supply, restrictions in rail and port materials handling, as well as militancy from organised labour. This negative outlook is mirrored by Fernandez (2022), who additionally cites declining ore grades and increasing environmental legislation as threats to sustainability.

Within this challenging operating context, an increase in employee participation, measured by the rate of innovation engagement, would likely benefit not just individual mining organisations but the industry at large. Stagnant and declining production volumes with associated job losses would appear to be fertile ground for this study which proposes corporate growth via shop floor innovation.

2.3 INNOVATION: FUNDAMENTAL CONCEPTS

2.3.1 Definition of Innovation

The words 'innovation' and 'invention' are often used in an ambiguous fashion. Various organisations may adopt differing definitions of each, according to the business context.

While the terms 'innovation' and 'invention' are often used interchangeably, the two concepts are not identical (Trott, 2021). According to the author, the two concepts differ in that invention may be considered to be the conception of the idea, whereas innovation is the subsequent translation of the invention into the economy.

The Oslo Manual, published by the Organisation for Economic Co-operation and Development (OECD), defines a business innovation as "*a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or bought into use by the firm.*" (OECD/Eurostat, 2018).

The South African National Standard SANS 56000:2020, published by the South African Bureau of Standards (SABS), defines innovation more simply as a "*new or changed entity, realising or redistributing value*".

2.3.2 Measurement of Innovation

The measurement of innovation is vitally important, both to business practice and academic theory, yet for some time, research literature reflected such a wide variety of measurement methodologies, classifications, and definitions as to often appear disorienting and contradictory (Adams et al., 2006).

Around the same time, another researcher identified a complication in the measurement of innovation due to the ambiguity of formal classifications. Coccia (2006) highlighted how almost impossible it can be to compare various academic studies. He cited the numerous types of economic innovation, technical metrics, management of change, and management methodologies as a hinderance to the development of these fields of study.

This situation has not changed in recent times, and it may be that the attributes of innovation have much to do with the wide assortment of often opposing theories. According to Glaesner and Lang (2024), the unique attributes of innovation are what make measurements so difficult. They note that many types of innovation are confidential, so public disclosure is uncommon, resulting in an inability to conduct benchmarking. The novel or newness character of innovation further complicates comparative studies, and the evolutionary nature of innovation means that many innovations are not singularly owned within a single company.

This observation was previously explained by Edison et al. (2013), in that quantifying innovation is naturally problematic because it requires comparisons that can be made in a benchmarking process. Innovation is, by definition, something new and original. Comparison is, therefore, often meaningless between industries.

If measurement of innovation is to take place, the definition becomes critically important. The questions listed below give an idea of the complexity associated with the quantitative definition of innovation for a mining firm (Valacchi et al., 2023):

- What are the qualifiers and disqualifiers of innovation?
- How are ideas from different parts of the value chain measured?
- How should qualifying innovations be ranked?
- How does one report on the rate of innovation?
- How can the impact of innovation participation be quantified?

Valacchi et al. (2023) proposed the number of patent filings as a proxy for measuring the rate of innovation. The authors conceded that this metric is only suitable on a global scale, and virtually impossible to apply on a firm-by-firm basis. The use of patent filings as a proxy for innovation is convenient due to ease of data acquisition at a global scale. However, the metric used by Valacchi et al. (2023) and others have a significant drawback in that it ignores innovation activities that occur outside of a research and development (R&D) environment. For example, process innovations about equipment parameters, organisational improvements, and cost-cutting innovations on the shopfloor may not feature on any patent database. This is because there is no realistic need for companies to patent these interventions.

Another disadvantage of using patent filings is that it is a lagging indicator. It may preclude any data or participation from companies that innovate daily without ever having the financial and legal resources to be bothered with filing of a patent.

Throughout the industry, awareness is growing that companies must do more than allocate funds to innovation and develop ambitious targets. Over and above funding, Bjork et al. (2023) argued that companies must track the results and benefits of their innovation through measurement. This is because identifying how best to measure the effectiveness of innovation initiatives is critical in ensuring that those efforts realise a tangible contribution to an organisation's overall goals. Furthermore, the authors explained that without measuring investment in innovation, organisations are less likely to realise a return on their investments. If that happens, companies are more likely to overlook key opportunities by focussing on variables that are not material. They note that the benefits of innovation measurement are better understood as time progresses. However, what is less clear according to these researchers, is how to adopt innovation metrics in day-to-day operational activities?

The Oslo Manual, which is considered the standard for statistical measurement of innovation in business, ties innovation to invention and commercial exploitation (Gault et al., 2023). Published by the Organisation for Economic Co-operation and Development (OECD), the manual defines a business innovation as "a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or bought into use by the firm" (OECD/Eurostat, 2018). In its current state, the Oslo Manual provides guidance to 38 OECD member countries, including the European Union, Brazil, China, India, Indonesia, and South Africa (Gault et al., 2023).

The Oslo definition of innovation, however, may not suit the South African mining industry in the sense that it focuses on (i) new products and (ii) commercial exploitation. The OSLO definition may overlook ‘soft’ contributors such as safety, social impact, broad-based black economic empowerment, supplier development, local recruitment targets, and environmental aspects of the mining industry, all of which are imperative in today’s world.

Crawford (2018) argued that the Eurocentricity of the Oslo definition of innovation overlooks numerous low and medium-technology innovations. These types of innovations frequently arise from the shopfloor of primary industries such as mining. Such innovations also stem from daily activities where one learns by doing or by using a product while refining the product for enhanced value. This essentially means that operators, semi-skilled artisans, and even supervisors are unlikely to contribute to innovation in a manner that satisfies the Oslo definition. This is because many shopfloor workers lack tertiary education, have no direct access to facilities, and generally never have the opportunity to create (i) a new product that can be (ii) exploited in the market, as stipulated by the OSLO method.

The limitations of traditional innovation metrics become more apparent when considered in the context of low to medium-technology-intensive industries, which are discussed in the next section.

2.3.3 Value of Innovation

This section considers the value of innovation within the competitive industry.

In his classical work, Porter (1990) reported on a four-year, ten-nation study, concluding that the prosperity of a nation is not inherited, it is rather created. According to Porter, a Nation’s competitiveness is a function of its industrial capability to innovate and improve.

Modern researchers also advocate for the criticality of innovation in achieving both advantage and sustainability. Zuhroh and Rini (2024), emphasise the necessity of a strategic focus on innovation to ensure long-term survival in today's economic environment of intense business competition and ever-escalating customer expectations.

According to Challoumis (2024), innovation is the foundation stone of economic progress – it serves as a catalyst for transformation within business and communities. Innovation increases productivity, reduces operating costs, and unlocks new paradigms for commercial activity. On a macroeconomic scale, innovation contributes to a country's GDP and the globe's economic growth by nurturing competitiveness, creating employment, and allowing national economies to react to changing commercial forces. The author concludes that innovation plays an equally important role in both capitalist and socialist political systems. In capitalism, market-driven innovation is the goal, where competitive forces and motivation for profit drive businesses to innovate in order to survive. By contrast, socialism encourages state-inspired innovation, where governments prioritise social welfare over profit through policies and investment.

It may be difficult to imagine any word that is used more frequently within the contexts of business or strategic leadership than 'innovation' (Kuratko et al., 2014). The word 'innovation' is, however, easier to use than to practice because of numerous barriers, which are considered in the next section.

2.3.4 Barriers to Innovation

Researchers have shown that technical innovation is essential to improved business performance and sustainability (Ediriweera and Wiewiora, 2021). According to the authors, innovation is especially relevant to the mining industry because it is faced with challenges that include the lowering of grades and deeper, difficult-to-access ore resources, both of which mandate the urgent adoption of technical innovation. The industry also faces mounting demands with respect to environmental impact, health and safety performance, and scrutiny in terms of usage of water and other limited resources.

Despite the fact that technological innovations can facilitate the reduction of operating costs, reduce environmental impact, and increase productivity, mining organisations are frustratingly slow to implement technical innovations (Ediriweera and Wiewiora, 2021). The authors reference a lack of engagement with external stakeholders, market uncertainty, and cyclical pricing as core barriers to the implementation and adoption of new technology. Other barriers cited by the authors included the inflated risk profile of new technology as well as business cultures that were optimised for maximum volumetric production.

In any company or organisation that is required to produce a product of a specified quality and within a certain cost, there is a competing demand between achieving operational stability and the achieving creativity (Crawford, 2018). The mining industry is not unique in the experience of this fundamental tension. The industry does, however, appear to face certain obstacles in relation to innovation that are somewhat unique.

To start off, the author identified several barriers to innovation that negatively impact the mining industry. He observed that mining is already inherently hazardous, and therefore, investment in new technology and its uncertain outcomes contribute to the operational risk. This situation is not attractive to a conservative industry. He then asserted that mining companies usually have an emphasis on near-term and cost-saving enhancements, as opposed to long-term growth. As such, allocating resources to research and development is difficult because of the negative correlation between innovation and profitability. The author also noted that this innovation-profitability tension becomes pronounced particularly in negative commodity pricing cycles, as company resources must typically compete for limited operational budgets. The Human Sciences Research Council (2023) expanded further on the barriers to innovation as listed by mining and quarrying organisations. The findings are summarised in the Figure 2.2, where costs and competition, and difficulty in obtaining grants are identified as three of the major barriers to innovation in mining.

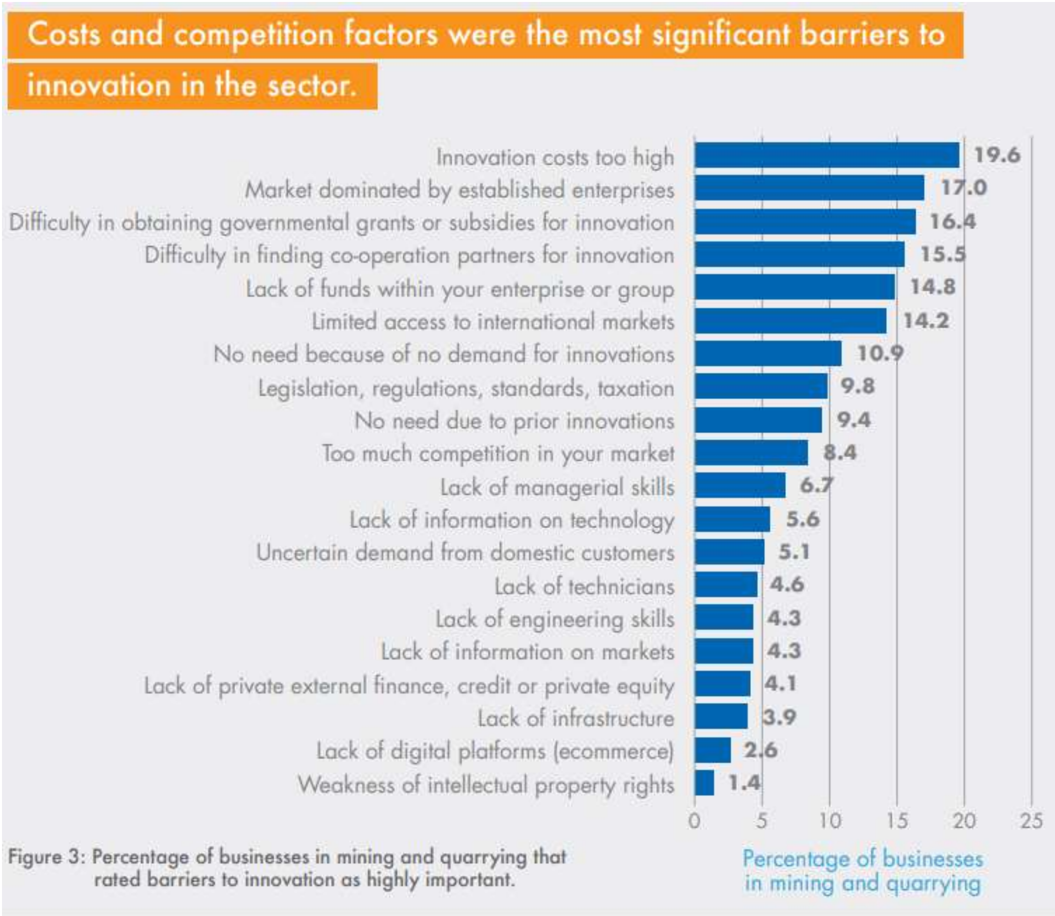


Figure 2.2 - Barriers to innovation in the mining sector (Human Sciences Research Council, 2023)

In a sense, the report by the Human Sciences Research Council (2023) confirms the observations made by Crawford (2018) that the majority of mines see innovation as being too expensive to afford.

In view of the above, mining industry leaders should not be asking whether they can afford innovation. Instead, they should ascertain and reflect on whether they can afford not to innovate. With this understanding, cost should never be an inhibitor of innovation in an organisation. As Phillips and Phillips (2018) point out, it costs very little to embrace a vision of innovation, to set smart objectives for technical ideas and innovations, and to ask employees for ideas. It is cheap to host brainstorming meetings, establish an intranet-based suggestion scheme, implement quick-win ideas, and empower the teams to experiment with initiatives in their places of work.

2.3.5 Types of Innovation: Four-quadrant Matrix

This section considers a four-quadrant matrix that measures both novelty and impact of different types of innovation as described by the ISO standard. “Over time and depending on the context, there can be periods of relatively minor changes, e.g., continual and predictable improvements and incremental innovations, that are intermingled with occasional step changes in value realisation to form new concepts, platforms, or generations of offerings, e.g., radical and disruptive innovations” (ISO 56000:2020, 2020, p. 14).

The Innovation Matrix is a categorisation tool that can be used to classify and prioritise four types of innovation based on their market impact and their level of technical risk.

Talin (2024) describes this method for detailing four types of innovation as incremental, architectural, disruptive, and radical. He notes that this four-block or four-quadrant matrix evolved from the work of Clayton Christensen at Harvard University, who first coined the phrase ‘disruptive innovation’.

The four-quadrant matrix plots how well the organisation is able to define the market impact of an innovation on the vertical axis against how well the technology is understood on the horizontal. Figure 2.3 provides a graphical representation of the four-quadrant matrix.

Figure 2.3 - Four main types of innovation (Alcorfund, 2025)

Incremental innovation (low risk / low impact) is one of the most common types, whereby existing technology is applied to bring about an improvement in an existing market. Cell phone upgrades are cited as an example.

Architectural innovation (low risk / high impact) occurs when an organisation makes use of its existing technical or organisational expertise to create a new market. Amazon and Google are listed as examples.

Radical innovation (high risk / high impact) is often the rarest form. It transpires when a brand-new technology is utilised to open up a new market. The invention of the airplane is an example.

Disruptive innovation (high risk / low impact) is the application of new technology and processes to an existing market. The iPhone applied existing technical features into a single touch-interface device.

2.3.6 Trajectory of Innovation

This section considers the trajectory, or intended target, of innovation efforts.

According to Dorin (2018) there is widespread recognition that new ideas can impact any activity, any part of the value chain, and not just the products and services which form the visible part of the iceberg.

Two common classifications considered by Dorin (2018), which partially address the trajectory of innovation is to classify forms of innovation as (i) process and (ii) product. Process innovations consist of stages or actions to enhance performance while product innovations imply specific objects launched into the market. Product innovation considers what is being produced and process innovation considers how is it being produced.

Other researchers such as Kuratko et al. (2014) argue that a third trajectory can be considered, such that innovation is split in terms of three basic domains relating to (i) processes, (ii) products, and (iii) services. While the definition of process and product innovation is similar to that used by Dorin (2018), service innovations are considered to be beneficial changes to the services that a firm's customers use.

For the purpose of this research, the fact was considered that in a production environment such as a mine, it may rarely be feasible or realistic for employees to actively participate in 'product' innovations. After all, a gold mine may have a single primary product which is unchanged over several decades, i.e. gold bullion. A gold mine may only have a single route to market, i.e. via the Rand Refinery. A copper producer with a concentrator and no smelter would likewise have a single product, such as flotation concentrate. A coal mine linked to a thermal power station would also have a single product that does not change over the life of the mine. In primary industries, it would be rare, if ever, that 'product' innovations occur.

In a similar vein, most mining companies produce a commodity that is sold into the open market. Contact with end-users or clients is, in many instances, negligible, which makes the consideration of 'service' innovation somewhat irrelevant.

If there are effectively zero ‘product’ and zero ‘service’ innovations being captured within an organisation, then every innovation becomes a ‘process’ innovation by default. If there is then a single subset of data (process), classification or categorisation becomes meaningless.

2.4 INNOVATION AS A STRATEGY FOR SUSTAINABILITY

2.4.1 Rate of Innovation in South Africa

Patent applications are often used as a proxy for measurement of innovation because it forms a convenient way to undertake comparisons and benchmarking (Valacchi et al., 2023). In their study of Mining Innovation and Economic Cycles the authors simplified the measurement of a complex process by substituting the number of patent applications as a proxy for the overall rate of innovation. The authors conceded that this metric is only suitable on a global scale and virtually impossible to apply on a firm-by-firm basis. Even so, country-by-country comparisons can reveal useful information.

According to the World Intellectual Property Organisation (WIPO), a United Nations agency that distributes intellectual property statistics, the country profile for South Africa shows a stagnant trend in both total number of patent applications and also in the number of applicants resident in South Africa, per million as per Figure 2.4 below. Number of applications per year for the last 30 years is approximately half of where it was in the first decade of data collection (World Intellectual Property Organisation, 2023). South Africa is ranked 59th out of 132 countries on WIPO’s Global Innovation Ranking, placing the country in the second quartile globally, and in first position within Sub-Saharan Africa.

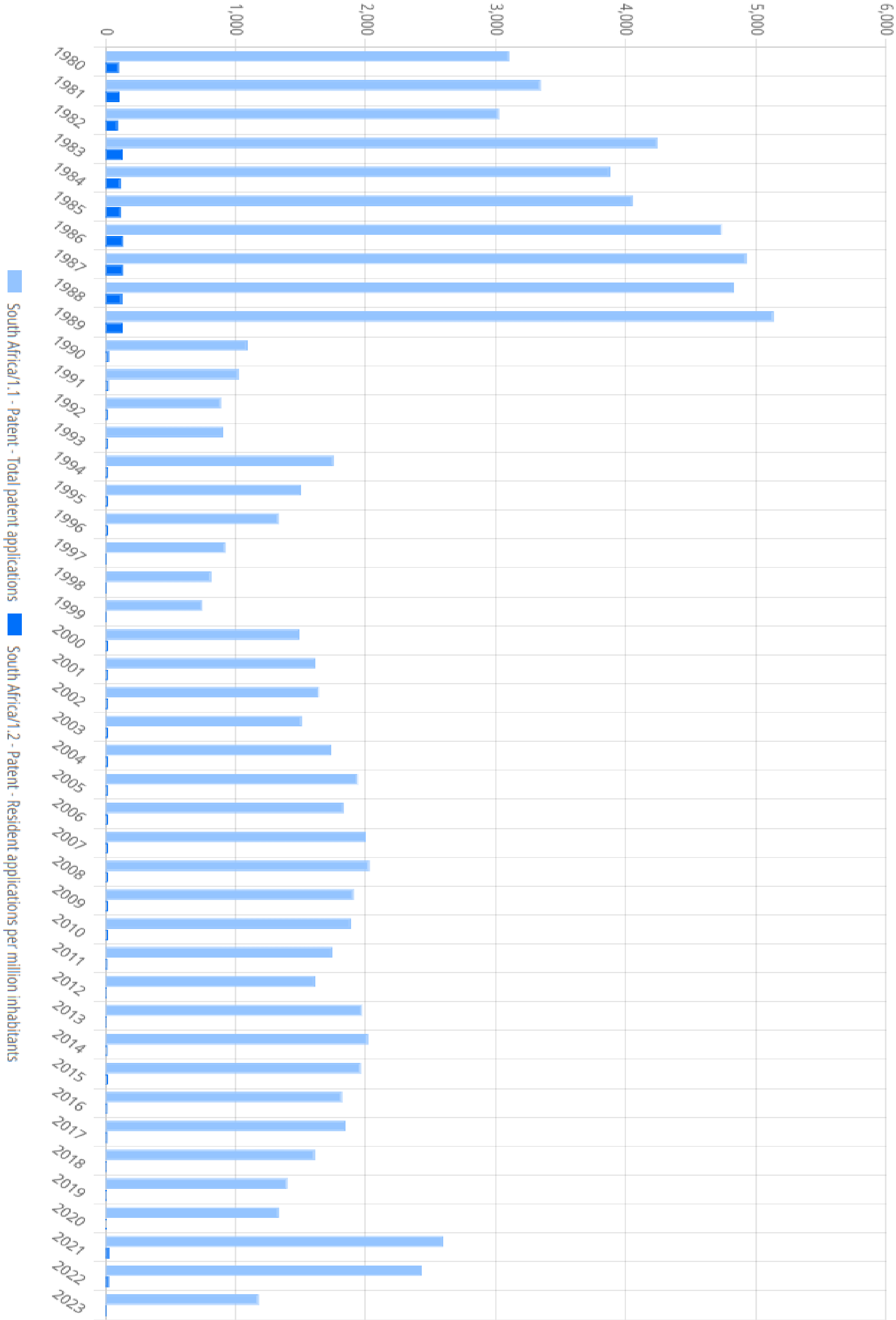


Figure 2.4 – Intellectual property statistics for South Africa (World Intellectual Property Organisation, 2023)

2.4.2 Innovation in Primary Industries

Natural resource-intensive industries, also referred to as primary or low-technology-intensive industries, are those that extract natural resources and convert them into consumable products. Examples of primary industry are mining, agriculture, forestry, and fisheries (World Atlas, 2025). Natural resources are harvested from the planet by the primary industry so that the secondary industry can manufacture finished products and the tertiary industry can market these products to consumers.

Reichert and O'Brien (2023) studied the modes of innovation in primary industries. They note that despite a relatively low R&D expenditure, low-technology industries account for a large proportion of economic activity. They argue that regardless of geographical location, the study of innovation in low-technology or primary industries remains under serviced due to an ongoing bias towards high-technology, R&D intensive innovation.

The two authors state that the highest investment in innovation in primary industries, such as mining, is in machinery and equipment acquisition (Reichert and O'Brien, 2023). The sources of innovation in this sector are mainly the absorption of new ideas and technology through:

- Networks of suppliers
- Clients
- Competitors
- Industry fairs and expos
- Digital information networks

They proceed by explaining that these industries often rely less than high technology sectors on the following sources of innovation:

- Institutional stakeholders
- Universities
- Testing and certificate organisations

- Professional training
- Technical assistance centres
- Specialised publications
- Consultancy companies
- Peer companies

The authors conclude by noting the need to develop new metrics for capturing innovation in primary or low - medium-technology industries.

Resource-intensive or primary industries have little scope to innovate in terms of their product (Hossein et al., 2021). A barrel of oil, a tonne of iron ore, a pound of copper, for example, have virtually the same physical characteristics and functional use now as they did several decades ago. For this reason, metrics that measure the sale of new products as a percentage of total sales will indicate zero innovation in primary industries, making the metrics almost irrelevant.

According to Hossein et al. (2021), primary industries rely on innovations that occur chiefly via technology adoption rather than research and development, thus R&D expenditure or patent filings are unreliable indicators of innovation activities within resource-intensive companies. The authors note that service and supplier companies are more inclined to invest in R&D, which results in products that are adopted by producer firms. This results in many process innovations that do not reflect on standard metrics.

Furthermore, the authors identify the fact that access to natural resources is almost always controlled at governmental level, which tends to encourage single monopoly market structures within primary industries. In the past, they argue, many resource-intensive firms have remained profitable in business for several decades with little technical innovation.

Robertson and von Tunzelmann (2009) corroborate the lack of emphasis on reporting of innovation in the primary industry. They point out an unfortunate tendency to under report and even overlook the importance of technological change outside of research and development-intensive industries such as information and technology and biotechnology. The authors note that low and medium-technology industries are often regarded as being old-fashioned.

They argue that the extent of innovation in low and medium-technology firms may be under-estimated because of technological absorption when these firms buy technological expertise from other firms. These authors make an important distinction in the classification of industries by technological intensity. They explain that companies in these sectors are far from homogeneous. Most companies in primary or low-medium-technology industries have substantial resources within the firm that belong in higher technology-intensive categories when measured based on R&D capacity.

For this reason, Robertson and von Tunzelmann (2009) concluded that low-tech firms perform similarly, and sometimes better than their medium and high-technology counterparts when it comes to process innovation although they may fall behind in new product-related innovation.

2.4.3 Innovation in the Mining Industry

Mining activities have been recorded from the earliest human history. While the industry has undoubtedly enabled human technological progress, it remains one of the most conservative and resistant to change of all human endeavours (Xheko, 2024).

Despite the potential of modern technical advances, mining organisations struggle to adopt and implement the latest innovative technologies. One of the barriers identified by the author is resistance to change at an organisational level. The author notes that innovations require changes to existing processes, and since this may impact revenue, adoption in impeded due to the characteristics of the mining industry.

Research on innovation in mining is rather limited (Gruenhagen and Parker, 2020). They found no comprehensive review in literature that examined the diffusion and adoption of innovation within the mining sector. Other authors concur with the existence of a knowledge gap in respect of mining innovation.

According to Ediriweera and Wiewiora (2021), there are numerous studies that consider technical innovation within the manufacturing and service sectors; however, there exists a scarcity of literature that focuses on the barriers, enablers or adoption of technical innovation in the mining sector.

The literature on innovation suggests that most, if not all, traditional innovation indicators and even some mining sector-specific metrics, measure imperfectly the true scope of innovation in the mining sector (Valacchi et al., 2023). In the case of mining, innovation activities are unlikely to register in measures of new product patents or formal R&D expenditure. This makes measurement and benchmarking problematic.

According to Bartos (2007), investment in the mining industry has been low in comparison to other mature manufacturing sectors. The author concluded that improvements in mining productivity were often the outcome of innovative technology being absorbed into the industry from external manufacturers and service providers. This observation was confirmed in later research by Fernandez (2022), Reichert and O'Brien (2023), as well as Valacchi et al. (2023).

There are selected examples of positive innovation in the industry at the present time, much of which is being absorbed from original equipment manufacturers (OEMs) and third-party service providers. In a study of patent filings in the sector, Fernandez (2022) notes that the primary channel of innovative technology adoption is through suppliers and service providers.

Use of artificial intelligence and machine learning to optimise blasting operations, haul truck movements, and maintenance planning, use of wearable sensors to improve workforce performance, digitisation of supply chain and use of analytics to identify patterns in safety data are some of the most prominent innovations according to Deloitte (2019).

Flores-Castenada et al. (2024) reviewed 1755 research manuscripts and used the PRISMA methodology to identify 63 that satisfied their inclusion criteria. They state that the main digital technologies being applied in the industry are currently Internet of Things (IoT) and artificial intelligence (AI). Unfortunately, the above group of authors found that mining innovation in Africa appears to lag the rest of the globe when measured by publication, as shown in Table 2.1.

Table 2.1 Published scientific articles by continent (Flores-Castenada et al., 2024)

Continent	Number of papers
Australasia	23
Europe	23
Americas	12
Africa	5

Valacchi et al. (2023) studied information relating to mining patents from 1970 through 2015. Innovation in mining was found to be cyclical in that the number of patents increases when commodity prices are high, and they decrease during recessions, following long-term rather than short-term market fluctuations. The authors found that mining equipment, technology, and service (METS) companies contribute significantly to innovation in the mining sector and that mining firms were increasingly dependent on the absorption of technology from METS companies, which were also found to be greater investors in R&D.

There may be several attributes unique to the mining industry that combine to make innovation in mines harder to implement than in other sectors. Shook (2015) cites three difficulties in respect of technology adoption that relate to the specific operating characteristics of this sector:

i. mining occurs predominantly in remote areas cut off from sources of technical support,

ii. mining involves extreme health and safety hazards that require strict policy and procedures, and

iii. mining occurs on a huge scale, which makes for major capital costs when changes to the process or equipment are envisioned.

While this section considered factors specific to innovation in the mining industry, the next section considers the return on investment.

2.4.4 Return on Innovation Investment

This section considers the realistic return on innovation investment (ROII) that organisations may anticipate from corporate innovation programs.

Business expectations are normally founded upon comparison or benchmarking of peers; however, in the case of innovation returns, Ghura and Burak (2024) point out that little is known about corporate innovation programs. They explain that there is no ‘one-size-fits-all’ approach to organising innovation activities within a company, and this uniqueness means that benchmarking of innovation is extremely difficult. Edison et al. (2013) made the same observation - these authors also attributed the fact that comparisons are often meaningless to the fact that innovation activities are, by definition, new and novel.

According to Heher (2006), there existed widespread and unrealistic expectations of innovation return, which were fuelled by the sensational successes of a few well-known institutions. He argued that the rewards of innovation commercialisation were proportional to the expenditure in research and development.

Heher (2006) proposed that in the absence of a well-funded research facility of the highest technical standards, it would not be possible for technical innovation to make any significant economic contribution to an organisation. He stipulated that a large portfolio of patents and technical licences was the minimum requirement for positive innovation returns on investment. Furthermore, he proposed that this requirement may be impossible for smaller companies and institutions to satisfy.

Heher (2006) promoted the inclusion of highly trained innovation professionals as a minimum condition for organisations to have any possibility of registering international benchmarks of innovation performance.

According to Phiilips and Phillips (2018), there are several difficulties associated with measuring innovation returns. A credible measurement process, according to these authors, requires a balanced set of data in order to be believable and realistic from the perspective of key stakeholders. Measurement of the returns from innovation investment means specific value must be ascribed to outcomes that are often hard to value using purely financial metrics. Majka (2024) proposed the formula below for return on innovation investment (ROII):

$$\boldsymbol{ROII = \frac{Net\ Benefit - Cost\ of\ innovation}{Cost\ of\ innovation} \times 100\%} \qquad \textbf{(2.1)}$$

According to Majka (2024), the benefits of innovation investments are often not immediately apparent. The positive impact and secondary implications of R&D may become evident over years, not weeks or months. This requires a long-term outlook when calculating ROII. The author also notes that many benefits of innovation are not financially measurable. Innovation processes frequently contribute to qualitative rather than quantitative improvements, including improved brand recognition, customer satisfaction, and working environment, which are factors that could secure sustainability and competitiveness without being directly attributable. He encourages organisations to embrace a holistic approach to the practice of ROII calculation, such that both quantitative financial metrics and qualitative indicators of success are equally considered. The calculation of ROII should not be viewed as a simplistic, one-size-fits-all metric, but rather as an approach or general framework that should be flexible enough to fit the specific business context and to prioritise those innovation objectives that are aligned to the organisation's innovation strategy.

2.5 FACTORS INFLUENCING INNOVATION IN MINING

2.5.1 Innovation and Age

Significant research exists comparing longitudinal age development and creative output. According to Simonton (1988), numerous researchers over the past century have confirmed a generalised hump shaped curve that predicts creative contribution vs age. Various empirical studies have supported the fact that creative output increases rapidly to a peak before declining gradually. Simonton presented a model for predicting chronological age against creative productivity in Figure 2.5 as follows:

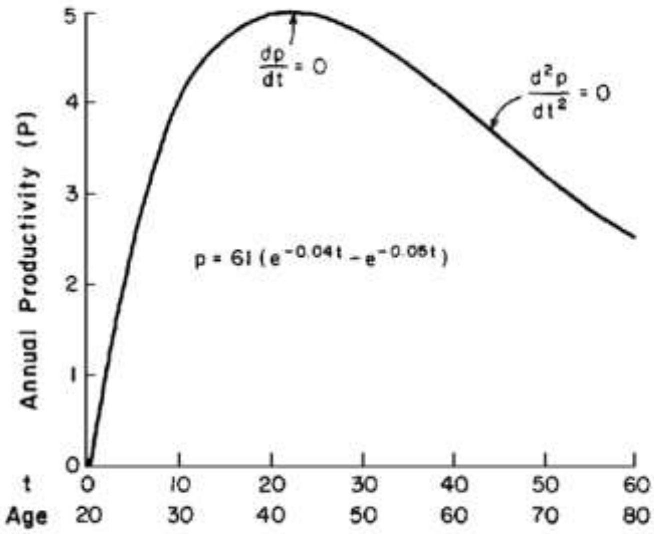


Figure 2.5 - The age-productivity curve for creative output (after Simonton, 1988)

According to Simonton (1988), creative output is likely to start around the mid 20's and increase quickly until a maximum output is reached in the late 30's or early 40's. After this, creative output has been found to gradually reduce until the age of 70, at which time innovative creativity is approximately half of what it was at its peak.

Simonton's model was broadly confirmed by Frosch (2011), who described the age vs creative performance curve to be hump-shaped in both the arts and sciences. Frosch's research showed that most inventions are produced between the ages of 35 and 50.

2.5.2 Innovation and Gender

Baer and Kaufman (2008) report a consistent similarity of performance between boys and girls in creativity test scores as well as in creative output. The authors conclude there is no inherent difference between male and female genders that could explain a difference in adult achievement.

According to Chrisler and McCreary (2010), the way boys and girls approach problem-solving is different; however, all children have equal creative potential. Importantly, Chrisler and McCreary (2010) note that all adults do not fulfil their potential equally. This may lead scholars to conclude that the under-representation of women in the highest levels of mathematics and sciences is due to shortcomings in ability. The authors point out, however, that girls face strong pressures to conform to cultural norms with respect to gender roles, and furthermore women perform the majority of household and childcare duties. In society, both factors may constrain the fulfilment of academic potential in girls.

Travers (2022) provides additional context to the question of gender differences in creative potential. According to the author, from an empirical standpoint, men and women are equally creative, even though a public perception exists that men may be more creative than women. Fortunately, there is evidence that this stereotype (men are more creative than women) is eroding in recent times, especially in countries that have more gender equality.

A more recent study by Saad et al. (2024) reinforced the equality of gender-based potential. Girls use a different approach from boys. The authors noted that girls demonstrated the ability to collaborate in problem-solving better than boys, and that girls could quickly see the error in a given solution and therefore find deeper meaning in their answers.

2.5.3 Innovation and Years of Service

Parsons (2015) considers a longitudinal career progress to include four stages: exploration, establishment, maintenance and decline. He argues there is a different tolerance for risk of failure vs reward of success at each career stage. Attempts to innovate introduce risk of failure. Parsons (2015) notes that older employees in the maintenance or decline stages are likely to focus more on stability and job preservation than younger employees who may have greater appetite for innovative reward when compared to aversion to failure.

2.5.4 Innovation and Job Grading

Menhas and Siddiqui (2023) researched the effects of seniority on job performance and innovation. They reference a growing body of research that demonstrates a positive relationship between seniority and creative output. The two researchers propose that seniority promotes improved creative engagement and a more favourable climate for leader–member exchanges, both of which deliver enhanced creative job performance.

These researchers argue that an organisation's culture and climate may prove critical to determining whether newcomers feel free to contribute creatively. They reference the fact that less senior employees often lack the organisation-specific information, values, and history, and thus are not as well equipped to make creative suggestions when compared to more senior employees.

Hernaus et al. (2024) demonstrated that job demand and job complexity, which may be considered as a proxy for job grading, are not a determining factor in discretionary innovative work behaviour. They showed, in contrast, that the level of support received from a direct supervisor is more critical in predicting high levels of a subordinate's innovation.

2.5.5 Knowledge Gap

Section 2.4.2 highlighted the fact that the study of innovation in mining remains relatively unexplored.

The mining industry in South Africa is facing several challenges, which are decreasing its contribution to the economy relative to other sectors, as discussed in Section 2.2.2. There exists a gap in knowledge in terms of how to incorporate innovation so that stagnant and declining production volumes can be reversed.

The quantification of innovation using sector-appropriate metrics is problematic in mining and other primary industries. Traditional measures may under-report the true scale of innovation on mines, as discussed in paragraphs 2.4.2 and 2.4.3.

Mines often see innovation as something that is too expensive to afford. The barriers to mining were considered in Section 2.3.4. There is a gap in knowledge in how to overcome these barriers, especially the perception that innovation costs too much to undertake, as discussed in Section 2.3.4.

Literature reflects a stagnation over time in the number of South African patent applications discussed in Section 2.4.1. How can Africa catch up to the rest of the world in scientific publications as discussed in Section 2.4.3, and how can South Africa facilitate a positive inflection in patent applications?

There exists a gap in understanding how to measure innovation return on investment as outlined in Section 2.4.4. If innovation is to be managed effectively, it is imperative that the outcomes of innovation investment are quantified.

2.5.6 Concluding Comments

This chapter included a critical analysis of innovation literature to identify knowledge gaps that could be addressed in this research.

The topic of innovation was considered first with reference to the South African Mining industry; thereafter fundamental concepts of innovation were explored. This was followed by innovation as a strategy for sustainability and finally, a review of factors influencing innovation in mining.

The next chapter presents the procedure followed in the collection and analysis of relevant data needed to effectively answer the research questions in Section 1.3.5.

CHAPTER 3 – METHODOLOGY AND DATA COLLECTION

3.1 INTRODUCTION

The previous chapter included a critical review of innovation theory and existing gaps in relation to shopfloor innovation in mining and other resource-intensive industries. This chapter now lays out the procedure followed to effectively collect the relevant data in line with the research objectives set out for the study. It encompasses the collection of secondary data from the corporate innovation program of Palabora Mining Company (PMC). The study was undertaken in order to establish facts relating to employee innovation on a South African mine.

The chapter begins with an explanation of the research design and the research method, including the selection of quantitative variables. A combination of historical, descriptive, and correlational research designs was selected for this study. The three research designs were used to inform the collection of relevant program data. Finally, the data process flow and procedures for data analysis are discussed.

3.2 THE CONTEXT OF THE VIP PROGRAM WITHIN PMC

The VIP Corporate Innovation Program at PMC is open to all employees and contractors working on the mine. Its strategic intent is to support workers on the shopfloor. Its focus, therefore, is primarily, but not exclusively, aimed at unskilled, semi-skilled, and artisanal workers who make up the majority of the workforce.

In September 2023, the VIP program was launched. By the end of August 2024, the new corporate innovation program had registered 1005 submissions. The data generated in the first full year of the program presented the researcher with an opportunity for a case study by means of historical research.

3.3 RESEARCH METHODOLOGY

This section outlines the methodology followed, beginning with the adoption of three complementary types of research design. Next, the research variables are described, followed by the research method, which considers how the research was practically undertaken. Finally, the ethical matters associated with the research are touched upon.

3.3.1 Research Design

The term 'research design' is utilised in a variety of different contexts. It is also often used interchangeably with 'research method'. However, Jalil (2013) defines research design as the logical structure adopted for the research process that is crafted to answer the research question. Accordingly, the design of a research study is primarily a logical problem rather than a logistical problem. Jalil (2013) also points out that the types of research design can be classified according to the research question (e.g., exploratory, predictive, descriptive, etc.) or according to the data collection tools (e.g., survey, qualitative, observational, etc.).

Walliman, (2022) explains that the research design should provide a framework for data collection and analysis. He argues that the choice of research design depends on the nature of the problem and the specific research questions that need to be answered. Based on this, fourteen types of research designs are proposed: historical, descriptive, correlation, comparative, experimental, simulation, evaluation, action, ethnological, internet, feminist, cultural research, arts-based, and heuristic research.

Descriptive research relies on observation of systems or populations in their natural setting and is used to establish and explain the norm. Correlation research, on the other hand, examines a relationship between 2 or more concepts. Comparative research compares parallel situations or events where the researcher has no control over events. In experimental research, attempts are made to isolate and control an independent variable in order to observe subsequent effects on a dependent variable. Simulation research is utilised to devise a simplified representation of a larger, more complex system. Evaluation research is equally and frequently selected to deal with complex systems, but of a social nature.

From the point of view of social enquiry, action research is more of an ‘on the spot’ procedure, constructed to solve a specific problem within a particular context. In the same breadth, ethnological research focuses on the long-term observation of people within natural surroundings and settings. And next to it is feminist research that considers the theories and demographic differences usually between men and women across classes and races, among others. Cultural research is another similar type of research that is concerned with language and cultural interpretations. Arts-based research uses narrative, poetry, fiction, dance, and theatre, for example, as a means of exploring social phenomena. This type of research can challenge stereotypes and create critical awareness of social trends. Heuristic research may be adopted when solutions are urgently required based on incomplete information available or a partial definition of the problem. Therefore, heuristic research is sometimes considered to be a ‘quick and dirty’ approach, still useful in the preliminary stages of a study.

Finally, internet research is a relatively new type of research. It can deliver a rich field of stored communications, data, and descriptive information. Internet research can also be utilised to collect both primary and secondary sources of data (Walliman, 2022).

Based on the above definitions and in the context of this research study, historical research was selected as the primary research design. This is because this type of research design can be used to establish facts and draw conclusions about past events, normally through the analysis of historical primary data. This research type was complemented with descriptive research and correlation research, in line with the research intent investigated at PMC. The three shortlisted research designs are further discussed in the next sub-section.

3.3.2 Selection of Research Design for this Study

The context of this study was considered in relation to the various research designs classified by Walliman (2022). This research study involved primary data gathered during the first twelve months of a corporate innovation program. For this reason, historical research was considered an appropriate design that could be used to establish facts and draw conclusions relating to past events, specifically employee participation in shopfloor innovation.

Because the research problem involved observation, measurement, and categorisation of a population (i.e., mine employees and contractors at PMC) generated within the natural setting of a work environment, descriptive research was also considered to be suitable.

Finally, the research study aimed to explore a correlation between employee participation in innovation and net benefit derived (i.e., return on investment). This research objective called for the use of correlation research.

Since the subject under investigation was complex and numerous variables were involved with a large population over several months, a mixed research design was considered. Walliman (2022) supports this approach, specifically noting that where research considers both technological impact as well as human response, a mixed design can provide the best approach.

A strategy of mixed research design was then adopted for this study. The mixed research included (i) Historical (ii) Descriptive and (iii) Correlational designs as follows:

- Historical research design was used to measure the rate of employee participation in a corporate innovation program.
- Descriptive research design was used to categorise innovation participation by employee demographic. This helps to identify the most prevalent types of innovation and the norms regarding the intended target domain of shopfloor innovation.

- Correlation research design was used to measure the ratio of idea generation versus idea implementation in order to reveal the correlation between innovation response and return on investment.

3.3.3 Selection of Research Variables

One important consideration at the outset of this study was to identify the measurements (variables) that would be involved. Variables are fundamental to many types of engineering processes and to any research strategy. Goddard and Melville (2006) considered any observation or measurement that can potentially possess more than one possible value to be a variable. In other words, if the value of an item can be recorded and if the value of the item can change, then it is a variable.

Variables can be either qualitative or quantitative (Price et al., 2017). Qualitative variables normally vary by grouping, category, or on a spectrum such as poor, mediocre, good, or excellent. Quantitative variables, on the other hand, normally vary between numerical settings such as 1g/t, 2 g/t, 3 g/t. Quantitative variables are further categorised as ‘continuous’ (e.g., a set of real numbers) or ‘discrete’ (e.g., a finite number of settings on a machine). Quantitative variables are normally analysed using statistical techniques.

Where the researcher intends to manipulate a variable to observe its effects on a secondary variable, the manipulated variable is called the independent variable, and the other is called the dependent variable. Manipulation of a variable to observe the impact on a second variable is often used in the experimental method to explain causal relationships, i.e., cause and effect (Hinkelmann and Kempthorne, 2008). When a researcher simply measures variables as they occur naturally in a laboratory, an organisation, or a country, there is no researcher manipulation of an independent variable.

This method of research is considered to be non-experimental. Its goal is normally to describe or predict relationships where systems and events are observed in their natural environment, and without interference from the researcher. Additional instances where non-experimental research may be applicable include where the research question is complex and descriptive in nature (Price et al., 2017).

The research approach in this study was planned for both qualitative and quantitative data obtained through observation of employees and contractors in their natural work environment. No manipulation of independent variables was planned. Instead, the study aimed to focus on observation, prediction, and description of naturally occurring shopfloor innovation at PMC. For these reasons, a non-experimental approach using quantitative data was adopted for the study.

The variables that were defined for this research study allowed the collection of 20 discrete datasets aligned to the six descriptive questions below:

1. WHAT is our rate of innovation?
   i. What is the overall rate of ideas submission?
   ii. What is the conversion ratio of ideas into implementations?
2. WHO is doing the innovation?
   i. Participant demographics by job grade
   ii. Participant demographics by gender
   iii. Participant demographics by department
   iv. Participant demographics by age
   v. Participant demographics by years of service
3. WHEN are employees and contractors innovating?
   i. Innovation response by calendar timeline
   ii. Innovation response by innovation challenge
   iii. Innovation response by outreach method
4. WHY are they innovating?
   i. Financial return on investment from innovation participation (tangible)
   ii. Intangible secondary benefits to the organisation

5. HOW are they innovating?
    i. Incremental innovation
    ii. Architectural innovation
    iii. Disruptive innovation
    iv. Radical innovation
6. WHERE are they innovating?
    i. External domain
    ii. Internal workplace domain
    iii. Production domain
    iv. Product domain

At the time of commencement of the program, it was not yet clear to either the business or the researcher what the potential benefits of the program would amount to. It was decided to utilise the SAP system at PMC to generate demographic data. All employees and contractors are allocated a unique payroll number on the SAP system. As soon as workers submitted their innovations, their payroll number was captured. This in turn, allowed for a retrospective ‘count’ of employee statistics without the release of any confidential information. In this way, many of the questions above could be answered and subsequently utilised in this research.

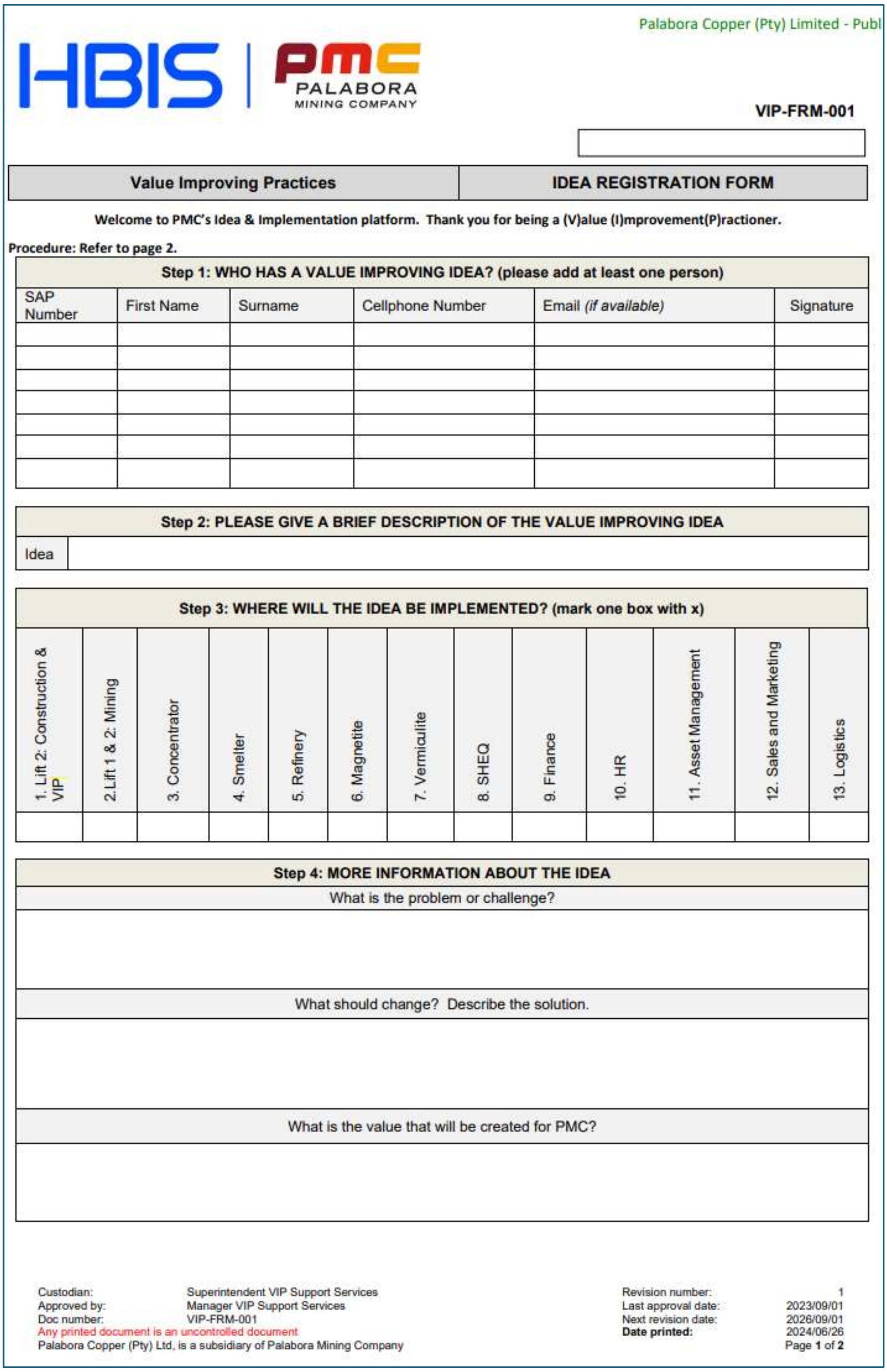
3.3.4 Data Collection Methods

This section considers the research methodology in relation to the collection of research data. It introduces the forms and templates within the corporate innovation program of PMC that were utilised to capture all the information relevant to the research undertaken.

While the terms ‘research method’ and ‘research design’ are often used interchangeably, Jalil (2013) argues that research method should be considered distinct from research design. The author explains that research method deals primarily with the mode of data collection. In other words, the research method answers the questions of ‘how to practically undertake the research?’ and ‘how to collect the information required?’

In September 2023, PMC launched a new division to facilitate knowledge sharing, to improve workforce participation in innovation, and to recognise and celebrate both the originators and the implementers of value-improving ideas. The new division was called the Value Improving Practices (VIP) Division, and any staff member contributing towards the innovation program run by VIP was recognised as a Value Improving Practitioner. This study involved a systematic analysis of primary qualitative and quantitative data from the first 12 months of the corporate innovation program launched by VIP, to better understand innovation at the Palabora mine. The corporate innovation program at the mine was aimed at all employees and contractors employed on the mine property, many of whom lacked tertiary education. The research method was designed to measure and manage innovative responses from the shopfloor. Employee responses were measured and tracked in terms of both ideas generated as well as ideas that were subsequently converted into implemented innovations.

Under the auspices of the VIP Division at PMC, and specifically the corporate innovation program, a database of innovative submissions was created in order to measure and track the performance of the program. The workflow was designed around two sequential forms, Form 1 and Form 2, shown below in Figures 3.1 to 3.4.



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VIP-FRM-001

Value Improving Practices	IDEA REGISTRATION FORM

Welcome to PMC's Idea & Implementation platform. Thank you for being a (V)alue (I)mprovement(P)ractioner.

Procedure: Refer to page 2.

Step 1: WHO HAS A VALUE IMPROVING IDEA? (please add at least one person)

SAP Number	First Name	Surname	Cellphone Number	Email *(if available)*	Signature

Step 2: PLEASE GIVE A BRIEF DESCRIPTION OF THE VALUE IMPROVING IDEA

Idea	

Step 3: WHERE WILL THE IDEA BE IMPLEMENTED? (mark one box with x)

1. Lift 2: Construction & VIP	2.Lift 1 & 2: Mining	3. Concentrator	4. Smelter	5. Refinery	6. Magnetite	7. Vermiculite	8. SHEQ	9. Finance	10. HR	11. Asset Management	12. Sales and Marketing	13. Logistics

Step 4: MORE INFORMATION ABOUT THE IDEA

What is the problem or challenge?
What should change? Describe the solution.
What is the value that will be created for PMC?

Custodian: Superintendent VIP Support Services
Approved by: Manager VIP Support Services
Doc number: VIP-FRM-001
Any printed document is an uncontrolled document
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Revision number: 1
Last approval date: 2023/09/01
Next revision date: 2026/09/01
Date printed: 2024/06/26
Page **1** of **2**

Figure 3.1 - Form 1 page 1 (Idea Registration steps 1 - 4)

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Step 5: HAS THIS IDEA ALREADY BEEN IMPLEMENTED?	
Yes	**No**

Step 6 (OPTIONAL): ATTACH A PHOTO OR A SKETCH
Please submit supporting documentation. For example, by submitting additional pages to this form

Procedure:

- STEP 1 : Compete this form and email to vip@palabora.co.za to register a value improving idea.
- STEP 2 : A Divisional Champion will identify the implementer and complete VIP-FRM-002 to screen and sort the idea.
- STEP 3 : The VIP Implementation Office will receive screened and sorted ideas to support the implementation.
- The VIP Idea & Implementation office will keep you updated on progress.

NOTE : Steps1 to step 5 must be completed to register an idea

Office use – VIP Administration

Date captured in Database	*VIP Representative*	*VIP No*	*Divisional Champion*	*Idea Submitted via SMS*

Custodian:	Superintendent VIP Support Services	Revision number:	1
Approved by:	Manager VIP Support Services	Last approval date:	2023/09/01
Doc number:	VIP-FRM-001	Next revision date:	2026/09/01
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Figure 3.2 - For 1 page 2 (Idea Registration steps 5 & 6)

Form 1 was designed around 6 data fields to capture biographical information of the idea originator, along with a brief description of the problem and the proposed solution. The form was designed for ease of use, such that the process of registering an idea would not be perceived to be onerous, nor would it require technical information that shopfloor employees may not have access to. Registering of the original ideas was performed centrally by the VIP department.

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VIP-FRM-002

Value Improving Practices	IDEA SCREENING AND SORTING FORM

Welcome to PMC's Idea & Implementation platform. Thank you for being a (V)alue (I)mprovement(P)ractioner.

Information from the Idea Registration Form [VIP-FRM-001]

WHO HAS A VALUE IMPROVING IDEA?				
SAP Number	First Name	Surname	Cellphone Number	Email *(if available)*

MORE INFORMATION ABOUT THE IDEA
What is the problem or challenge?
What should change? Describe the solution.
What is the value that will be created for PMC?

WHERE WILL THE IDEA BE IMPLEMENTED

SCREENING & SORTING							
Area Supervisor's Payroll Number		Name and Surname		Signature			
3.1	I am aware of this idea and I understand how the solution may add value.	☹	☹	☺	☺		
3.2	I believe this idea needs to be supported and I am willing to drive it's implementation.	☹	☹	☺	☺		
3.3	I am prepared to engage with those who are needed to make it successful.	☹	☹	☺	☺		
3.4	I have explained this value proposition to my Supervisor and will keep him/her aware of our progress.	☹	☹	☺	☺		
3.5	My Supervisor and my Colleagues are very excited about supporting this value proposition	☹	☹	☺	☺		
4.	I believe this idea:	(tick one)					
	4.1 has already been successfully implemented						
	4.2 can be successfully implemented within our own Department						
	4.3 can be successfully implemented with some assistance from VIP						
	4.4 needs to be implemented by VIP with assistance from my Department						
	4.5 cannot be recognised at this time by my Department for a good reason						

Custodian: Superintendent VIP Support Services
Approved by: Manager VIP Support Services
Doc number: VIP-FRM-002
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Revision number: 2
Last approval date: 2023/09/01
Next revision date: 2026/09/01
Date printed: 2024/06/26
Page **1** of **2**

Figure 3.3 - Form 2 page 1 (Idea Screening and Sorting)

Form 2 was designed around 5 data fields to validate the preliminary data captured in Form 1, to further the understanding of the original idea, and to test the merits of each idea through decentralised peer review. In other words, the appraisal of an idea's worth, lack or merit, was undertaken by subject matter experts within each Division.

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VIP-FRM-002

5.	What feedback would you like VIP to give the Idea Generator?		(tick one)
	5.1 Great idea, the Area Supervisor [Name] is going to support this.		
	5.2 Thank you for your idea, we may be unable to recognise it now because	please complete sentence with reason	
	5.3 Way to go, we will do it ourselves!		
	5.4 This idea is being considered by VIP for further evaluation		
	5.5 (a) Great idea, that has been recognised as an opportunity and implemented in this calendar year		
	5.5 (b) Great idea, that has been recognised as an opportunity and implemented in a previous calendar year. Please speak to your Supervisor for more information.		

MORE INFORMATION ABOUT THE IDEA *(OPTIONAL)*
What is the problem or challenge?
What should change? Describe the solution.
What is the value that will be created for PMC?

Procedure:

- STEP 1 : This step is complete. The idea is registered.
- STEP 2 : A Divisional Champion will identify the implementer (Supervisor) and complete VIP-FRM-002 to screen and sort the idea.
- STEP 3 : The VIP Implementation Office will receive the screened and sorted ideas where assistance is required.
- The VIP Contact Centre will keep you updated on progress.

Office use – VIP Administration

Date captured in Database	*VIP Representative*	*Park (yes/No)*	*Respond and thank you sent to Idea Generator – Yes/No ;date*	*Filed Yes / No*

Custodian:	Superintendent VIP Support Services	Revision number:	2
Approved by:	Manager VIP Support Services	Last approval date:	2023/09/01
Doc number:	VIP-FRM-002	Next revision date:	2026/09/01
Any printed document is an uncontrolled document		**Date printed:**	2024/06/26
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Figure 3.4 - Form 2 page 2 (Idea Screening and Sorting)

An innovation register was established to capture the relevant information from Forms 1 and 2 into Microsoft® Excel® such that subsequent data analysis could be undertaken.

3.3.5 Ethical Considerations

This study has complied with ethical requirements stipulated in the 'policy on research ethics' available at the University of South Africa (UNISA). The following rules were therefore adhered to:

- No data was collected without ethical clearance
- Nobody suffered any harm as a result of the data collection
- No human rights were directly or indirectly violated during this project

Data used in this research was supplied on password-protected Excel® files through a VIP gatekeeper appointed by the mine. Prior to the transfer of raw data, all personal details of the innovation program participants, such as name, surname, and contact details, were deleted to avoid the risk of this information being utilised in any subsequent studies performed.

The gatekeeper consent letter is included for reference in Figure 3.5.

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SOUTH AFRICA
PO Box 65
Phalaborwa
1390
Telephone: +27 15 780 2911
Facsimile: +27 15 781 0448

Registered in the Republic of South Africa
1 Copper Road, Phalaborwa,1390
Registration No. 2007/033694/07
VAT Number 4950252124
Employer Tax Number Ref: 7430771826
Income Tax Ref: 9193800167

Memorandum

Date: May 08, 2025

To: Aidan Schoonbee – Executive Manager – Lift II Construction, Concentrator & VIP

From: Mabore Macheru – Manager - Training Development and Contractor Onboarding

Subject: Gate Keeper Consent

Following your request to conduct research project at Palabora Copper for the completion of your **Masters Eng** at UNISA, permission is hereby granted on the basis that:

- Ms Wendy Maritz – VIP Lead Manager shall act as the gatekeeper of all databases and information shared for the research. Such material shall be password protected, after all personally identifiable data has been removed and stored in restricted access research folders managed by the gatekeeper.
- You familiarise yourself with the POPI act and ensure that no personal identifiers or other information of employees is used for this research.
- You sign the Confidentiality Agreement.
- If at any point there is exposure to confidential company information, you exercise the requirements of the confidentiality clause of the signed Confidentiality Agreement.
- You will maintain and treat company information for the purpose of your studies.
- Access will be granted strictly to information related to the research topic in question, and no personal identifiers or information may be shared or utilized in this research.
- Simple counts (totals per category) may be provided for use in the research from the SAP system - no personal identifiers or individual information is permitted or provided.

It is the responsibility of your immediate Supervisor to ensure compliance to the above.

Compiled by

Ms Mabore Macheru
Manager – Training Development and Contractor Onboarding

Mr Dennis Modise
Executive Manager Human Resources

top EMPLOYER South Africa 2025 FOR A BETTER WORLD OF WORK

Palabora Copper is a subsidiary of Palabora Mining Company (Pty) Ltd, 1 Copper Road, Phalaborwa, 1389

Directors: Guangmin Wei (Chairman) #^, Zhengqin Zou#^, Clifford Zungu, John Maluleke, Mathukana Mokoka, Modise Matlala, Hilton Lazarus, Chao Yu^, Qingsong Zhao^, Jing Wang^, Gang Li^, Bin Guo^, Yanli Bao^.

Chief Financial Officer: Dikeledi L Nakene
Company Secretary: Mamokone Carol Maile
#Executive Director ^Chinese Director

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Figure 3.5 - Gatekeeper consent

3.4 DATA COLLECTION

3.4.1 Sample Population

This section describes the sample population from which research data was obtained.

In September 2023, the VIP Division launched the first corporate innovation program aimed to encourage workforce participation in innovation, to facilitate knowledge sharing, and to recognise and celebrate both the originators and the implementers of value-improving ideas. PMC has over 9000 employees and contractors on its vendor list, with approximately 4700 workers at any one time entering the property. Full-time employees are just over 3000, with the remainder being contract workers. Both employees and contract workers were eligible for the innovation program; hence, the sample population was made up of both employees and contractors who responded to the call. The innovation program is ongoing with renewed themes and calls; however, only primary historical data generated from September 2023 to August 2024 was considered for this research. This primary data was anonymised before it was received from the corporate innovation program for analysis. The original approach aimed to collect a minimum of 700 data points for critical appraisal. To this end, a contact centre was established under the VIP Division to ensure that ideas could be registered in an efficient manner and that no shopfloor submissions would be lost. By the end of August 2024, over 1000 ideas had been registered through the corporate innovation program.

3.4.2 Two-monthly Challenges

In order to stimulate interest in the program, ‘challenges’ were issued every two months. This allowed for fresh topics to be introduced on a regular basis while ensuring that shopfloor participation could be periodically stimulated. Nominal prizes as recognition were awarded for each challenge in order to further promote interest in the program. Figures 3.6 and 3.7 respectively, provide examples of the challenge advertising and a sample of the recognition awarded post the challenge:

Figure 3.6 - Advertising for Challenge 1, Year 1 (Source: PMC, 2023)

Figure 3.7 - Recognition of winners from Challenge 1, Year 1 (Source: PMC, 2023)

Innovation participation was therefore promoted through regular two-monthly adverts and by publication of winners for each challenge. As a result of this participation, the program registered primary data that could be used to research how different demographic groupings participated in innovation in the mine. Individual ideas and implementations were analysed in order to categorise the type of innovation that was most prevalent, as well as the intended target domain of shopfloor innovation. Employee responses were measured and tracked in terms of both ideas and implementations submitted within the program. The value added to PMC because of employees implementing their ideas was calculated in order to determine Return on Investment from shopfloor innovation.

This research study focussed on shopfloor ideas generated on site by the workforce. This was because the Chief Executive Officer wanted the VIP program to mirror similar initiatives that already exist in China, and which are active within the HBIS Group. The belief within the parent company is that much knowledge of an organisation is vested within the workers on the shopfloor, and it is through these resources that a company can effectively promote innovation in order to improve business performance. The data sample, therefore, excluded new technology adoption from original equipment manufacturers, research and development programs, and other external mining or metallurgical test work conducted in partnership with third-party consultants under the auspices of formal capital and life-of-mine extension projects.

Finally, the research only included ideas and completed implementations that passed the VIP screening. In other words, only innovation submissions that complied within the VIP definition of innovation were considered. This criterion may differ from the way in which other organisations may define and measure their internal rates of innovation. As such, difficulty in benchmarking against corporate innovation programs that are undertaken elsewhere in the mining sector was anticipated. Be that as it may, the next sub-section describes the basis for inclusion and exclusion of submissions that was used at VIP.

3.4.3 Data Pre-processing: Inclusion and Exclusion Rules

The first basis of inclusion was calendar-based in that only those data points congruent with the first 12 months of the corporate innovation were included. The second basis of inclusion was performed according to the satisfaction of five program inclusion/exclusion criteria that were directly derived from the program's definition of 'innovation'.

In their paper on corporate innovation and entrepreneurship, Ghura and Burak (2024) point out that there is no one-size-fits-all innovation program that works for every organisation and occasion. Organisations tend to create solutions to innovation management that do not solve the problems they are facing. This results in the lack of uniformity in the path to innovation across organisations and industries. If different organisations have different definitions and metrics for innovation, then, benchmarking is problematic because of the lack of a proper basis of comparison. This contributes to the fact that little is known about different corporate entrepreneurship (or corporate innovation) programs.

Based on the literature reviewed and considering the strategic emphasis of Palabora Mining Company (PMC) on 'using what we already have', a bespoke approach was adopted for PMC's VIP program. The approach was derived from the following internal definition of an innovation (VIP Operating Procedure, 2024):

> **VIP Innovations are defined as new solutions to existing problems that improve value by better using the resources we already have.**

The below selection criteria should be noted from the VIP definition of innovation:

- **new** – has not been done in this way or in this place.
- **solutions** – approaches, ideas, methods, designs, capabilities, uses, processes, sequences.
- to **existing problems** – relating to safety, ergonomics, cost, efficiency, quality, throughput, waste, spillage, etc.
- that **improve value** – satisfaction of needs / use of resources = value.
- by better using the **resources we already have -** people, places, skills and assets.

It was advised that for an idea to qualify as an innovation under this program, at least 3 of the above 5 selection criteria needed to be satisfied. In other words, three or more of the following five questions had to be answered in the affirmative for an idea or submission to be accepted as an innovation, and hence as a data point in the sample population.

- ✓ Did the idea address an existing problem?
- ✓ Was the idea a solution to the problem?
- ✓ Was the idea new?
- ✓ Did the solution add value?

- ✓ Did the idea utilise what we already have?

Innovation submissions that satisfied 3 or more of the above criteria were therefore included into the sample population, while all other submissions were excluded. The shortlisted submissions were finally taken for processing, as is described in the next section.

3.4.4 Data Process Flow

The VIP corporate innovation program was set up to include Service Desk agents whose responsibility was to ensure the smooth running of VIP services rendered to the business. These agents, in conjunction with area champions in each of the mine's business divisions, ensured that innovation data processes followed the sequence below:

- **Idea definition** - Form 1, referred to earlier in Figures 3.1 and 3.2, was received from an idea generator or sent on their behalf. VIP service agents acknowledged receipt by sending a "Thank You" message via SMS or email to the idea generator.
  - The VIP agent then proceeded to capture the details of the actual name of the idea generator and of the idea itself in the database. In an instance where the idea was logged via SMS, the agent called the idea generator to solicit more information and populate Form 1.
  - A unique tracking number was assigned at this stage.
- **Idea registration** - Form 1 was completed with all the required data. The information was then populated into the VIP database so that the idea status became 'registered'.
- **Inclusion and exclusion screening** was conducted in consultation with divisional champions. Before Form 2, referred to earlier in Figures 3.3 and 3.4, was populated, the VIP team screened the ideas that were registered in consultation with the divisional champions from each area.

- All screened ideas that met less than 3 out of the 5 above-mentioned criteria of the definition of an innovation were excluded. These oversized ideas were parked with the reason provided by the divisional champions.
- All screened ideas that met at least 3 out of the 5 selection criteria of an innovation were included in the database for further sorting. The VIP agent populated Form 2 and sent it to the divisional champion for engagement with the area supervisor, where the idea was to be implemented. Divisional champions were considered to be Subject Matter Experts (SMEs) within their divisions and therefore knew whom to engage for each idea submitted.

- **Idea screening and sorting** - the objective of screening and sorting was to assess the feasibility of implementation and the level of support from the area personnel. It was also to determine whether the idea would require VIP assistance or would be implemented by the department on its own. The divisional champion engaged the area personnel responsible and assisted the area supervisor in completing or approving Form 2.
- For a project or implementation to be successful, the stakeholders immediately involved in the process, and especially those who manage the areas in which the project was proposed, needed to react favourably, or at least not negatively (Phillips and Phillips, 2018). Form 2, therefore, aimed to assess the level of support of immediate stakeholders.
- **Post idea screening and sorting** - after Form 2 was completed, the divisional champion sent it back to VIP services. The agent at VIP services captured the responses in the database.
- **Feedback** - throughout the idea management process, feedback was provided to the idea generator through SMS via the VIP support services department.

3.4.5 Data Analysis Procedure

Upon sorting the data in the previous sub-section, a sequential eight-step process was adopted for data analysis. This is presented under the above heading. But before that, it should be noted that the definition for data analysis adopted for this research study is “the systematic process of inspecting, cleaning, transforming, and modelling data to uncover meaningful insights, support decision-making, and solve specific problems” (Montgomery and Runger, 2018).

Now coming back to the sequential step process, data analysis primarily consisted of the use of descriptive statistics to summarise and explain the raw data collected. The raw data (i.e., shortlisted submissions) was therefore changed from unorganised into user-friendly data displaying relevant statistical summaries. To this end, the eight (8) sequential step process for data analysis by Montgomery and Runger (2018) was adopted in this study:

Step 1 - Define the objectives: The research problem was explained, and the research questions that needed to be answered through the study were defined.

Step 2 - Data collection: Relevant information regarding shopfloor innovation participation was obtained from the VIP corporate innovation program.

Step 3 - Data cleaning: Data was sanitised by removing idea submissions that were inconsistent with the VIP definition of ‘Innovation’.

Step 4 - Data exploration: Exploratory data analysis was conducted to identify patterns and relationships. Descriptive statistics such as measures of central tendency, mean, median, and standard deviation were examined in relation to researcher-defined demographic sub-samples.

Step 5 - Data transformation: Raw data was transformed into user-friendly formats such as tables, graphs, models, and schematics to assist with Descriptive Analysis.

Step 6 - Analysis and interpretation: Modelling and analysis were undertaken in order to understand the data and draw conclusions regarding the rate of innovation, type of innovation, trajectory of innovation, and value added through innovation.

Step 7 - Reporting and visualisation: Here, the research findings are presented later in Chapter 4 using graphs, tables, charts, and dashboards to support the written analysis.

Step 8 - Decision making and implementation: Insight gained from this data analysis was used to make recommendations regarding the design and administration of corporate innovation programs in resource-intensive industries such as mining.

3.5 DELIMITATIONS & LIMITATIONS

Delimitations (boundaries intentionally set by the researcher for this study) included:

- Geographic scope of the study was delimited to the PMC mine in Limpopo Province, South Africa.
- Participation in the program was delimited to shopfloor innovation registered by employees and contractors; other innovation and business improvement relating to third-party vendors and capital project upgrades were excluded.
- The study was delimited to the first 12 months of historical data from September 2023 to August 2024.
- Ideation, or the process of generating, sharing, and evolving ideas, was not included within the scope of this study.
- Time to implement was not considered within the scope of this study.

Limitations ((factors outside of the researcher's control) included:

- This research considered only those shopfloor innovations that were registered within the corporate innovation program. It is possible that workers engaged in numerous other business improvements without formally registering these efforts in the system. Failure to register some ideas may have occurred due to a combination of lack of awareness, workload saturation, inconvenience, or mistrust.

- The demographic distribution of the participants may reflect the effectiveness of the program advertising and outreach i.e. it is possible that under-represented categories represent those employees that were least effectively reached through the program advertising.
- Financial business case development was limited to 16 submissions extracted from the top 60 implemented innovations in the year that demonstrated a direct commercial impact on the operation. Numerous other innovations that delivered 'soft' and intangible benefits, which could have secondary benefits to the mine's performance, were not commercially evaluated due to resource limitations.
- The role of the supervisor in fostering shopfloor innovation was not examined in this research. Similarly, the role of corporate culture in promoting innovation was not determined.
- Since this was the first year of a corporate innovation program, there was no prior data to review, hence no benchmark against previous innovation participation could be made.

3.6 SUMMARY

This chapter described the general approach to the collection and analysis of data associated with the research study. The study methodology was formulated in such a manner as to produce all the data needed to answer the research questions outlined in Section 1.3.5, Chapter 1.

The chapter began with an explanation of the research design and the research method, including the selection of quantitative variables. A combination of historical, descriptive, and correlational research designs was selected for this study. The three research designs were then used in the collection of relevant data. Finally, the data process flow and procedures for data analysis were discussed. Details about the data analysis and the interpretation of results generated from the endeavour are presented in the subsequent chapters.

CHAPTER 4 – CATEGORICAL ANALYSIS OF INNOVATION PARTICIPATION AT PMC

In this chapter, the raw data collected and pre-processed in Chapter 3 are analysed. Details are provided in terms of how the sample population contained the raw data, was cleaned. The results are then presented in the form of tables, graphs, and charts. Findings relevant to the study are finally summarised and where applicable, statistical analysis is done.

4.1 DATA CLEANING AND PRESENTATION

This section describes the process by which the data was cleaned. The process of data cleaning is sometimes also referred to as data scrubbing, data profiling, or data cleansing. It is aimed at improving the quality of raw information contained in the sample data, which in this research was secured through the VIP corporate innovation program. Data cleaning techniques may include standardisation, identification of outliers, duplication, and incomplete values, as well as validation (Rogers and Jonker, 2025).

The first step towards data cleaning was a direct calendar basis for inclusion and exclusion, whereby data points falling outside of 01 September 2023 through to 31 August 2024 were excluded. This means that data within this 12-month period was included in the analysis. The 12 months included in the study were selected on the basis that they constituted the first full year of the VIP corporate innovation program. In this way, standardisation of the data was ensured.

Calendar-based standardisation resulted in the omission of nil data points representing innovation submissions that were received outside of the period under review. A total of 1005 innovation submissions were received in the period prescribed; hence, this total constituted the sample population that was considered for further cleaning.

The second method of inclusion/exclusion was based on data validation, whereby the conformance of each submission to the program's defining criteria was analysed. In Chapter 3, a bespoke definition of 'innovation' was presented in Section 3.4.3. The program, therefore, required that all submissions to the corporate innovation program needed to satisfy at least 3 of the following 5 criteria in order to conform and hence be included for further evaluation:

1. Did the idea address an existing problem?
2. Was the idea a solution to the problem?
3. Was the idea new?
4. Did the solution add value?
5. Did the idea utilise what we already have?

The evolution of the sample population before and after cleaning is presented in Table 4.1.

Table 4.1 - Sample population pre- and post-cleaning

	Number of Entries		Number of Entries After Screening		
Challenge Number	All Entries Collected	Within 12 months	Entries Excluded	Entries Included	Percent Entries Included
1	28	28	4	24	85.7%
2	90	90	3	87	96.7%
3	113	113	5	108	95.6%
4	188	188	18	170	90.4%
5	365	365	121	244	66.8%
6	221	221	28	193	87.3%
Total	**1005**	**1005**	**179**	**826**	**82.2%**

It can be seen from the data in Table 4.1 that all the data points in the original population (1005) were compliant within the 12-month calendar period; therefore, no calendar-based cleaning was required. Moreover, of the 1005 original submissions, 826 or 82.2% complied with the VIP definition of innovation (see Section 3.4.3. of Chapter 3) by meeting at least 3 of the 5 innovation criteria as shown in Figure 4.1 below.

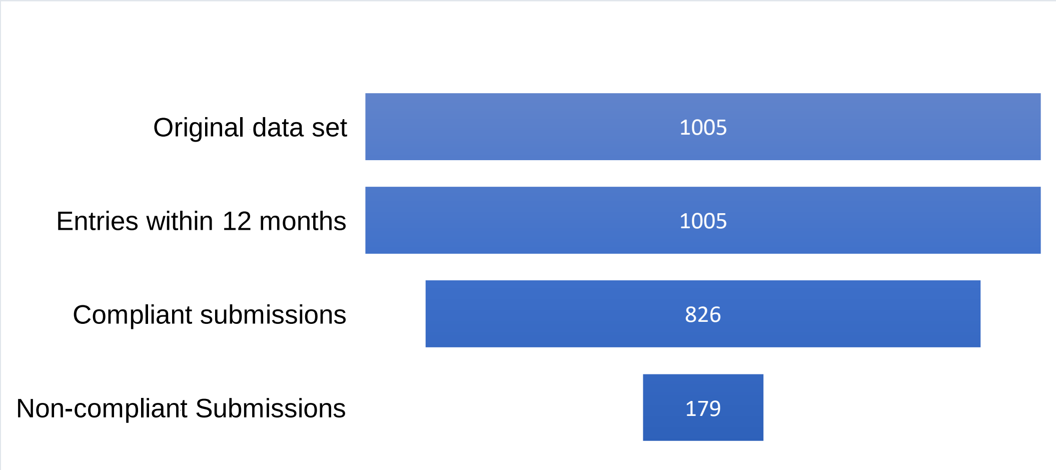

Figure 4.1 - Data cleaning by calendar and by compliance

Most of the challenges exhibited relatively high inclusion rates (i.e., above 85%), except for Challenge 5, which had by far the highest level of participation and, in contrast, the lowest level of compliant (included) innovation submissions. It is speculated that a higher ratio of contractor: employee engagement in Challenge 5 resulted in an influx of participants who were unfamiliar with the earlier VIP publications, and hence ignorant of the 5 acceptance criteria.

Entries excluded on the basis of satisfying 2 or fewer inclusion criteria amounted to 179 or 17.8%.

An analysis of all submission by inclusion criteria is summarised in Table 4.2.

Table 4.2 - Analysis of all submissions by inclusion criteria

Challenge Number	Original Data Set	Number of Inclusion Criteria Satisfied				
		#1	#2	#3	#4	#5
1	28	28	28	13	12	10
2	90	90	90	18	79	16
3	113	113	113	59	107	41
4	188	188	187	109	170	20
5	365	298	260	156	230	149
6	221	210	200	83	171	63
Total	**1005**	**927**	**878**	**438**	**769**	**299**

The first inclusion criterion, i.e., 'Did the idea address an existing problem?', reflected the highest compliance rate of 927 or 92.2%. The fifth criterion, i.e., 'Did the idea utilise what we already have?', exhibited the lowest level of compliance at 299 or 29.8% with criterion 3 ('Was the idea new?') also reflecting a lower level of compliance at 438 (44%)

Once the data were cleaned up, the next step was to convert it into meaningful results guided by the five research questions that motivated the study, namely:

- Q1: What is the rate of shopfloor innovation?
- Q2: How does employee participation differ by demographic (age, gender, years of service, job grading)?
- Q3: What is the distribution of innovation by type, using a four-quadrant model?
- Q4: What is the distribution of innovation by trajectory, using a four-domain model?
- Q5: What is the return on investment?

Corresponding results are presented and qualitatively interpreted in the next five sections. Each section corresponds to one of the research questions above as set out in Section 1.3.5 of Chapter 1.

4.2 QI: RATE OF SHOPFLOOR INNOVATION

This section considers data relevant to the first research question: 'What is the rate of shopfloor innovation?'.

The rates of shopfloor participation in the program are summarised in Table 4.3 as (i) a total number of ideas received during the first 12 months of the program, (ii) total number of ideas that passed initial screening (satisfied 3 or more of the inclusion / exclusion criteria), (iii) total number of ideas not yet implemented and (iv) total number of ideas already implemented.

Table 4.3 - Rates of Innovation participation by idea and by implementation

Months	Entries submitted in Year 1	Entries included	Entries not yet implemented	Entries already implemented
1-2	28	24	6	18
3-4	90	87	75	12
5-6	113	108	92	16
7-8	188	170	146	24
9-10	365	244	219	25
10-12	221	193	175	17
Total	**1005**	**826**	**713**	**112**

It can be seen that the total number of submissions increased from a low of 28 in the first 2 months to a high of 365 in months 9 and 10. A total of 1005 submissions was received in the first 12 months of the VIP corporate innovation program, representing an average of 84 (rounded off from the calculated 83.75) innovation entries per month. Of the 1005 original submissions, 826 conformed to the inclusion criteria and were hence considered compliant with the rules of the program. And of these, 112 ideas had already been implemented by the time of registration by the time the first 12 months closed.

4.2.1 Participation response to roadshows

An independent analysis was conducted by Nyarela (2024) using data from the first year of the VIP program to determine the relationship between employee roadshows and innovations registered. Her analysis was undertaken prior to this author’s research.

As with many new corporate initiatives, the VIP Division released promotional material across the mine using different media channels. Even so, in the early stages, there were some employees who had greater awareness of the program and its goals than others. This was due to structural factors such as access to a personal computer, access to e-mail, and dependence upon line management to make publication material available for convenient distribution.

To promote awareness among all employees and contractors regarding the objectives of the program and the mechanisms available for submitting ideas, roadshows were conducted. It was subsequently determined (Nyarela, 2024) that there exists a positive correlation between the conducting of face-to-face roadshows and the rate of innovation response. Correlation coefficients were calculated by the author between the number of roadshows conducted and the rate of innovation participation across various employee job gradings and divisions.

The interpersonal roadshow interactions were complemented by pre- and post-roadshow surveys, which were designed to assess changes in awareness regarding the location of VIP program offices, availability of VIP program forms, and identification of divisional champions.

The data showed a positive relationship between the number of roadshows performed and the rate of idea submissions across different divisions, suggesting that roadshows are an effective method for encouraging idea submission (Nyarela, 2024).

Engagement in the corporate innovation program was analysed using a 3-question survey summarised as follows:

> Survey question 1: Do you know where to get VIP Form 1 to log your innovation idea?
>
> Survey question 2: Do you know who your Divisional Champion is?
>
> Survey question 3: Do you know where VIP offices are?

Survey results pre- and post-roadshow confirmed that the face-to-face interactions were effective in improving engagement with the corporate innovation program. According to Nyarela (2024), interpersonal interactions disseminate information to the shopfloor and build trust, transparency, and inclusivity, as evidenced in Figures 4.2 and 4.3. For example, on question 1, 20.43% of respondents answered in the affirmative before the roadshows, while this number increased to 96.38% answering positively post the roadshow. A similar increase in engagement levels pre- and post-roadshow was observed for questions 2 and 3.

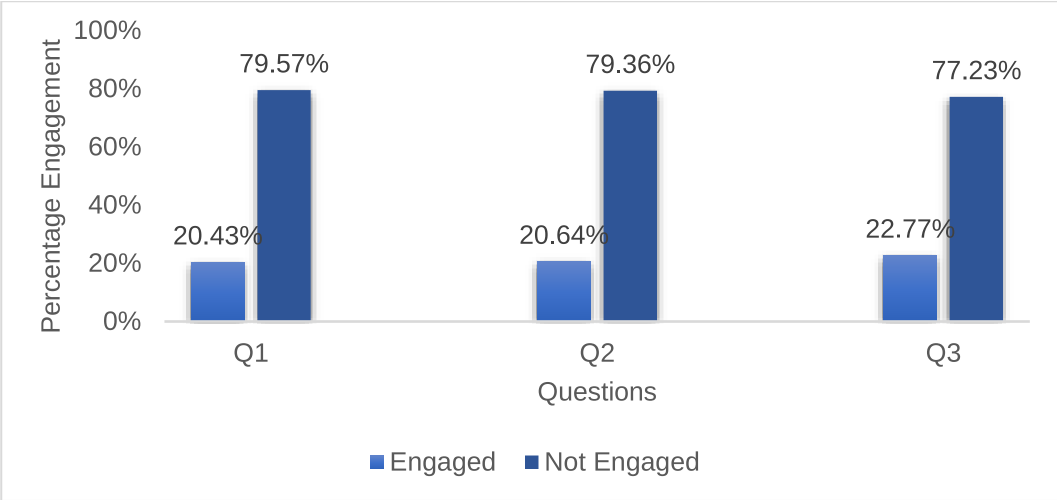

Figure 4.2 - Pre roadshow engagement levels (Nyarela, 2024)

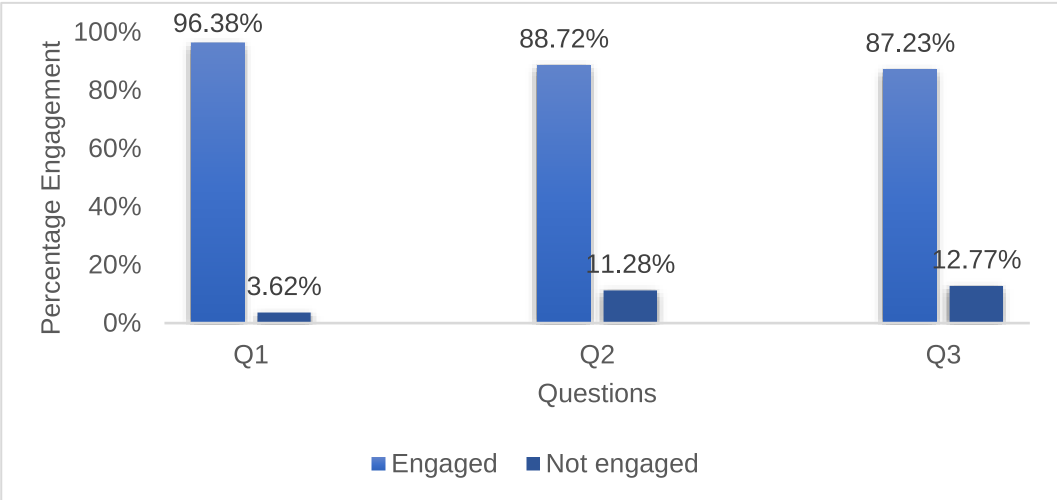

Figure 4.3 - Post roadshow engagement levels (Nyarela, 2024)

These results demonstrate the efficacy of using face-to-face interactions vs printed and electronic promotional media

4.3 Q2: PARTICIPATION BY DEMOGRAPHIC

This section considers data relevant to the second research question, ‘How does employee participation differ by demographic?’.

4.3.1 Participation vs age

The total number of employee-sourced innovation entries was categorised by age. Five researcher-defined age groups were selected, as reflected in Table 4.4 below.

Table 4.4 - Innovations registered per age category

Age Category (years)	Total Employees in Category	Percent Participation of Category	Percent Non-participation in Category
≤ 25	305	10%	90%
$25 < age \leq 35$	867	25%	75%
$35 < age \leq 45$	1132	26%	74%
$45 < age \leq 55$	888	20%	80%
> 55	252	21%	79%
Total	**3444**	**22%**	**78%**

The age categories corresponding to the over 55 years and under 25 years had the lowest total employees at 252 and 305, respectively. The under 25 years also had the lowest level of representation in the program at 10% innovations registered, i.e. 90% of employees in the category did not participate in the program during the 12-month period.

The category between 35 and 55 years of age had the highest level of representation at 26%. Average representation across all age categories was 22%, with the age distribution depicted in Figure 4.4. below.

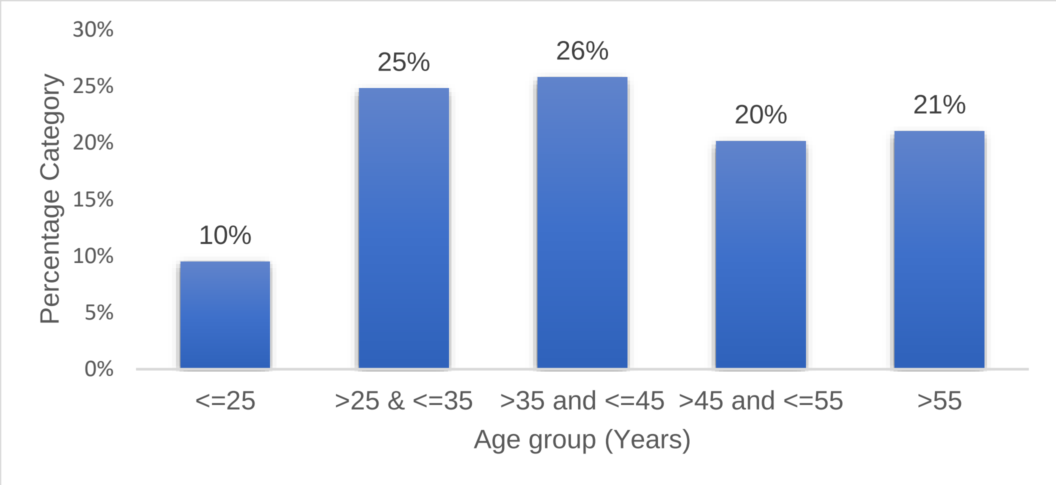

Figure 4.4 - Innovations registered by age expressed as % participation within each age category

In many instances, individuals registered more than one innovation each. For this reason, the total number of innovations registered exceeds the actual number of employees who participated for each age category. The percentage of employees who participated in each category, and accounting for the fact that some employees registered more than one idea, is therefore represented in Figure 4.5 below.

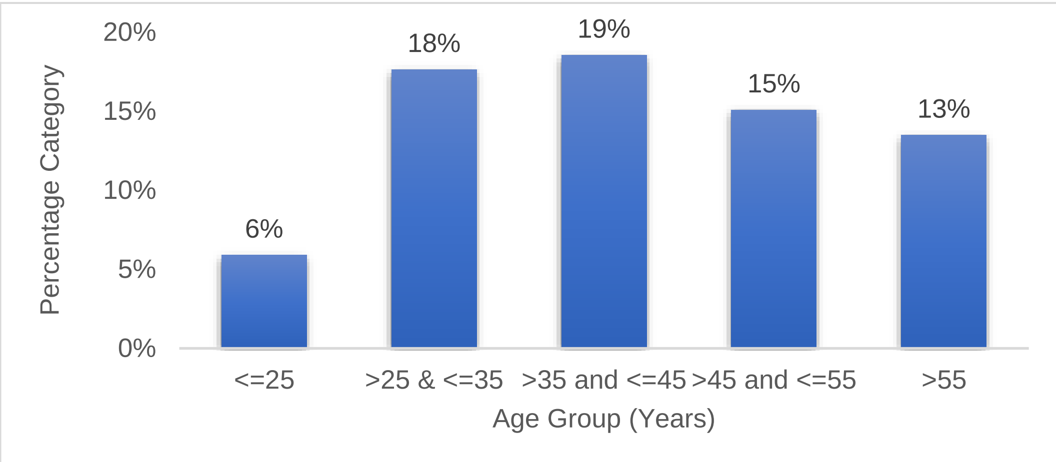

Figure 4.5 - Innovation participation of employees by age group

The percentage of participants per category is lower than the percentage of ideas registered per category due to the fact that some employees registered numerous innovations.

Whether measured by total number of innovations registered or by actual number of employees that participated, it can be seen in Figure 4.5 that those under 25 years old are significantly underrepresented relative to all other age categories. It can also be seen that the two age categories (25 < age ≤ 35 years and 35 < age ≤ 45 years) yielded the highest rates of participation.

Insofar as participation by age grouping is concerned, where the percentages are simply expressed as a % of the total ideas registered, the representation can be illustrated as follows in Figure 4.6. This representation does not take into account the number of employees within each category; it simply reflects ideas within each category as a percentage of the total ideas submitted. Figure 4.6 demonstrates that most ideas came from the > 35 to ≤ 45 years age grouping, while either end of the age spectrum (youngest and oldest) contributed the fewest ideas. This is not surprising given that the youngest and oldest categories have the fewest number of employees within each grouping, as per Table 4.4.

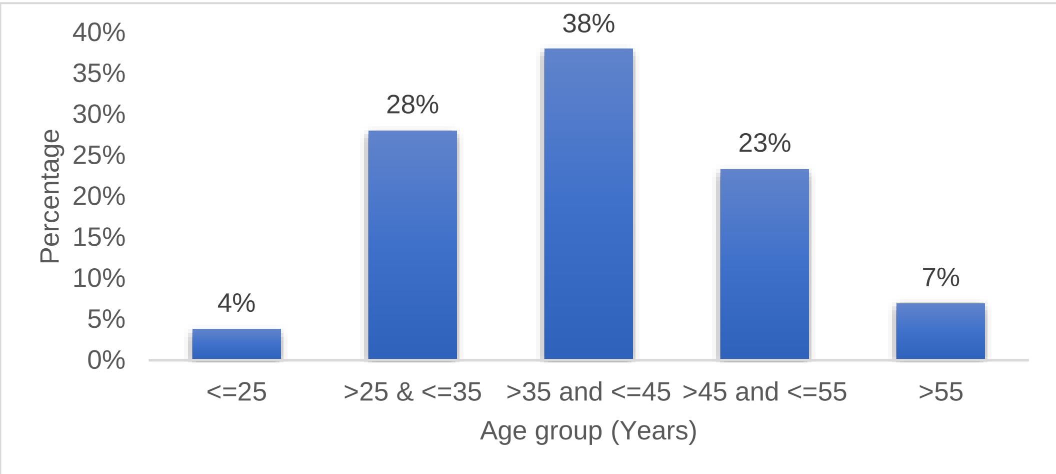

Figure 4.6 - Innovation by age expressed as % of total ideas registered

4.3.2 Participation vs gender

The total number of innovation entries was categorised according to gender. Table 4.5 provides a summary of the results produced.

Table 4.5 - Innovations registered per gender

Gender	Total Employees in Category	Percent Participation of Category	Percent Non-participation in Category
Female	912	21%	79%
Male	2532	23%	77%
Total	**3444**	**22%**	**78%**

Innovation participation in the VIP corporate innovation program represented 22% of the employee workforce, meaning nearly 1 idea registered per 4 employees over the course of the year.

Gender participation per category revealed a slight bias towards male participation, as can be seen in Figure 4.7.

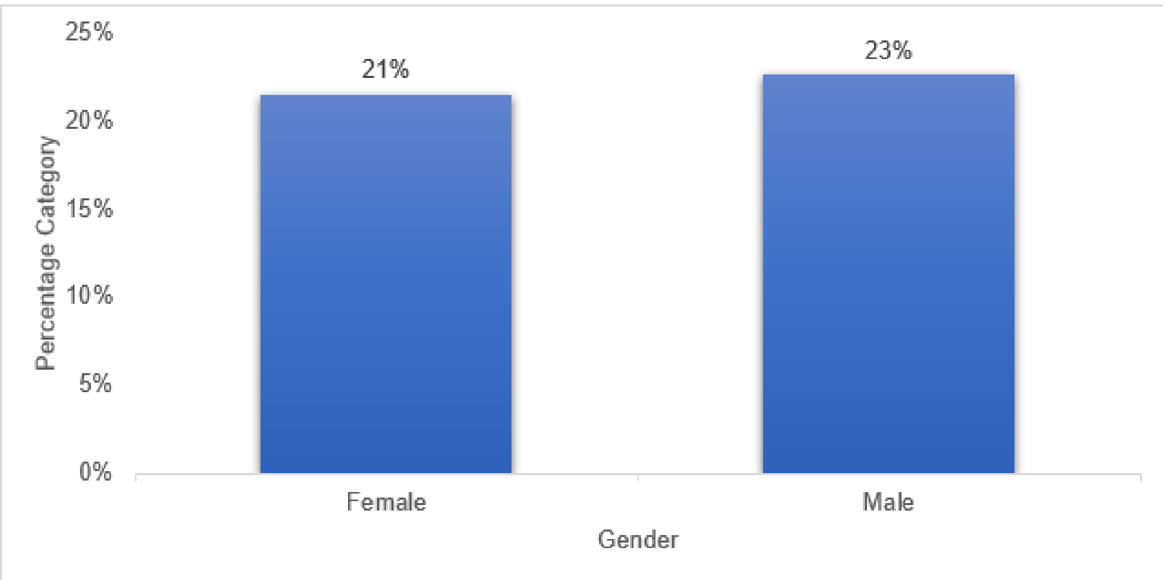

Figure 4.7 - Innovation registered by gender expressed as % participation within each category

Gender participation as a percentage of total ideas registered reflects a major bias toward male innovations, in the ratio of 74% vs 26%. This is in accordance with the fact that there are more males employed on the mine than females, as per Table 4.5. The percentage of total innovations registered per gender is reflected in Figure 4.8 below.

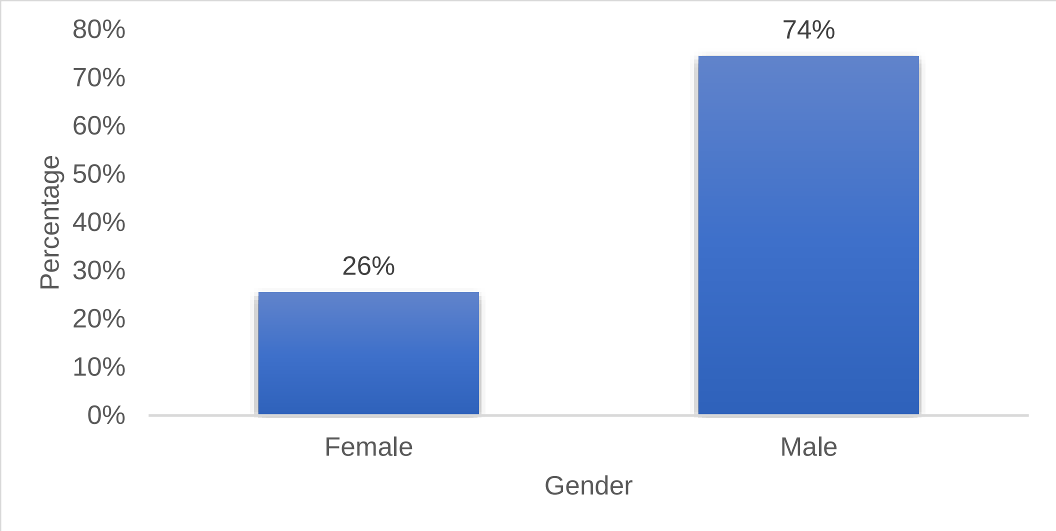

Figure 4.8 - Innovation registered by gender expressed as % of total participation

4.3.3 Participation vs years of service

Table 4.6 gives a summary of the total number of innovation entries categorised according to five groupings, descriptive of the number of years of service.

Table 4.6 - Innovations registered per years of service

Years of Service	Total Employees in Category	Participation as a Percent of Category	Percent Non-participation in Category
≤ 5	1501	17%	83%
5 < service ≤ 10	555	28%	72%
10 < service ≤ 15	601	24%	76%
15 < service ≤ 20	483	32%	68%
> 20	304	19%	81%
Total	**3444**	**22%**	**78%**

It can be seen that 483 participants have between 15 and 20 years of service. This group had the highest level of representation in the program, at 32% participation. The average participation across all categories was 22%, while the newer employees (i.e., less than 5 years of service) registered the lowest level of representation at 17%, followed by the more than 20 years of service category at 19%.

4.3.4 Participation vs job grading

Innovation submissions by job grading was categorised as reflected in Table 4.7.

Table 4.7 - Innovations registered per job grading

Job Grading	Total Participation (12 months)	Participation as a Percent of Category	Percent Non-participation in Category
Student	47	12%	88%
B Band	192	13%	87%
Lower C Band	156	18%	82%
Upper C Band	223	48%	52%
Lower D Band	123	78%	22%
Upper D Band	24	41%	59%
E Band	3	27%	73%
Contractor	237	4%	96%

Three grading categories contributed most of the innovation activity during the first year. Upper C Band (Specialists and Supervisors) innovated at 48% of their respective category, Lower D Band (Superintendents) reflected 78% of their category, and Upper D Band (Managers) participated at 41% of their grading segment.

4.4 Q3: CATEGORISATION OF INNOVATION BY TYPE

This section considers data relevant to the third research question, 'What is the distribution of innovation by type, using a four-quadrant model?'. Shopfloor participation in the corporate innovation program was grouped by type of innovation, referencing the four-quadrant innovation matrix discussed in Section 2.3.5. The four types of innovation considered under this study were Incremental, Architectural, Radical, and Disruptive.

Using a 2-product table, whereby each innovation was ranked according to Market Impact and Technology Awareness, the sample population was categorised then as reported Table 4.8.

Table 4.8 - Classification of innovations by technology awareness and market impact

Innovation Category		Number of Inclusion Criteria Satisfied			
		Existing	New to Department	New to PMC	New to Industry
Market Impact	Negligible	431	163	33	5
	Minimal	226	134	5	0
	Significant	1	2	3	0
	Maximum	0	0	2	0
Total		**658**	**299**	**43**	**5**

This categorisation of technology awareness against market impact was then aligned with the four-quadrant innovation matrix in Table 4.9 as follows:

Table 4.9 - Four types of innovation using the four-quadrant model

Four-quadrant Innovation Model		Technology Awareness			
		Existing	New to Department	New to PMC	New to Industry
Market Impact	Negligible	Incremental Innovation (954)		Disruptive Innovation (43)	
	Minimal				
	Significant	Architectural Innovation (3)		Radical Innovation (5)	
	Maximum				

Table 4.9 shows that the majority (954 + 3 = 957) of innovation submissions represented technologies already known to the PMC business, even if the innovation was, in some instances, new to the specific department. Known technologies represent Incremental and Architectural types of innovation.

Almost all entries (954 + 43 = 997) were categorised as having low market impact. Low impact on the market represents Incremental and Disruptive innovation types.

The sample population could therefore be divided into the four types of innovation as per the following two-way Table 4.10.

Table 4.10 - Innovation participation by type

Innovation Type	Total in Category	Percentage in Category
Incremental	954	94.9%
Architectural	3	0.3%
Disruptive	43	4.3%
Radical	5	0.5%
Total	**1005**	**100%**

Of the 1005 submissions, 954 or 94.9% represented the Incremental innovation category, with Disruptive innovation the next most frequent type of submission received. Architectural and Radical innovation categories had the lowest representation, at 0.3% and 0.5% respectively.

4.5 Q4: CATEGORY OF INNOVATION BY TRAJECTORY

Let us now look at the data from the point of view of the fourth research question, ‘What is the distribution of innovation by trajectory, using a four-domain model?’.

Participation in the corporate innovation program was grouped by trajectory of innovation (i.e., intended target) as per the model of innovation trajectory developed in-house for PMC. The four innovation trajectories that were considered under this study were External, Internal, Production, and Product, each defined as:

- **External Innovation Trajectory** - community, stakeholder, social security & reputational interventions that take place outside of the mine’s gates
- **Internal Innovation Trajectory** - the workplace, people, safety, health, facilities, and culture within the workplace
- **Production Innovation Trajectory** - equipment, processes, controls, methods, cost savings, parameters that directly impact mine production
- **Product Innovation Trajectory** - end users, packaging, logistics, market penetration, branding

The sample population could therefore be categorised into the four innovation trajectories as per Table 4.11 below.

Table 4.11 - Innovation participation by trajectory

	Innovation participation per category	
Innovation Trajectory	Total number	Percent contribution
External	9	1%
Internal	764	76%
Production	226	22%
Product	6	1%
Total	**1005**	**100%**

One notes that the majority of innovations were aimed at the Internal work environment (76%), with the Production environment at 22% being the second highest trajectory. External and Product environments each received less than 1 % of the total submissions.

4.6 Q5: RETURN ON INVESTMENT

Return on investment, or value improvement, for each innovation recorded in this study was considered first in terms of commercial return and secondly by categorisation of intangible (soft) benefits. Here, intangible benefits refer to people, culture, safety, health, environmental waste, maintenance approach, operations approach, amongst others.

4.6.1 Tangible return on innovation investment (ROII)

Tangible ROII was ascribed to the best innovations for each of the six challenges, which had a definable financial impact on the business. Business cases for individual innovations were then developed by the Business Value Planning department of PMC, which provided independence. Calculation of business return on investment was outside of the scope of this study. The standard procedure involved calculating the potential revenue generation over a 12-month period using market indices prevailing at the time and subtracting the once off cost to implement the idea, along with any recurring monthly or annual costs as a result of implementation. Revenue was typically calculated using the production hours gained / saved, multiplied by the production rate, the head grade, the recovery percentage and the market price of the relevant commodity. Commercial ROII was calculated for a total of 16 innovations, with the net return on investment categorised in Table 4.12.

Table 4.12 - Number of tangible returns on investment from shopfloor innovation by months and monetary value

Month	Measured Value (in thousands of ZAR)					
	<100	<250	<1,000	<5,000	<10,000	>10,000
1-2	0	0	2	0	0	1
3.4	1	0	2	2	1	0
5-6	0	0	1	0	0	1
7-8	0	1	0	0	1	0
9-10	1	0	0	0	0	1
10-12	0	0	0	1	0	0
Total 12 months	**2**	**1**	**5**	**3**	**2**	**3**

The best implemented innovations during the first year of the program included 16 innovations with tangible financial returns on investment. Of the 16, three (3) innovations reflected a return of more than ZAR10 million (ZAR10m) per calendar year, and thirteen (13) were deemed to contribute more than ZAR1m per calendar year. Note that ZAR stands for the South African Rand.

The best innovations with tangible ROII are listed below. Posters of each innovation are included in Appendix 4.

- ✓ Conversion of obsolete copper milling circuit to magnetite regrind
- ✓ Optimisation of the flotation plant through a new collector reagent
- ✓ In-house engine conversion from BF4M1013EC to BF41013

- ✓ New method to replace the service winder counterweights guide ropes
- ✓ Optimisation of anode moulds
- ✓ Improvement on the push-plate feeders of Crushers 1, 3, and 4
- ✓ Improvement of the life span of impeller blades by modification of wear resistance protection
- ✓ In-house development and utilisation of a pumping system simulation tool
- ✓ Baryte density measurement for improved control of anode mould spraying
- ✓ In-house labour and resources for roofing construction
- ✓ Install Y-piece on overflow line to enable both pumps to feed cleaner at the magnetic separator plant
- ✓ New water car gooseneck
- ✓ Emulsion waste reduction
- ✓ New method to use a spreader beam to lift head ropes from the winder drum
- ✓ Move the sync switches in the production shaft to improve maintenance
- ✓ Batch plant bag pallet implementation to reduce wastage

4.6.2 Intangible return on innovation investment

Intangible return on innovation investment (ROII) was ascribed to the best innovations for each of the six challenges, which were considered to provide secondary, or intangible benefit, without yielding a definable financial impact that could be ascertained via a commercial return on investment.

The VIP corporate innovation program assigned innovations with intangible value to seven categories as:

- Safety & Health (S&H)

- People & Culture (P&C
- Community & Stakeholders (C&S)
- Maintenance Approach (MA)
- Operations Approach (OA)
- Communications & Decision Making (C&D)
- Environment & Waste (E&W)

An analysis of intangible value addition by category is reflected in Table 4.13.

Table 4.13 - Intangible return on investment from shopfloor innovation

Month	Intangible Benefit						
	S&H	P&C	C&S	MA	OA	C&D	E&W
1-2	1	0	0	2	2	2	0
3.4	2	0	0	1	2	0	1
5-6	1	1	0	3	4	0	0
7-8	2	0	0	2	3	1	0
9-10	1	0	0	0	1	0	0
10-12	4	0	0	0	3	0	0
Total 12 months	11	1	0	7	15	3	1
% 12 months	**28.9%**	**2.6%**	**0.0%**	**18.4%**	**39.5%**	**7.9%**	**2.6%**

Intangible benefit listed as Operational Approach (39.5%) was the most frequent non-attributable impact, followed by Safety and Health (28.9%) and Maintenance Approach (18.4%) as per the following chart. There were no implemented submissions in the top 10 of each campaign, yielding a Community and Stakeholder impact.

4.7 SUMMARISED FINDINGS

This section summarises the critical findings identified through the data analysis presented in Chapter 4. Key results are organised and evaluated in relation to the five research questions described in Chapter 3.

4.7.1 Question 1: What is the rate of shopfloor innovation?

A total of 1005 submissions was received in the first 12 months of the VIP corporate innovation program, representing an average of 83.75 innovation entries per month. 112 or (11 %) of all innovation submissions were implemented during the 12-month period considered for this study, while 713 (71%) were ideas that had not been implemented. A total of 826 (82%) of submissions conformed to the program criteria.

The rate of participation in the program, measured by innovations registered as a percentage of the workforce, was 22% or just over 1 idea submitted for every 5 employees.

Pre- and post-roadshow survey results confirmed that the face-to-face interactions were effective in improving engagement in respect of the corporate innovation program. A positive relationship between the number of roadshows performed and the rate of idea submissions was established.

4.7.2 Question 2: How does employee participation differ by demographic?

The > 35 to ≤ 45 age category had the highest level of representation at 26% of the category. Average participation was 22%. The ≤ 25 years age category had the lowest level of representation in the program, at 10% participation.

The rate of gender participation in the program, measured by innovations registered, revealed a slight bias towards female participation, with females at 23% and males at 21% representation.

The > 15 to ≤ 20 years of service category had the highest level of representation in the program, at 32% participation. The ≤ 5 years of service category had the lowest level of representation at 17%, when measured by innovations registered.

Three Paterson grading categories contributed the majority of innovation activity: Upper C Band (Specialists and Supervisors), Lower D Band (Superintendents), and Upper D Band (Managers). Contractors, students, and B Band employees had the lowest representation.

4.7.3 Question 3: What is the distribution of innovation by type, using a four-quadrant model?

Shopfloor participation in the corporate innovation program was successfully grouped by type of innovation, referencing the four-quadrant innovation matrix discussed in Chapter 2.

Of the 1005 submissions, 954 or 94.9% represented the Incremental innovation category, with Disruptive innovation (4.3%) the next most frequent type of submission received. Architectural and Radical innovation categories had the lowest representation, at 0.3% and 0.5% respectively.

4.7.4 Question 4: What is the distribution of innovation by trajectory, using a four-domain model?

Innovation by trajectory or target domain was categorised using a researcher-defined model. Most innovations were aimed at the Internal work environment (76%), with the Production environment at 22% being the second highest trajectory. External and Product environments each received less than 1 % of the total submissions.

4.7.5 Question 5: What is the return on innovation investment?

Return on investment, or value improvement for each innovation recorded in this study, was considered first in terms of commercial return and secondly by categorisation of intangible (soft) benefits.

The best implemented innovations during the first year of the program included 16 innovations with tangible financial returns on investment. Of the 16, three (3) innovations reflected a return of > R10m per calendar year, and thirteen (13) were deemed to contribute > R1m per calendar year.

An analysis of intangible value addition by category showed that Operational Approach (39.5%) was the most frequent non-attributable impact, followed by Safety and Health (28.9%) and Maintenance Approach (18.4%).

CHAPTER 5 – DISCUSSION OF INNOVATION PARTICIPATION AT PALABORA MINING COMPANY

5.1 INTRODUCTION

Chapter 5 provides a discussion of pertinent findings revealed by the data analysis done in the previous chapter. Where applicable, findings are interpreted within the context of existing literature on innovation as referenced in Chapter 2.

In this Chapter, results from Chapter 4 are contextualised in relation to the research problem, outlined in Chapter 1 as 'How can a mining company use data to measure, manage, and promote shopfloor innovation in order to fundamentally improve business performance?'. The chronology of this interpretation follows the five research questions that underpinned this study.

This interpretation of results also explains whether the patterns and relationships identified in Chapter 4 met with the researcher's expectations. Possible alternatives for unexpected results are considered.

5.2 Discussion by Research Question

5.2.1 Research Question 1: Rate of Shopfloor Innovation

Valacchi et al. (2023) argued that for measurement of innovation to take place, a clear definition of innovation is of critical importance. This includes the qualifiers and disqualifiers of a particular innovation program.

In Chapter 3, Section 3.4.3 of this research study, the definition of innovation and the related conformance test developed from the outset by the researcher were presented. These VIP Innovations were defined based on the VIP Operating Procedure (2024) from PMC. It should be recalled from the definition of VIP innovation that at least 3 of 5 defining questions had to be satisfied for an idea or submission to conform to program requirements. The five screening questions that had to be answered in the affirmative are discussed in Section 3.4.3 “Data Pre-processing and Exclusion Rules”, and also in Section 4.1 “DATA CLEANING AND PRESENTATION”.

Of the 1005 original submissions, 826 (82%) conformed to 3 or more of the defining criteria and were therefore considered ‘compliant’. This means that 18% of entries were non-compliant in terms of the definition discussed in Section 3.4.3. of Chapter 3.

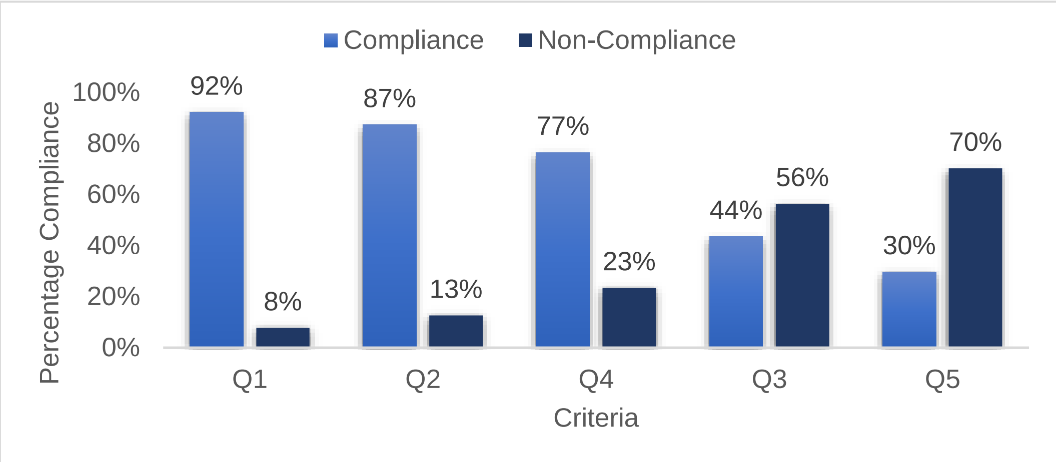

Figure 5.1 - Program compliance measured against the 5 ‘innovation’ defining criteria/questions

It can be noted in Figure 5.1 that the criterion with the lowest individual compliance (30%) was criterion #5 ‘Does the idea utilise what we already have?’ This criterion was answered in the negative for 70% of the total submissions.

Criterion #5 was originally included in the corporate innovation program definition to encourage employees to make better use of existing assets and resources on the mine. The program did not want to encourage employees to increase spending and simply ‘throw money at problems’. When looking at why this criterion had the lowest individual compliance, it is surmised that some employees attempted to use the VIP program as an alternative fund-raising mechanism to bypass constraints within the normal budget cycle. Examples of non-compliance to criterion #5 would be ‘we should buy more spares than are in the approved budget’ and ‘we should pay more bonuses to motivate employees more.’

Future engagement with employees and any further promotional material could reinforce the fact that the program seeks to emphasise innovations that make better use of existing assets and resources. This may improve conformance to criterion #5.

Criterion #3 - 'Is the idea new?' also scored relatively poorly against criteria #1, #2, and #4. Criterion #3 was included in the program to emphasise that innovation always implies something that is novel or new. In some instances, ideas were non-compliant to this criterion because the suggestion was simply to reintroduce a practice or technology that had already been used previously on the mine.

A total of 112 innovations out of the total 1005 (that is, 11%) were implemented during the 12-month period considered in this research. There appears, therefore, to be almost 10 times greater ability to identify innovative ideas than there is capacity to implement the same solutions. This observation is depicted in a funnel chart in Figure 5.2 showing the evolution from total submissions through to implemented innovations.

In the second year of the program, the business could potentially encourage implementation efforts over ideation. Data shows that approximately 11% of ideas were implemented, whereas a further 43% of unimplemented ideas were not only compliant with the program but also supported by line management. This additional 43% represents 434 ideas that can only add value to the business if they are implemented.

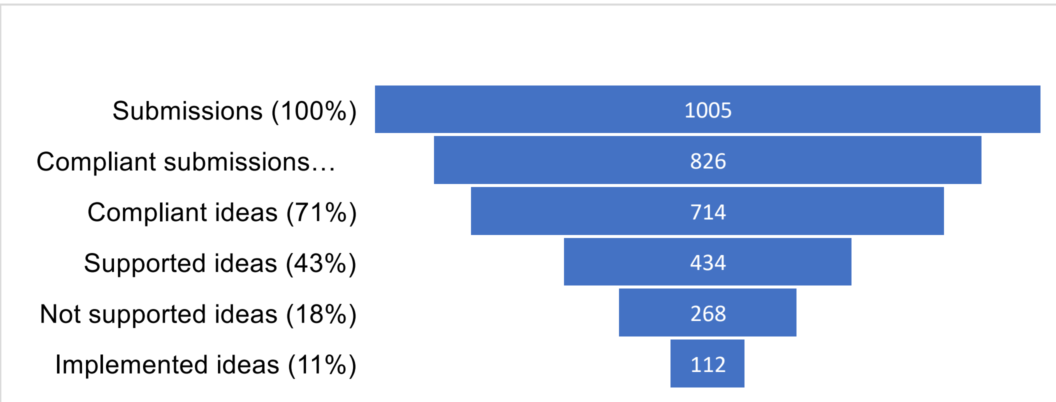

Figure 5.2 - Shortlisting process from total innovation submissions between September 2023 and August 2024 through to implemented ideas at PMC

Glaesner and Lang (2024) explained that one of the unique attributes of ‘innovation’ is that it is so difficult to measure and benchmark. However, using the approach adopted by the VIP program, Figure 5.2 reveals that the measurement of shopfloor innovation on the Palabora mine was both possible and practical.

The high rate of innovation observed in the mine appears to confirm available theories. Indeed, Reichert and O’Brien (2023) argued that the study of innovation in low-technology or primary industries remains underserviced. The two authors also identified a need to develop new metrics for capturing innovation in primary or low-medium-technology industries. Interestingly, the metrics used in this study to categorise the rate and demographics of innovation participation were used to successfully determine the rate of innovation participation, as reflected in Chapter 4. Similar metrics may be of application to other mines and/or organisations operating in the primary sector.

The first 12 months of the VIP Corporate Innovation Program have revealed a significant amount of previously untapped innovation potential coming from the shopfloor. The data generated in terms of rate of participation appears to have confirmed the assumption made in the original VIP policy statement: “Employees are deemed capable of innovation and able to identify improvement ideas and value propositions” (PMC Policy, 2023).

Participation in the corporate innovation program yielded the following approximate statistics over the 12 months that were reviewed:

- Overall participation rate ≈ 1 idea per 5 employees
- Overall participation frequency ≈ 20 ideas per calendar week
- Compliance with program requirements ≈ 8 in every 10 submissions
- Complaint ideas (not implemented) ≈ 7 in every 8 submissions
- Compliant ideas supported by line management ≈ 4 in every 10 submissions
- Implemented ideas ≈ 1 in every 10 submissions

The innovation response indicated by the above figures demonstrated a sustainable flow of idea submissions, which is well in excess of the program's original expectations.

Rate of participation data from the first 12 months of the VIP corporate innovation suggests an opportunity for the business to continue with the program since it appears to have addressed one of the key challenges outlined in the original policy as "our systems and structures are not optimised for implementation, and we lack implementation skills leading to fewer of our ideas and value propositions being successfully implemented" (PMC Policy, 2023).

Data from the VIP corporate innovation program appears to reveal a significant amount of innovation activity that would not be reflected on traditional metrics such as 'patent applications', 'number of new products released to market', and 'R&D expenditure'. As Reichert and O'Brien (2023) have argued, there is a knowledge gap in the study of innovation in primary industries; hence, there may be an opportunity to further research rates of innovation participation at other mines.

5.2.2 Research Question 2: Employee Participation by Demographic?

5.2.2.1 Participation by age grouping

The age group corresponding to the 35 – 45 years old had the highest level of representation at 26% of the category as reflected in Section 4.3.1. of Chapter 4. The under-25-year-olds registered the lowest level of representation in the program, at 10% participation. Average participation for all age groups was 22%.

When considering the results in Figure 5.3, it stands out that a single age category was anomalous to the others, i.e. the ≤ 25 years age category, which had less than half the participation of other age categories.

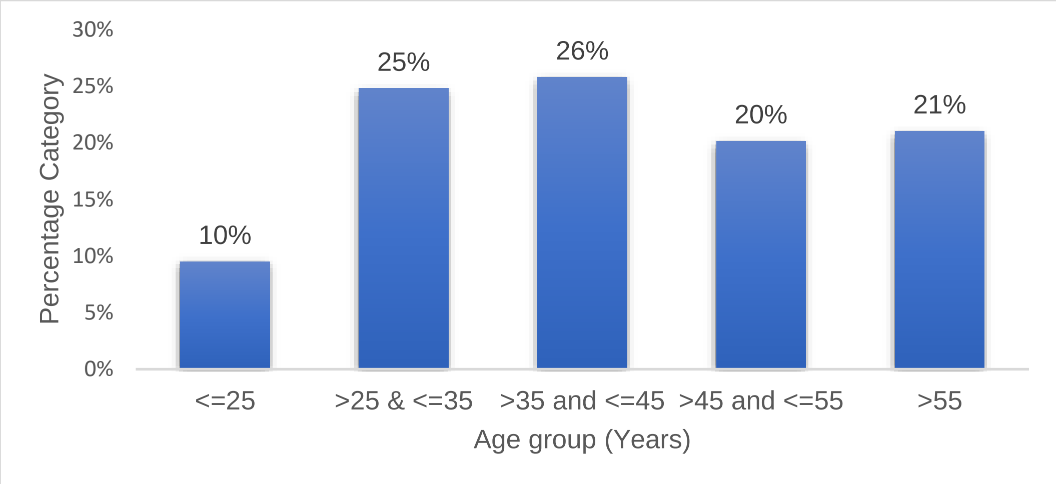

Figure 5.3 - Innovations registered at PMC by age group, expressed as a % of each age category’s participation

Simonton (2020) described a typical age curve that specifies how creative output evolves over time. He explained that the investigation into age-related productivity was one of the most mature social sciences, with the first study having been published in 1835. Simonton (2020) also asserted that creative output is likely to start around the mid-20s and increase quickly until a maximum output is reached in the late 30s or early 40s. Afterwards, creative output would gradually reduce until the age of 70, at which time innovative creativity is approximately half of what it was at its peak.

McQuillian (2019) confirms this assertion, noting that creative accomplishments tend to peak between the late 30s and early 40s. The findings at PMC are therefore in line with the existing literature. Indeed, Figure 5.3 shows that the highest creative output corresponds to the age group between 35 and 45 years old, thereby supporting the existing age-productivity theory.

Based on the above findings, there is potential for further promotional material and future two-monthly challenges during the second year of the innovation program to be aimed at the younger generation (< 25 years old), which appears to be under-represented. Social media could be leveraged, since these employees may be more digitally oriented and hence not as easily reached through traditional promotional mediums. It is also possible that the low participation of this grouping reflects the fact that some are still ‘trying to find their feet’ within the organisation.

5.2.2.2 Participation by gender

Gender participation, as a percentage of total ideas submitted, was approximately 3:1 in favour of males as indicated in Figure 4.8 of section 4.3.2. There are simply more male employees than female at the present time.

When measured as a percentage of their respective categories, the results only demonstrated a minor bias towards male participation, with females at 21% being slightly lower than males at 23%. This may imply that the program was equally successful at engaging both genders.

Baer and Kaufman (2008) observed that creativity test scores between girls and boys consistently showed a lack of gender difference. Genders also performed similarly on creative accomplishment. The authors argued that it was difficult to explain the later differences in creative output between women and men, whereby adult men consistently reflected a higher output. Furthermore, Travers (2022) reviewed new research in the Journal of Applied Psychology to provide additional context to the controversial question of gender differences in creative potential. According to the author, from an empirical standpoint, men and women are equally creative, even though a public perception exists that men may be more creative than women. Fortunately, there is evidence that this stereotype (men are more creative than women) is eroding in recent times, especially in countries that have more gender equality.

There may be an opportunity for future research to further analyse the patterns of gender innovation participation by determining whether there is any difference in the distribution of innovation by (i) type and (ii) trajectory between males and females.

5.2.2.3 Participation by years of service

The > 15 to ≤ 20 years of service category had the highest level of representation in the program, at 32% participation when expressed as a percentage of the category, as demonstrated in Section 4.3.1.3 of Chapter 4. This implies that 68% of employees in the same category did not participate in the program. The ≤ 5 years of service category had the lowest level of representation at 17%, as shown Figure 5.4 below.

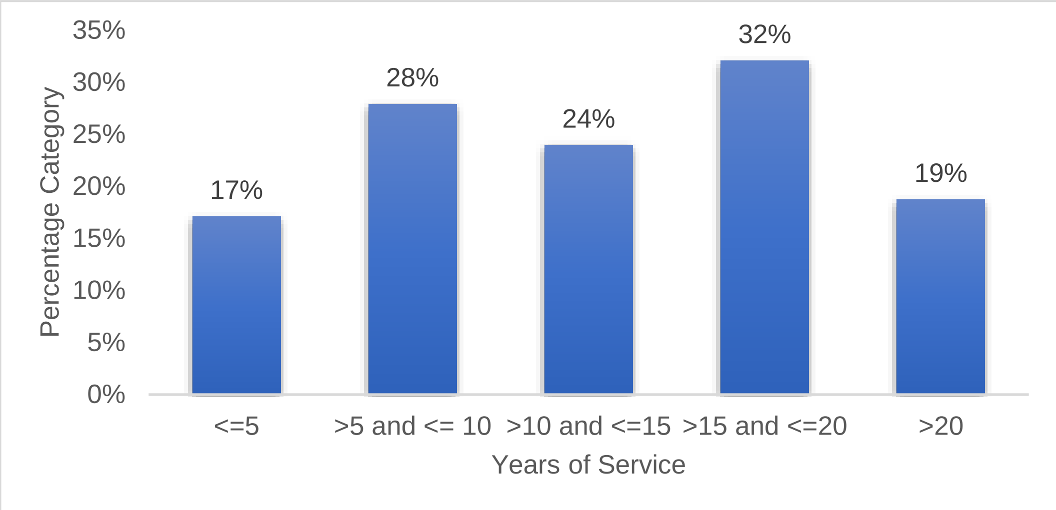

Figure 5.4 - Innovation participation registered as a percentage of category (years of service)

Parsons (2015) noted that older employees, in the maintenance or decline stages of their careers, were likely to focus more on stability and job preservation than younger employees, who may have a greater appetite for innovative reward when compared to their aversion to failure. His work appears to be confirmed in the study results due to the fact that there is a clear drop-off in innovation participation with increasing years of service beyond 20 years.

The decline in participation for the > 20 years of service category was more pronounced than the equivalent rate of decline for the > 55 years of age category as described in Section 4.3.1 of Chapter 4. It would therefore appear from the data as if the decline in participation beyond 20 years of continuous service, may have as much to do with a sense of comfort and complacency than an age-specific related decline.

Participation increased with increasing period of service until a peak between 15 and 20 years of service. Employees at the beginning and end of their work careers (less than 5 years of service and greater than 20 years of service) are less engaged in innovation than employees in the middle of their careers. There may be an opportunity for future promotional efforts to target those employees at the beginning and end of their careers in order to ensure a more equal participation by years of service is realised.

There appears to be an opportunity for future research to benchmark the profile of years of service participation against other mining organisations to evaluate differences across sub-sectors within the mining industry. Benchmarking could also be undertaken against other primary industries which are also resource-intensive, such as agriculture, forestry, and fishing.

5.2.2.4 Participation by job grading

Three Paterson grading categories contributed to the majority of innovation activity: Upper C Band (Specialists and Supervisors), Lower D Band (Superintendents), and Upper D Band (Managers). This distribution, which reflects participation as a percentage of the category, is depicted in Figure 5.5.

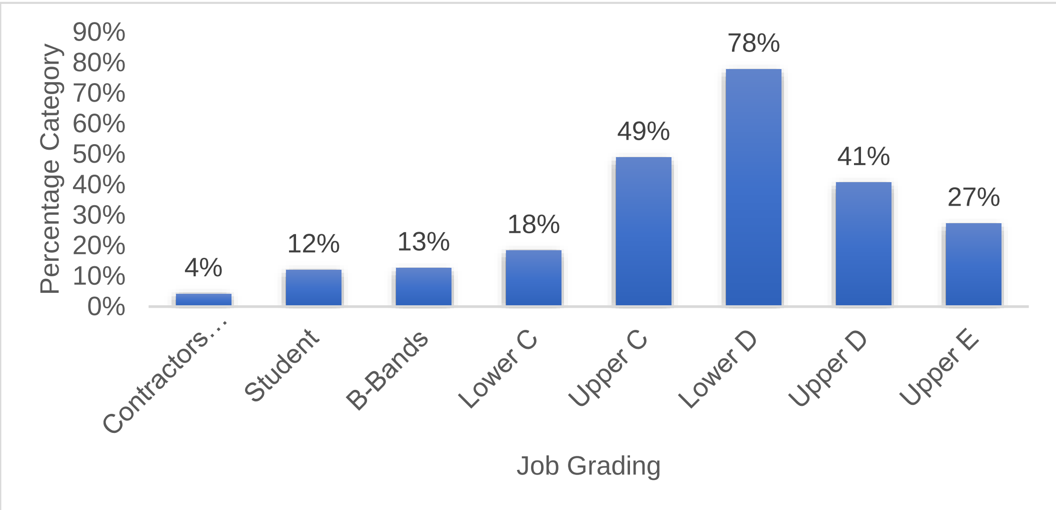

Figure 5.5 - Innovation participation as a percentage of job grading category

This researcher was unable to identify clear correlation between job grading and work innovation in the literature; however, there are a number of studies that reference job complexity and job demands as a function of creativity in the workplace. Hernaus et al. (2024) demonstrated that job demand and job complexity, which may be considered as a proxy for job grading, are not a determining factor in discretionary innovative work behaviour.

The findings on job grade participation observed within this study are not consistent with Hernaus et al. (2024). In my study, participation was biased in favour of supervisory and management grades, with semi- and unskilled labour being relatively underrepresented.

One explanation for this trend in the VIP study could be the fact that supervisors and management have better access to electronic media and, therefore, find it more convenient to submit an idea electronically from their own desk as opposed to submitting an idea in person at the VIP contact centre.

A second explanation could relate to program awareness, whereby there could be a lack of effective communication down to the ground floor (mushroom effect), and as a result, junior job grades simply had lower exposure to promotional material, hence lower program awareness.

There may be benefit in focussing further promotional efforts on those employees and contractors who lack access to their own personal computers. Supplementing two monthly challenge adverts with face-to-face visits at morning line-ups could also improve the response pattern of junior employees.

5.2.3 Research Question 3: Distribution of Innovation by Type

Of the 1005 submissions, 954 (94.9%) represented the Incremental innovation category, with Disruptive innovation (4.3%) the next most frequent type of submission received. Architectural and Radical innovation categories had the lowest representation, at 0.3% and 0.5% respectively, as demonstrated in Section 4.4 of Chapter 4. These categories of innovation follow the four-quadrant model discussed in Section 2.3.5 of Chapter 2.

Innovation at PMC as a function of technology awareness is illustrated in Figure 5.6. One can see that almost two-thirds of innovation submissions represented technologies already known to the PMC business, even if the innovation was, in some instances, new to the specific department. This was reflected in Table 4.8 of Chapter 4.

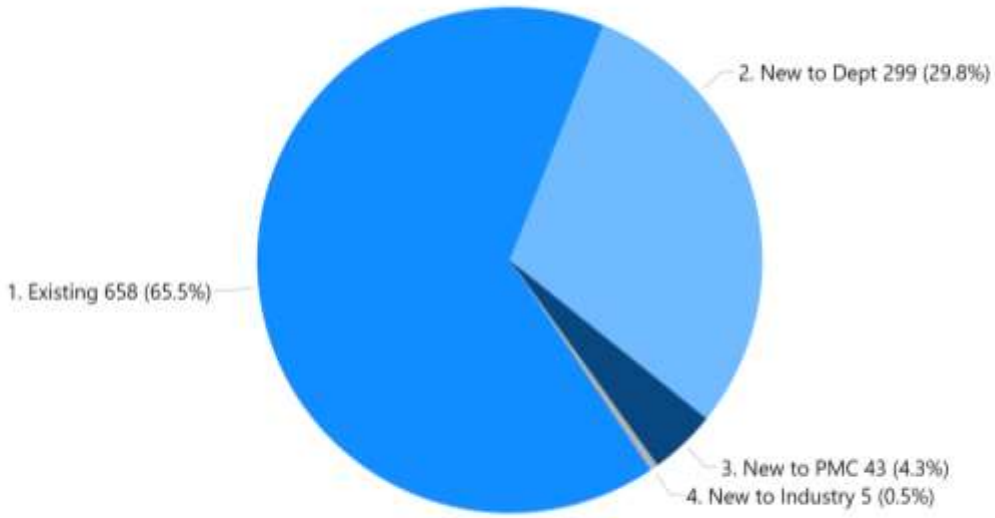

Figure 5.6 - Innovation as a function of technology awareness

Incremental innovation followed by Disruptive innovation were the most frequent types of submission received, as illustrated in Figure 5.7.

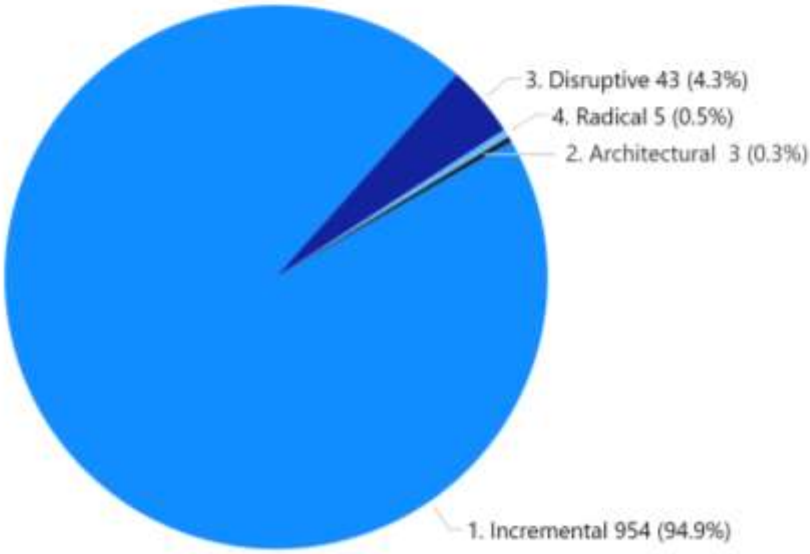

Figure 5.7 - Innovation distribution by type

More than 9 in every 10 innovation submissions represented Incremental innovation, where known technology is applied within an existing market.

It seems clear that radical and architectural innovation types, which may be well represented in the formal research and development environment, occur rarely at the shopfloor level. This is possibly a function of the fact that many shopfloor employees lack tertiary education and also, they are not exposed to research opportunities in their day-to-day production-oriented scopes of work. If these employees are 'learning by using' and 'learning by doing', then it fits that most of their innovations will revolve around existing technologies they have already had exposure to.

Innovation participation that involves existing technologies may not be as exciting or glamorous as radical innovation activities; however, they should still be valued and encouraged as much as any other innovation type.

There may be an opportunity for future research to maximise the impact of incremental shopfloor innovation, potentially by enhancing the ideation process to custom-fit this category.

5.2.4 Research Question 4: Distribution of Innovation by Trajectory

In Section 4.5 of Chapter 4, innovation by category was discussed. Trajectory may be thought of as the target domain in which the improvement is sought. Starting from outside the mine gate (External), the domains move to the workplace inside the mine (Internal), to the operations and maintenance activities (Production), and finally to the final product and its distribution (Product) domain.

Most innovations were aimed at the Internal work environment (76%), with the Production environment at 22% being the second highest trajectory. External and Product environments each received less than 1% of the total submissions, as shown in Figure 5.8.

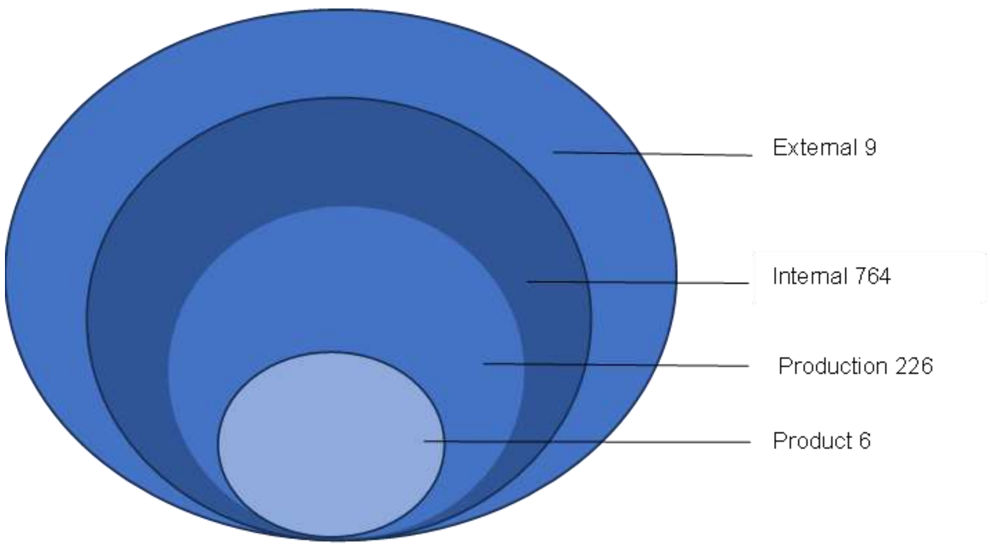

Figure 5.8 - Distribution of innovation participation by trajectory

The Internal innovation trajectory, which represents the workplace, people, safety, health, facilities, and culture, received more than 75% of the submissions by trajectory. This implies that shopfloor workers are most interested in improving work conditions. This may be a function of the fact that shopfloor workers are exposed to a narrow subset of the entire business, for example, their own workshop or their own section of a process plant. It is possible that the trajectory of a sales-oriented distribution company would show a much higher focus on the final product and its distribution.

Primary industries like mines are output- or production-focused. It is therefore not surprising that the Production innovation trajectory (equipment, processes, controls, methods, cost savings, parameters that directly impact mine production) also received relatively strong attention at 22%. This shows that workers are not only interested in improving their immediate working conditions, but they are also seeking to participate in innovation that can improve the operating performance of the business.

The Internal and Product innovation categories used in this study both conform to the description of 'process innovations' by Dorin (2018). This description indicates that process-related innovation is generally the dominant trajectory or intended target in a production-focused business like PMC.

Future research could explore the relationship between job grading and innovation trajectory. For example, it may be hypothesised that junior employees are more likely to focus on their immediate working conditions (internal innovation environment). On the other hand, senior employees may be more likely to focus on product and production environments because this is where most business KPI's are located.

5.2.5 Research Question 5: Return on Innovation Investment experienced at PMC

This section considers data relevant to the fifth research question 'What is the return on investment?'. Kolk and Eager (2014) highlighted the fact that a simple question such as 'how much return is the company getting on the total investment in innovation?' can be very difficult to answer. They explain that in theory, the approach sounds straightforward – work out how much was spent on innovation and compare it to the value derived based on net present value, internal rate of return, or another financial metric. However, the practice of measuring value added through innovation is extremely complex. The authors point out that standard economic metrics fail to consider benefits which are difficult to quantify, such as enhanced reputation, improved ergonomics, or improved customer satisfaction.

The nature of innovation investment returns may further vary according to whether the innovation is aimed at the business processes, the service provided, or the product quality (Kolk and Eager, 2014).

There were several practical considerations to consider when it came to assigning value to shopfloor ideas in this study. The first consideration was the fact that many ideas and suggestions pertained to workplace improvements that were not tangible in terms of direct financial impact or business case. For example, innovations that improved health and safety, or employee morale, may contribute a long-term impact on business performance that could not be quantified through the development of a commercial business case.

The second consideration was the fact that numerous ideas that were submitted through the program had not been implemented at the time of submission and were also not implemented during the period under review. Value improvement in the business was only assigned to those ideas that were implemented in the workplace.

The third consideration was the time and effort required to build accurate business cases for the hundreds of innovation submissions that were submitted in each two monthly challenges. In view of the practical constraints of developing an independently verified business case around specific innovations, the VIP program elected to develop business cases around the top implemented ideas per campaign only.

5.2.5.1 Tangible return on innovation investment (ROII)

It is time-consuming and potentially subjective to perform hundreds of business analyses on submitted innovations. In this study, the top implemented ideas were analysed. Business cases were then developed for those innovations demonstrating a clear and measurable commercial benefit. Independent business case analysis was thus performed for the top 16 tangible returning innovations, with results shown in Figure 5.9 below.

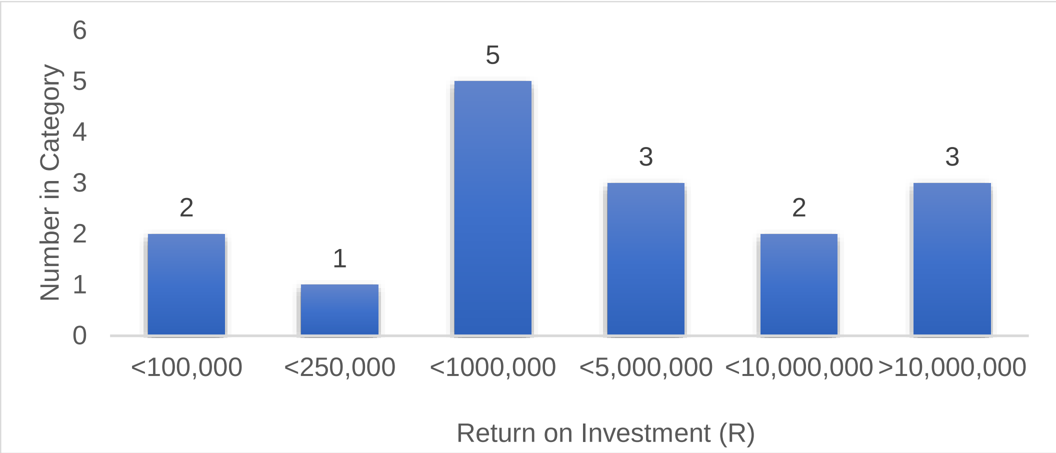

Figure 5.9 - Tangible (commercial) return on innovation investment of the top ideas implemented at PMC

Figure 5.9 highlights that a significant number of innovations (13) yielded ROII above ZAR1,000,000 (i.e., ZAR1m). This is a return of more than 1 shopfloor innovation per month with a business impact of more than ZAR1m.

Of the three innovations that reflected more than ZAR10,000,000 ROII, some had such a high potential business impact as to be measured in the hundreds of millions. When a single implemented idea makes such a major commercial contribution, it is considered unlikely that the idea in isolation could produce such outcomes. In other words, an innovation reflecting more than ZAR100,000,000 ROII was almost certainly dependent on several other business changes and implemented innovations for the full benefit to be realised. The analysis of commercial benefits in this study, therefore reflected these ideas as having an impact greater than ZAR10,000,000 without specifying an upper limit.

The VIP corporate innovation program was able to elicit more than 1000 business improvement ideas from the shopfloor in its first year of existence. Even though a limited number of commercial business cases (16) were evaluated, more than 1 shopfloor innovation per month, with business impact after costs, of more than R1,000,000, was realised.

It is possible that the relatively low number of lower-value innovations <R100,000 and >R100,000 <R250,000 reflected in the data is a function of the fact that independent business cases are time-consuming and sometimes difficult to

quantify. For practical reasons, the development of business cases was limited to an analysis of those ideas that seemed likely to have the greatest impact on commercial results.

Acknowledging that it can be time-consuming and potentially subjective to perform business analyses on innovations, the practice of analysing the best implemented innovations should be continued. Without Return on Innovation Investment (ROII) statistics, it would be difficult to benchmark or even to demonstrate the value improvement realised by the corporate innovation program.

5.2.5.2 Intangible return on innovation investment (ROII)

The VIP corporate innovation program assigned innovations with intangible value to seven categories as described in section 4.6.2 of chapter 4.

There were no implemented submissions in the top innovations of each campaign, yielding a Community & Stakeholder impact. Secondary benefits listed as Operational Approach were the most frequent non-attributable impact, followed by Safety & Health and Maintenance Approach, as evidenced in Figure 5.10

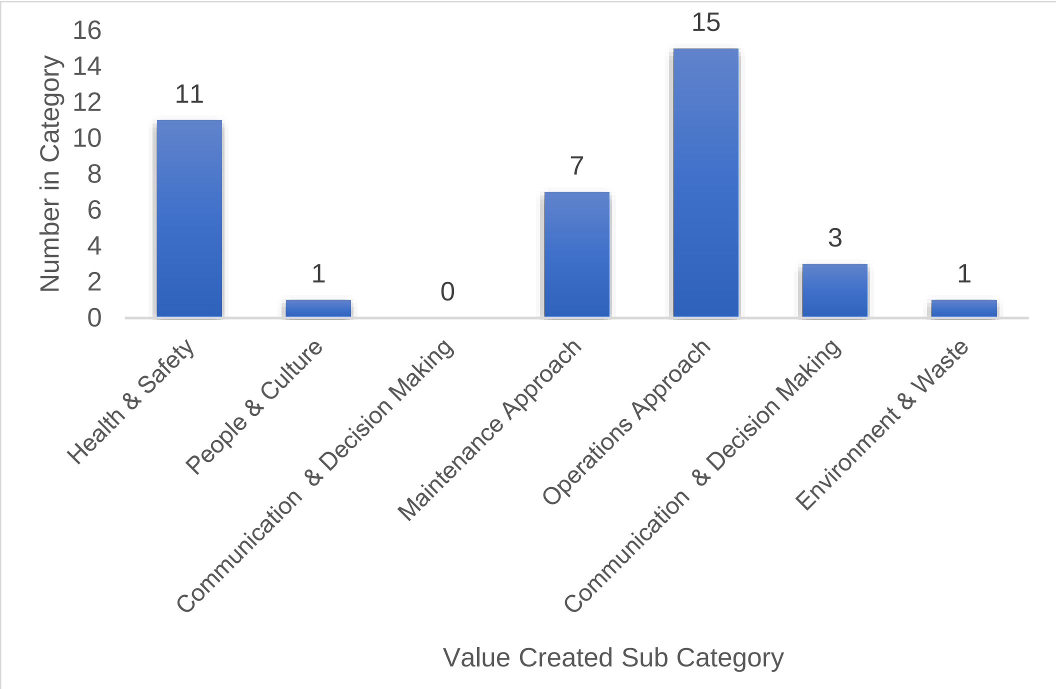

Figure 5.10 - Intangible (non-commercial) return on innovation investment of the Top 60 ideas implemented at PMC

Most employees and contractors working in the primary sector in an operational mine would likely be engaged with producing the final product and/or maintaining the equipment needed to do so. Since mining is a hazardous industry, it also seems natural that Safety & Health innovations would occur in a high proportion. For this reason, there are no surprises that the majority of intangible benefits focus on these 3 domains.

It is possible that for a business providing a tertiary service, intangible benefits would likely show more emphasis on Community & Stakeholders, People & Culture, and/or Environment & Waste. In other words, the distribution could possibly be reversed in a service-oriented company.

Employees focus slightly more on production improvement than on safety and health. This could imply that safety and health are already well managed on the mine. Alternatively, it could reflect the fact that employees' production bonuses are dependent on achieving operational targets, hence the focus in this area.

5.3 IMPLICATIONS & SIGNIFICANCE OF THE FINDINGS

The aim of this research was to measure and categorise employee participation in a value-improving innovation program within the South African mining industry so that the management of innovation can be improved. The implications of effective innovation management for PMC, and in fact for any business, are profound since "An organisation's ability to innovate is recognised as a key factor for sustained growth, economic viability, increased well-being and the development of society" (SABS, 2020).

This research addressed several important characteristics in relation to employee innovation in the South African mining industry using the corporate innovation program at PMC's VIP Division as a case study. Sufficient data was obtained to draw conclusions in respect of (i) rates of shopfloor innovation, (ii) participation by demographic, (iii) type of innovation, (iv) trajectory of innovation, and (v) return on innovation investment (ROII).

A combination of Historical, Descriptive, and Correlational Research Design was selected for this study. Although the research methods used in this study were not novel, they were combined in ways that had not been performed previously, and they were applied to a field that has limited historical literature.

The results provide a new insight into the management of innovation on a South African mine, and potentially within other resource-dependent organisations operating in the primary industry. The results complement existing creativity vs. demographic literature and build on innovation theory in an understudied sector.

In respect of both the types and trajectories of innovation activity, the data contributes a clearer understanding of how and why employees seek to improve not only their working environment, but also the performance of the organisation they belong to.

The research provides a new insight into the return on innovation investment when calculated, using both tangible (commercial) and intangible (soft) benefits.

The results could be considered when planning or launching a corporate innovation program. While previous research has focussed on traditional innovation metrics such as patent filings, new products to market, and expenditure on research & development (R&D), this research highlights a wealth of innovation activities at the shopfloor level that would otherwise ’fly under the radar’. The data shows that employees and contractors are ‘learning by doing’ and ‘learning by using’, and that creative output can thrive outside of the formal laboratory environment.

The study also uncovered aspects of shopfloor innovation management that could be addressed by future researchers, with opportunities for further study as follows:

- How does ideation (the process of generating, sharing, and evolving ideas) (ISO 56000:2020, 2020), drive creative output, and can formal management of the ideation process promote further innovation?
- How does ‘time to implement’ vary with differing types and trajectories of innovation?
- What is the role of line supervision in fostering innovation from the shopfloor?
- What is the ratio of shopfloor innovation to absorbed or adopted innovation via third-party technology providers?

If mining is to survive the current headwinds faced by the industry, it is imperative that our greatest asset (human capital) is actively engaged in constantly improving safety, working conditions, and business performance.

The promotion of innovation management in mines holds the potential to positively transform organisations. Research into shopfloor innovation, therefore, needs to be ongoing if the industry is to transform itself from within.

5.4 CONCLUSION

If mining is to survive the current headwinds faced by the industry, it is imperative that our greatest asset (human capital) is actively engaged in constantly improving safety, working conditions, and business performance. The promotion of innovation management in mines holds the potential to positively transform organisations. Research into shopfloor innovation, therefore, needs to be ongoing if the industry is to transform itself from within.

This chapter discussed the findings obtained from examining the first 12 months of data generated by PMC's VIP corporate innovation program.

The chapter began with a review of key findings contained in Chapter 4 – Categorical Analysis of Innovation Participation at PMC. Outcomes were considered in chronological order according to the 5 research questions posed in Chapter 3 – Methodology and Data Collection.

This was followed by a discussion of the research data, again in chronological sequence of the 5 research questions. In each instance, opportunities for the corporate innovation program and for further research were offered. The implications of this study and questions that could be answered through further research were examined.

CHAPTER 6 – CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The aim of this research was to measure and categorise employee participation in a value-improving innovation program within the South African mining industry. The Palabora mine was used as a case study with five research questions as discussed in Section 1.3.5.

The business objective was to use this data to develop commercially relevant recommendations for managing innovation at Palabora Copper Mine (PMC).

As such, an appropriate definition of innovation was developed for PMC along with a standardised set of criteria by which to measure, categorise, and analyse innovation participation across the value chain. Key findings are summarised, the relationship to previous research is discussed and recommendations for future research are listed in the next sections.

6.2 KEY OUTCOMES IN RELATION TO RESEARCH OBJECTIVES

Critical findings impacting on the research objectives are summarised.

6.2.1 Findings on the rate of innovation

The adoption of a program-specific definition of innovation with clear exclusion and inclusion criteria enabled the measurement of innovation at PMC. Response to the innovation program was higher than originally anticipated. Evidence was found of the existence of previously untapped innovation potential coming from the shopfloor. Indeed, a total of 1005 submissions were received in the first 12 months of the VIP corporate innovation program. This represented an average of 84 (more precisely 83.75) innovation entries per month. And of all innovations submitted, 112

(11 %) were implemented during the 12-month period considered for this study, while 713 (71%) were ideas that were yet to be implemented by the end of year, possibly due to resource limitations and competing production demands. A total of 826 (i.e., 82%) of submissions conformed to the program criteria. It can be concluded that the rate of participation in the program at PMC, measured by innovations registered as a percentage of the workforce, was 22% or just over 1 idea submitted for every 5 employees.

6.2.2 Findings on the demographics of innovation

Employees and contractors on the Palabora mine demonstrated broad-based participation in the innovation program.

In terms of age groups, the highest level of participation per category, at 26%, was noted from employees between 35 and 45 years old. The rate of participation in the program by gender, measured by the proportion of innovations registered, revealed a slight bias towards greater male participation at 23% in contrast to their female counterpart at 21%.

Looking at the number of years of service, employees who have been at PMC for 15 to 20 years registered the highest level of representation in the program at 32% participation per category. Three Paterson grading categories also contributed most of the innovation activity: Upper C Band (Specialists and Supervisors), Lower D Band (Superintendents), and Upper D Band (Managers).

Finally, demographic groupings that were relatively under-represented included:

- The under-25 years age group,
- Employees with less than 5 years of service,
- Employees with more than 20 years of service,
- Contractor, students, and B-Band job gradings

Future program outreach efforts could target these under-represented categories in order to improve overall innovation participation.

6.2.3 Findings on the type of innovation

Shopfloor participation in the VIP corporate innovation program was successfully grouped by type of innovation with reference to the four-quadrant innovation matrix discussed in Chapter 2. Most of the innovation taking place entails the use of existing or known technologies within existing markets. This type is known as incremental innovation.

Of the 1005 submissions received at the VIP counter, 954 or 94.9% represented the Incremental innovation category, with Disruptive innovation (4.3%) the next most frequent type of submission received. Architectural and Radical innovation categories had the lowest representation, at 0.3% and 0.5% respectively.

If employees are ‘learning by using’ and ‘learning by doing’, then it fits that most of their innovations will revolve around existing technologies they have already had exposure to in the workplace. Innovation participation that involves existing technologies may not be as exciting or glamorous as radical innovation activities; however, the cumulative impact of continuous and incremental improvement should still be valued and encouraged as much as any other innovation type.

6.2.4 Findings on the trajectory of innovation

Most innovations were aimed at improving the Internal work environment (76%), with the Production environment at 22% being the second highest trajectory. This shows that most employees are concerned with innovating with respect to their own working conditions and the production performance of the mine. External and Product environments each received less than 1% of the total number of innovation submissions during the 12 months.

6.2.5 Estimated Return on Innovation Investment (ROII)

Net return on investment, or value improvement for each innovation recorded in this study, was considered first in terms of commercial return and secondly by categorisation of intangible (soft) benefits.

Of the Top 16 implemented ideas for which independent business cases were developed, three (3) innovations reflected a net return of more than ZAR10,000,000 per calendar year, and thirteen (13) were deemed to contribute more than ZAR1,000,000 per calendar year – indeed a favourable endorsement of the VIP corporate innovation initiative.

Finally, an analysis of intangible value addition by category showed that Operational Approach (40.4%) was the most frequent non-attributable impact, followed by Safety and Health (27.5%) and Maintenance Approach (20.0%). Most employees and contractors working on an operational mine would likely be engaged with producing the final product and/or maintaining the equipment needed to do so. This could explain the distribution of intangible ROII experienced.

6.3 RELATIONSHIP TO PREVIOUS RESEARCH

The study of innovation within resource-intensive industries remains relatively unexplored (Bartos, 2007; Colman et al., 2020; Hossein et al., 2021; Ranestad, 2018; Reichet and O'Brien, 2023; Valacchi et al., 2023). As a result of this, mining, along with other resource-intensive industries such as forestry, agriculture, and fisheries, is often considered to be an industry that is conservative, resistant to change, and of low-technology intensity (Crawford, 2018). The current research study actually shows the contrary, possibly because of the underreporting of innovation in mining organisations. Robertson and von Tunzelmann (2009) corroborated the lack of emphasis on reporting innovation in the primary industry. They pointed out an unfortunate tendency to underreport and even overlook the importance of technological change outside of research and development-intensive industries such as information and technology and biotechnology.

According to Ediriweera and Wiewiora (2021), there are numerous studies that consider technical innovation within the manufacturing and service sectors. However, there exists a scarcity of literature that focuses on the barriers, enablers, or adoption of technical innovation in the mining sector. And the literature on innovation suggests that most, if not all, traditional innovation indicators, and even some mining sector-specific metrics, measure imperfectly the true scope of innovation in the sector. In the case of mining operations, shopfloor innovation activities are unlikely to register in metrics such as ‘new product patents’, ‘new products to market’, or ‘formal research and development (R&D) expenditure’. This makes measurement and specifically benchmarking problematic.

Bjork et al. (2023) argued that companies must track the results and benefits of their innovation through measurement. This is because identifying how best to measure the effectiveness of innovation initiatives is critical in ensuring that those efforts realise a tangible contribution to the overall goals of the organisation. According to Glaesner and Lang (2024), the unique attributes of innovation are what make measurement so difficult. The two authors note that many types of innovation are confidential. So, public disclosure is uncommon, which results in the inability to conduct benchmarking. The novel or newness character of innovation further complicates comparative studies. And the evolutionary nature of innovation means that many innovations are not singularly owned within a single company. This research has shown that despite the difficulties in measurement, mine-specific innovation data is practically achievable. The results obtained in this study create a basis for subsequent benchmarking, whether in the future at PMC or at other peer mining organisations.

When it comes to the barriers of innovation in the sector, many mines see innovation as being too expensive to afford (Xheko, 2024; Human Sciences Research Council, 2023). Mining industry leaders should not be asking whether they can afford innovation. Instead, they should ascertain and reflect on whether they can afford not to innovate. It costs very little to embrace a vision of innovation, more so to set smart objectives for technical ideas and innovations, and to ask employees for ideas. It is also cheap to host brainstorming meetings, establish an intranet-based suggestion scheme, implement quick-win ideas, and empower the teams to experiment with initiatives in their places of work (Phillips and Phillips, 2018). This study has confirmed the argument put forward by the authors – the cost of innovating is far less than the benefits realised!

Perhaps it is important to mention that no relevant literature covering shopfloor innovation in mines could be identified during the literature review. In this light, the research study done may have contributed to the body of knowledge by opening a window on shopfloor innovation in the sector.

In the next section, recommendations for further work in the field of innovation management on mines are offered.

6.4 RECOMMENDATIONS FOR FUTURE WORK

Favourable rates of participation data from the first 12 months of the VIP corporate innovation support a recommendation for the business to continue with the program since it appears to have addressed one of the key challenges outlined in the original policy. In the second year of the program, the business could encourage implementation efforts over ideation. Data shows that approximately 11% of ideas were implemented, whereas a further 43% of still-to-be-implemented ideas were not only compliant with the program but also supported by line management.

Future engagement with employees and any further promotional material could reinforce the fact that the program seeks to emphasise innovations that make better use of existing assets and resources. This could improve conformance to criterion #5 (using what we already have).

It is recommended that future promotional material could be aimed at those demographic categories that are currently under-represented. This includes the under-25 years age group, employees with less than 5 years of service, employees with more than 20 years of service, contractors, students, and B-band job gradings.

It is recommended that further promotional efforts focus on reaching those employees and contractors who lack access to their own personal computers. Investigate ways to make the submission of ideas more convenient to those who lack the ability to make electronic submissions.

It is recommended that future two monthly challenges be designed to encourage employees to broaden their thinking so as to optimise innovation in the external and product innovation environments, both of which are underrepresented in terms of trajectory.

The practice of analysing the best implemented innovations for ROII should be continued. Without statistics, it would be difficult to benchmark or even to demonstrate the value improvement realised by the corporate innovation program.

There is a knowledge gap in the study of innovation in mining; hence, it is recommended that further research on rates of innovation participation be undertaken at other mines.

Future research could further analyse the patterns of gender innovation participation by determining whether there is any difference in the distribution of innovation by (i) type and (ii) trajectory between males and females.

There appears to be a knowledge gap in terms of the study of job grading versus innovative participation. Future studies could explore the relationship between ideation and job grading.

Future research could benchmark the commercial ROII of the PMC corporate innovation program against other mining organisations to evaluate differences across sub-sectors within the mining industry.

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APPENDICES

Appendix 1 – Database

Innovation Number	IDEAS TO BE IMPLEMENTED	IDENTIFIED VALUE	PARK	PARK REASON	PARK REASON TEXT	TOTAL	Idea submitted by SMS or Email etc	Short Description of the Idea*	Implementation Area	What is the problem/challenge? (Version 1)	What should change? Describe the solution. (Version 1)	What is the value that will be created for PMC? (Version 1)	Idea Implemented?	Date Idea Submitted*	Challenge Number
VIP-MIN-083	1					1	Email	Water down decline with dust a side or E/Cat	Mining	sufficient due to the tramming TMM's,	Add a dust A side product	Health benefit. Safe on diesel	No	6-May-24	#5
VIP-AM-067			1	Divisional Screening	The idea is already in the pipe-line	1	Email	Install an online condition monitoring system	Asset Managem	specialist check the vibrations, misalignment and temperature on all	monitor the condition of the equipment, an online condition	breakdowns as assets performance will be monitored	No	6-May-24	#5
VIP-L2-071	1					1	Form	Chute on stand-by	Lift 2	maintenance or reparing. Production is	temporarily be on the chute that is	the chute will not disrupt	No	7-May-24	#5
VIP-MIN-084			1	Divisional Screening	The rock breaker & cabin is part of the design and are being installed	1	Form	Crusher 5 blockage	Mining	The issues is the blockage of crusher 5 because of the big rocks & wire mesh, this always delays production, normally we need blasting or cutting the wire	The solution is to build the Grizzly platform on top of the tipping point and also build a cubby to house the operator for manual	Production increases, there will be no blockage of crusher 5.	No	7-May-24	#5
VIP-L2-073	1					1	Email	Parking space	Lift 2	challenges regarding parking space	identified an area previously	Technical Building will reduce	No	7-May-24	#5
VIP-FIN-022	1					1	Email	Laboratory Automation - The use of automated	Finance	results due to subjective interpretation	and found to be accurate, precise,	our customer hence better	Yes	7-May-24	#5
VIP-L2-072	1					1	Email	Building a Sample storage cubby in front of th	Lift 2	are taken to the lab (sample	built, it should also include a	which contributes to ensuring	No	7-May-24	#5
VIP-MIN-085	1					1	Email	Lift 1 Live System Feed	Mining	about the cave availability with regards	and be displayed on a TV in the	of tasks and ensure sampling	No	8-May-24	#5
VIP-MIN-086	1					1	Form	Blasting siren underground & Surface	Mining	blasting time.	siren and switch off ventalation	will be able to hear the siren	No	8-May-24	#5
VIP-MIN-087			1	Exclusion	On going project	1	Form	PDS VDS to be audisble and pointing direction	Mining	working on our machines.	program audio and pointing	sound detecting and focus on	No	8-May-24	#5
VIP-HR-045			1	Exclusion	The idea is not feasible, and cannot be considered.	1	Form	Training manuals (form of book)	HR	Lost of hours of work. Lost of time	Print trainings manuals so we can prepare at homebefore we go and do our trainings. Have website	Reduce lost of hours of work. Reduce injuries & damage to equipment. Remind us about	No	8-May-24	#5
VIP-AM-068			1	Exclusion	Idea already submitted by another employee, REF VIP-AM-038. Implementation is currently taking place.	1	Email	Installing of streets lights	Asset Managem	Poor illumination from HR offices going down to UMM parking, vehicles when driving at night from that road. The road is not clear of animals such as elephants & Buffalos, therefore people might end up bumping animals.	The area should be installed with streetlights to increase the illumination in the close vicinity where animals might be spotted and that will prevent vehicles to bump aminals even when	This will minimise the hit and run done by people driving at night when they have bumped the animals and it will also preserve lives for the wild animals.	No	9-May-24	#5
VIP-MIN-088		1				1	Email	Dual Battery System for PDSNDS	Mining	left on it kill's the battery of the vehicle	two extra Batteries in series	batteries and no OEM	Yes	9-May-24	#5
VIP-MIN-089			1	Divisional Screening	Dust is not caused by the conveyor, it will not prevent dust.	1	Form	How to get rid of dust on C5 (conveyer belt)	Mining		Installation of pipe lines that will wash the belt before it moves	Less people get lung infections caused by dust that comes from C5	No	9-May-24	#5
VIP-SHE-040		1				1	Form	Sharing the resulting impact of injuries.	SHEQ	severity of safety incidents in the mining	the consequences of safety	attention to safety incidents.	Yes	9-May-24	#5
VIP-MIN-090	1					1	Form	Excessive dust	Mining	spillages and causes more dust. Since	sacrificials and C5 to remove dust	infection cases and zero harm	No	9-May-24	#5
VIP-AM-069			1	Divisional Screening	It is a short piece of road that is currently being managed	1	Form	Tarring the road	Asset Managem	We are using our own transport or vehicle on muddy and dusty road to our workplace (Old DBA plant)	Tar the road up to the gate or entrance of Old DBA plant	Benefit all private vehicle owner from maintenance / car or vehicles breakdowns.	No	10-May-24	#5
VIP-VO-2308-019	1					1	Email	Installing a cone crusher in the place of the B	Vermiculite	Vermiculite Flakes), due to crushing	required plant feed (ROM material	created for the VO plant by	No	10-May-24	#5
VIP-VO-2308-020			1	Exclusion	Compliance: we have measures in place to deal with it.	1	Email	Driving Behaviour	Vermiculite	challenge. Driving while using cell phones, driving unsafe and damaging vehicles Driving on or at places different	change especially while operating company vehicles. There is an element of not being	happened and to link a more correct timeline to any reportable incidents	No	10-May-24	#5
VIP-MAG-061	1					1	Email	I improvement on Magnetite using pressed pe	Magnetite	has been a problem and the customer	of our XRF instrument and how to	and implemented it will assist	No	13-May-24	#5
VIP-SHE-041			1	Exclusion	Earplugs is a part of PPE which the employer should provide to employees, not an innovation.	1	Form	Ear plugs to be effectively implemented to all	SHEQ	The Noise, long term effect on staff	Ear plugs should be purchased and distrubuted to all staff	Taking care of ones health & safety	No	13-May-24	#5
VIP-MIN-100	1					1	Form	Installation of air canon at C15 and C5	Mining	conveyor belt 15 chute and conveyor 5	canon to help minimise the delay	employee fatigue will be	No	13-May-24	#5
VIP-MIN-101			1	Exclusion	Current bay is 850m as required by law.	1	Form	Building a refuge bay next to the station	Mining	confusion when evacuating shaft underground. There is no refuge bay next to the station, when the problem is from	station so that employees must use it in the event of emergency evacuation coming from station to	It will improve the evacuation system at PMC and ensure the safety of employees	No	13-May-24	#5

Appendix 2 – Demographics

2	Innovation Number	Grade Category	Division	Department	Section	GENDER	AGE RANGE	YEARS @ PMC	Challenge	Submission Date
81	VIP-SML-2308-002	C1-C3	Smelter & Refinery	Smelter & Refinery Maintenance	Smelter Services	Male	47	18	#2	3-Nov-23
82	VIP-SML-2308-003	C1-C3	Smelter & Refinery	Smelter Operations	Anodes & Converters Operati	Male	41	19	#2	31-Oct-23
83	VIP-CON-2308-007	Supv/Specialist C4-C5	Lift II Construction, Concentrator & VIP	Concentrator Maintenance	SMP Conv Circuit & Tertiary Fl	Male	50	8	#1	0-Jan-00
84	VIP-CON-2308-008	Supv/Specialist C4-C5	Lift II Construction, Concentrator & VIP	Concentrator Maintenance	SMP Conv Circuit & Tertiary Fl	Male	50	8	#1	0-Jan-00
85	VIP-CON-2308-009	Supv/Specialist C4-C5	Lift II Construction, Concentrator & VIP	Concentrator Maintenance	SMP Conv Circuit & Tertiary Fl	Male	50	8	#3	0-Jan-00
86	VIP-CON-001	B1-B5	Lift II Construction, Concentrator & VIP	Concentrator Maintenance	Secondary Crusher & Automil	Male	30	3	#2	3-Nov-23
87	VIP-SHE-002	Supv/Specialist C4-C5	Asset Management	Projects Services	Project Study & Execution	Female	43	18	#2	1-Nov-23
88	VIP-FIN-003	Supv/Specialist C4-C5	Asset Management	Projects Services	Project Study & Execution	Female	43	18	#2	1-Nov-23
89	VIP-REF-004	Supv/Specialist C4-C5	Smelter & Refinery	Refinery Operations	Refinery Technical & Nickel P	Male	53	8	#2	2-Nov-23
90	VIP-REF-005	Supv/Specialist C4-C5	Smelter & Refinery	Refinery Operations	Refinery Technical & Nickel P	Male	53	8	#2	2-Nov-23
91	VIP-AM-006	Supv/Specialist C4-C5	Smelter & Refinery	Smelter Operations	Acid Plant & Gas Handling	Male	50	18	#2	3-Nov-23
92	VIP-MIN-007	Supv/Specialist C4-C5	Vermiculite, Magnetite Mining & Processi	Magnetite Mining & Technical	Magnetite Mining Technical	Female	33	6	#2	2-Nov-23
93	VIP-HR-008	B1-B5	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	50	3	#2	11-Nov-23
94	VIP-MAG-009	B1-B5	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	50	3	#2	10-Nov-23
95	VIP-MIN-010	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Underground Mining	Logistics	Male	45	13	#2	11-Nov-23
96	VIP-SML-011	Supv/Specialist C4-C5	Smelter & Refinery	Smelter & Refinery Maintenance	Construction	Male	50	1	#2	13-Nov-23
97	VIP-MIN-012	C1-C3	Lift II Mining & Underground Developmen	Mining Maintenance	UG Maintenance Surface	Male	52	15	#2	13-Nov-23
98	VIP-AM-013	Supv/Specialist C4-C5	Asset Management	Projects Services	Project Study & Execution	Female	43	18	#2	9-Nov-23
99	VIP-MAG-014	C1-C3	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	43	13	#3	11-Oct-23
100	VIP-MAG-027	B1-B5	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	50	3	#2	10-Nov-23
101	VIP-MAG-016	B1-B5	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	30	5	#2	21-Nov-23
102	VIP-MIN-017	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Mining Maintenance	Mobile Maintenance	Male	34	7	#2	21-Nov-23
103	VIP-MNW-2308-030	Supv/Specialist C4-C5	Finance	Information Services & Technology	IS&T	Male	50	10	#2	16-Nov-23
104	VIP-MIN-019	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Underground Mining	Logistics	Male	51	11	#2	15-Nov-23
105	VIP-L2-020	Supv/Specialist C4-C5	Lift II Construction, Concentrator & VIP	Construction		Male	49	16	#2	22-Nov-23
106	VIP-MAG-039	B1-B5	Lift II Mining & Underground Developmen	Underground Mining		Female	41	18	#2	10-Nov-23
107	VIP-MAG-041	Supv/Specialist C4-C5	Smelter & Refinery	Smelter & Refinery Maintenance	Construction	Male	50	1	#2	23-Nov-23
108	VIP-SHE-023	C1-C3	Lift II Mining & Underground Developmen	Mining Maintenance	UG Maintenance Surface	Male	52	15	#2	10-Nov-23
109	VIP-AM-024	Supt D1-D3	Asset Management	Engineering Services	Electrical Infrastructure	Male	59	10	#2	9-Nov-23
110	VIP-MAG-025	C1-C3	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	43	13	#2	29-Nov-23
111	VIP-MAG-026	C1-C3	Vermiculite, Magnetite Mining & Processi	Magnetite Processing & Technical	Magnetite Operations Strean	Male	43	13	#2	29-Nov-23
112	VIP-L2-027	Supt D1-D3	Lift II Mining & Underground Developmen	Horizontal Development/UC & Drawbells	Horizontal Development and	Male	47	24	#2	30-Nov-23
113	VIP-AM-028	Supt D1-D3	Asset Management	Engineering Services	Electrical Infrastructure	Male	59	10	#2	1-Dec-23
114	VIP-MIN-020	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Underground Mining	Secondary Breaking Unit	Male	42	18	#3	11-Dec-23
115	VIP-L2-028	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Mining Technical	Geology Section	Female	34	7	#2	18-Dec-23
116	VIP-MIN-021	Manager	Lift II Mining & Underground Developmen	Horizontal Development/UC & Drawbells		Male	47	25	#2	20-Dec-23
117	VIP-MNW-2308-019	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Mining Technical	Geology Section	Female	34	7	#2	21-Dec-23
118	VIP-SML-025	B1-B5	Smelter & Refinery	Smelter Operations	Acid Plant & Gas Handling	Male	42	16	#2	27-Dec-23
119	VIP-SML-026	B1-B5	Smelter & Refinery	Smelter Operations	Acid Plant & Gas Handling	Male	42	16	#2	27-Dec-23
120	VIP-SML-023	Supv/Specialist C4-C5	Smelter & Refinery	Smelter Operations	Acid Plant & Gas Handling	Male	47	11	#2	22-Dec-23
121	VIP-SML-027	Supv/Specialist C4-C5	Smelter & Refinery	Smelter Operations	Acid Plant & Gas Handling	Male	50	18	#2	24-Dec-23
122	VIP-HR-022	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Mining Maintenance	Instrumentation & UG Electri	Male	52	13	#3	2-Jan-24
123	VIP-SML-024	B1-B5	Smelter & Refinery	Smelter Operations	Acid Plant & Gas Handling	Male	42	16	#3	2-Jan-24
124	VIP-MIN-022	student	Human Resources	Training Development & Contractor Manage	Training & Development	Male	31	0	#3	5-Jan-24
125	VIP-MIN-023	Supv/Specialist C4-C5	Lift II Mining & Underground Developmen	Underground Mining	Logistics	Male	45	13	#3	5-Jan-24
126	VIP-MIN-024	student	Human Resources	Training Development & Contractor Manage	Training & Development	Male	24	0	#3	8-Jan-24

Appendix 3 – ROII

2				Tangible Innovations						Intangible Innovations			
3	Innovation numbe	Short discription of the idea	Challenge Number	<100,00	<250,00	<1,000,000	<5,000,000	<10,000,000	>10,000,000	Operation approacl	Health & Safety	Maintenance Approach	Communication & Decision Makinį
4	VIP-L2-2308-001	Undercutting Design Change	#1							x			
5	VIP-SML-2308-001	Smelter baryte density measurement for improved control of anode mould spraying	#2			x							
6	VIP-MIN-2308-003	Crusher 1,3 and 4 push plate feeders improvement	#2				x						
7	VIP-MIN-2308-004	Emulsion waste reduction	#1			x							
8	VIP-FIN-2308-001	PowerBI:Project Dashboard	#1										x
9	VIP-SML-2308-001	Optimisation of Anode Moulds	#2					x					
10	VIP-MIN-2308-009	Revolutionising Survey Drone Underground	#1								x		
11	VIP-L2-2308-002	Power cable Ducting and safe working platform at the MRAP Crusher 5	#1									x	
12	VIP-CON-2308-004	Optimisation of Flotation plant through new reagent	#1						x				
13	VIP-MNW-2308-015	Install Solar Streetlights on he main road	#2								x		
14	VIP-MIN-2308-012	Improvement of life span of impeller blades by modification of stainless-steel welded sheet plate wear resistance	#2				x						
15	VIP-AM-2308-003	Increase PC weigbridge system to 80 ton	#2							x			
16	VIP-MAG-2308-008	Establish optimum operational parameters for efficient process control and improved product quality.	#1							x			
17	VIP-VO-2308-001	Roof parking inhouse at a cost of R250 000 avoiding spending R1.2M	#1			x							
18	VIP-CON-2308-005	AutoMills relining in 10 days vs planned 14 days	#1									x	
19	VIP-L2-2308-007	Improve Crusher 5 construction schedule compliance through compliance through digital shift reports	#1										x
20	VIP-SML-2308-002	Preventing baboons from getting into laggerbin	#2										
21	VIP-CON-2308-009	Initiating the split stator component for the agitator mechanism	#3									x	
22	VIP-L2-020	Batch plant bag pallet implementation to reduce wastage of bags and ensure clear driveways	#2	x									
23	VIP-AM-024	Mobile mud-press for underground de-watering section	#2							x			
	VIP-MAG-025	Install Y-piece on overflow pump 1 line to enable both pumps to feed cleaner				x							

Appendix 4 - VIP Implementation Posters

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Optimization of Flotation plant through new reagent

✓ = Agree X = Disagree

Is there a problem	Is this a solution	Is this a new solution	Does it add value	Use existing resources
✓	✓	✓	✓	✓

Idea Originator:

Eric Mualusi

Idea Implementor:

Concentrator team

Problem Statement:

Copper floatation was carried out using a highly selective collector which led to lower copper recoveries averaging 75% in 2023 at a very high concentrate grade which indicates low mass pull.

Solution:

Introducing a dual collector system consisting of the highly selective K1 and K2 to improve on mass pull leading to a higher recovery at a lower concentrate grade.

Value Created:

The dual collector system led to a 20% increase in mass pull and a 5.54% increase in copper recovery from an average of 75% to 81.8% over the 7 week plant trial phase. This results in an estimated value of R84.4M over 4 months.

Photos:

PMC PALABORA — VIP

Is this optimization approach adding value?

August Performance Case Study

= $\frac{\text{R21.1m}}{\text{R0.86m,}}$ = 24.6

4 months Value Estimate= R 84.4m

VIP

Use Internal Skills to Maximise Value

Idea Originator:	Idea Implementor:
VO Maintenance Team	VO Maintenance Team Members

Problem Statement:

Stoppages of the bus transport created a parking problem at Vermiculite Business as sufficient parking was inadequate. To erect additional parking would have costed R1.4m, which VO was not prepared to spend.

Solution:

Do under roof parking in house at a cost of R250k.

Value Created:

- Avoid spending R1.2m.
- Improve compliance to traffic management plan.
- Boost employees morale which equates to improve productivity.

Before photo/s

After photo/s

HBIS GROUP | pmc PALABORA MINING COMPANY | VIP

Creating Value from Unused 1000L Flow bins

Idea Originator:

Pierre du Preez

Idea Implementor:

Ishmael Ramoshaba

Problem Statement:

- The waste emulsion used to be stored in large waste cassettes in the underground.
- It would then be transported to surface and manually loaded from the cassettes into 210L drums
- The cost of one waste disposal drum (991013600) is R1 891.66.
- The emulsion is corrosive and steel drums rusted and leaked if they were not removed quickly.

Solution:

- There were lots of unused 1000L flow bins discarded, which could be used for the same purpose. Necessary permission Environmental Dept. was obtained to utilize these flow bins.
- Empty flow bins were then sent underground to be used as waste containers and were also use at the emulsion silo to clean up spillages.

Value Created:

#1

#2

#	Value	Reason
1	Waste reduction	The flow bins regarded as waste can now be reused
2	Cost saving	Sending 30 x 210L drums for treatment costed us R [illegible]
3	Less exposure to chemicals	No handling of waste emulsion by hand
4	Environmentally friendly	The flow bins are not affected by the corrosive emulsion

#3

#4

Before photo/s:

After photo/s:

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Moved the old Synch Switches in the Production Shaft

☑ = Agree X = Disagree

Is there a problem	Is this a solution	Is this a new solution	Does it add value	Use existing resources	
☑	☑	X	☑	☑	

Idea Originator:

Stephen Du Plessis

Idea Implementor:

Theo Grundlingh, Karel Buitendag, Wouter Oberholzer

Problem Statement:

The position of the old Synchronising Switches in the Production Shaft was at 230m. If there was a problem with any of the 8 switches in the Production Shaft all production needed to be stopped to go down and do the necessary repairs on them. The switches and cabling were damage by failing ore / rocks and excessive movement of the skips. The repairs could be between 4 to 6 hrs at a time.

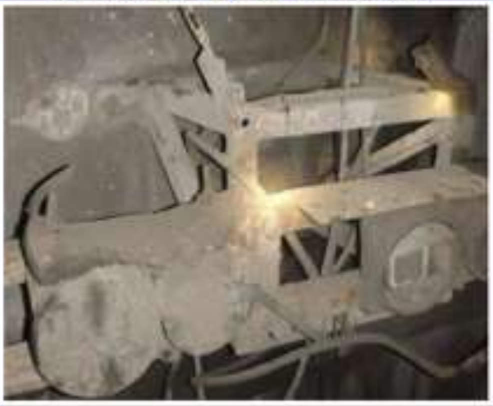
Solution:

Repositioned the Synchronising Switches to Sub Bank level at 35m. This means that we always have access to the Sync Switches and that repairs could be done while the other Winder is still running. Only half production will be influenced while the repairs is being done. Repair downtime reduced to 30 min.

Value Created: (Value/ Benefit created)

Reduced downtime and revenue loss.
The production loss due to the repairs to be done in the Production Shaft is around **R796 665** Tons/h loss. This is for two winders standing.
Scenario 1: 2 Production Winders Standing for 6 hrs is estimated **R2.8 Million** p/m Loss.

Before & After photo/s:



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Unlocking Business Value Through the In-house Development and Utilization of a Pumping System Simulation Tool

☑ = Agree X = Disagree

Is there a problem	Is this a solution	Is this a new solution	Does it add value	Use existing resources	
☑	☑	☑	☑	☑	

Idea Originator:

René Coetzee

Idea Implementor:

René Coetzee

Problem Statement:

Although pumping systems have a very basic function, they can often be the root cause of shifting from a stable, profitable operation to an operation plagued with disastrous, costly business interruptions. Changes made to pumping systems without being properly assessed, leads to inefficiencies and reliability issues. Solely relying on external pumping system experts is not always practical in a dynamic mining environment where changes need to be made timeously therefore requiring swift pumping system assessments.

Solution:

An Excel-based, pumping system simulation tool was developed in-house, that enables us to hydraulically simulate different pumping systems across the mine under a multitude of different scenarios. It therefore enables us to make timeous, educated calls on proposed changes to pumping systems so as to determine which change/scenario is feasible and best suited for the application.

Value Created: (Value/ Benefit created)

By developing internal competence and a pumping system hydraulic simulation tool, pumping systems can now be assessed and advised on, allowing for saving time and money and ultimately resulting in more effective operation. In some instances, Consultants can charge > R200 000 for these hydraulic simulations/assessments/designs depending on the complexity thereof. Considering a conservative figure of ~R100 000 per assessment and that we have done more than 10 simulations across the business already, an estimated ~ R1.0-million in consultancy fees have been saved/avoided. However, the time saved due to doing these simulations in-house, enabling the business to make quick changes and thereby getting pumping systems operational to support production, is substantial although difficult to quantify.

Before & After photo/s:

Raw Water Pump Station Simulation for equivalent pump replacement suitability assessment (Existing installation)

Return Water Dam Dredge Booster Pump Station Simulation for pump suitability assessment (New installation)

Install Y-Piece on Overflow Pump

✓ = Agree X = Disagree

Is there a problem	Is this a solution	Is this a new solution	Does it add value	Use existing resources	

Idea Originator:

Stephen Mathole, Aubrey Raseasala, Daniel Mafahla

Idea Implementor:

Daniel Mafahla, Vincent Mofokeng, Enock Nkuna, Shadrack Modise.

Problem Statement

Stream 1 plant produces coarse iron ore (63% Fe) and DMS (82% passing 45 microns and 93% Magnetics). Stream 1 consists of six (6) rougher magseps, four (4) cleaner magseps and four (4) recleaner magseps. Current arising TFP rougher tails from the concentrator flotation circuit are pumped to Stream 1 rougher magsep distribution box and processed through the rougher magsep circuit. The overflow from the rougher distribution box is gravitationally fed into the overflow handling sump at a rate of around 1200 m3/hr. Overflow handling pump 1 feeds the cleaner distribution box while overflow handling pump 2 feeds the recleaner distribution box, because of the low overflow volumes only two magseps from each circuit will be running at a time, while the standby magseps are idling. This causes energy and water waste and introduces more water into the system which compromises flow and density control.

Solution

Installation of a Y-piece on overflow handling pump 1 line which enables it to also feed the recleaner distribution box. With the Y-piece installed, the four cleaner magseps can be stopped completely (saving water and energy) while the other four recleaner magseps are running.

Value Created:(Value/Benefit)

Saving water and energy costs and Increase Plant flexibility. Increases redundancy and saves maintenance costs

Before & After photo/s:

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New Method to use Spreader Beam					
☑ = Agree	X = Disagree				
Is there a problem	Is this a solution	Is this a new solution	Does it add value	Use existing resources	

Idea Originator:

Hansie Peach

Idea Implementor:

Hansie Peace, Koos Victor

Problem Statement:

The current procedure to lift winder ropes from the drum involves lifting each rope at a time using a crane and placing it on the floor. The task used to take 12 hrs to remove the ropes from the drum.

Solution:

Employee suggested a new method to use a spreader beam with an Overhead crane to lift head ropes from the winder drum.
This task takes 4 Hrs.

Value Created:

The task was normally performed in 12 hours, it is now reduced to 4 hours. The task takes less half the time to remove the ropes from the drum there for giving back the winder earlier to hoist. It took long hours to perform task, it used to affect production and it took 4 hours to hoist ore. +- R200 000.00 cost saving for reducing the hours and loss of production. Winder stopped

Photos

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Replace Service Winder Counterweight Guide Ropes					
☑ = Agree	X = Disagree				
Is there a problem	Is this a solution	Is this a new solution	Does it add value	Use existing resources	

Idea Originator:

Mark Robinson

Idea Implementor:

M Robinson, W Viljoen, K Victor, H Peach, L du Doit, J Vosloo & D Meyer

Problem Statement:

The challenge was the replacement of the guide ropes at the service winder which had never been replaced since the winder was commissioned in 1999. There was no Safe Working Procedure and risk assessment to replace the ropes on the service winder. In addition to this, there are service columns installed in the service shaft which makes it more complicated. A service provider which has experience in replacing ropes and installing winders was sourced and requested to submit a proposal. The proposal was technically and financially not viable.

Solution:

A method to use a Friction Winch with a dummy rope and guide rope connected using 10 x three bolt clamps was developed and risk assessed. A sample of rope connection prepared and tested to verify if the connection will be safe prior to doing the actual work. The rope connection was tested successfully using a 50-ton load and was there approved to change guide ropes.

Value Created:

Cost saving to the amount of R6m and safety due to the fact that the task was completed using this method by the PMC team, no contractors were used to do the work, a risk assessment was conducted, and a Safe Working Procedure was implemented for the task.

Before & After photo/s:

Friction winch

Value/Benefit

Guide ropes

VIP

New Water Car Gooseneck

Idea Originator:

Jaco Klopper

Idea Implementor:

Kabedi Macheru, Rassie Smit, Cornelius Viljoen, Coreen Malatji, Lukas Viljoen, Siphiwe Gama, Amore Mgiba, Willem Schaap, Harold Lubisi, Mark Mailula & Ntsako Mathebula

Problem Statement:

Logistics had no water point to do dust suppression on the road and the magnetite mining areas. To get water for dust suppression and some projects every day were a BIG problem. We went days without water and old water point is 2km from Cleveland.

Solution:

With the help of management to get permission to connect to the correct and closes the water line took a few meetings. The first quote was for R380 000.00 all material supplied by contractor; PMC was not happy with price. Luckily projects had reclaimed pipes for us to use, which reduced the cost to R85 000.00 for the pipeline, we used a reclaimed Gooseneck which also helped reduce the reduce the price. The new 310m water line to the Gooseneck was finished 21/02/2024 with a lot of smiles.

Value Created:

Cost and time. The new waterpoint is 300m from the Cleveland offices. Travelling time is 100% better and cost on fuel. Most hours can be put in on dust suppression and other projects.

Before and After Photos

Optimization of Anode Moulds

Idea Originator:

Samson Banda, Johan Breitenbach, Eugene Nkwamba

Idea Implementor:

Kabedi Macheru, Lukas Viljoen, Samson Banda, Johan Breitenbach, Eugene Nkwamba

Problem Statement:

Smelter Anode Section cannot cast any anode copper without anode moulds. The current moulds at Smelter Anode Section are not fit for operation because of multiple deep cracks on the moulds. Trading in the cracked anodes for newly casted anode moulds requires over R11million. The lack of good quality anode moulds shall cause Smelter downtime.

Solution:

Smelter For the Smelter Anode Section be ready for start-up, good quality moulds must be available:Repair the cracked Anode Moulds by copper welding and machining. (copper welding and copper machining was unknown to the operation – this is new to Smelter Operation.)Use machined copper pieces for Refinery Batch Plant to increase copper tenors in electrolyte

Value Created:

- Smelter Anode Section is thus made ready for start-up.
- Avoided the cost of casting new moulds at **R11.7M**.
- Downtime due to poor quality anodes is eliminated/avoided.
- Off-spec electrolyte will be in-spec upon electrolyte commissioning (**38g/L to 46g/L**).

Before and After Photos

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Batch plant Bag Pallet to reduce waste

Idea Originator:

Lylence Hlungwane

Idea Implementor:

Lylence Hlungwane, Ally Usinga &Shaun Brown.

Problem Statement:

The batching of concrete underground requires that all the raw material gets placed in a bag and transported U/G where it gets batched. The bags are reusable, but bag management is time consuming and a lot of bags go to waste because people don't want to double handle the bags.

Solution:

Normal practice U/G is to stack all the bags for several shifts and then use one trailer to bring out the re-useable bags. This causes a lot of damage to bags during the stacking and the leading process. Lylence came up with the idea to fabricate a steel pallet the size of a folded bag and have it standing next to the batch plant. Once a bag is emptied the bag gets place on the steel pallet and once the pallet is full it gets strapped and the pallet gets loaded on the first available trailer.

Value Created:

- Operational Efficiency, reducing the damage to the concrete bags during handling and transportation, saves costs if replacing bags
- Reduces spillage of material due to improved handling.
- The dedicated mobile area with protective frames and straps for securing the bags on the pellet is effective in minimizing damage.
- Currently losing 140/1000 bags in a 3-month cycle and the indication is that we can bring this down to below 60/1000 bags in a 3 month cycle.
- The cost per bag is R548.00.
- Loss of 140 bags = **R76 720.00** per quarter(savings)

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Defeating Limitations of in-line Density Measurement

Idea Originator:

Sibusiso Sibuyi, Johan Breitenbach, Eugene Nkwamba, Sam Banda

Idea Implementor:

Kabedi Macheru, Rassie Smit, Cornelius Viljoen, Coreen Malatji, Lukas Viljoen, Siphiwe Gama, Amore Mgiba, Willem Schaap, Harold Lubisi, Mark Mailula & Ntsako Mathebula

Problem Statement:

Baryte is used to coat the Anode Moulds before the casting of copper anodes. However, Operators have been mixing and coating Anode Moulds with Baryte Slurry density that is out of spec. To improve density control requires in-line density meter but the available density meters can only be installed on a 100NB pipe whilst the Baryte slurry pipe is 25NB

Solution:

Install VegaBar 82 device on the Baryte slurry tanks to measure both level and slurry density, thus avoiding the limitation of pipeline sizes. (measure density and tank level with one device). Automate the coating of the Anode Moulds with the in-line Density Meter to prevent the Anode Moulds from being coated with slurry density that is off-spec. Total cost of R300 000

Value Created:

(Avoid the cost of a new level transmitters (**R400 000**)
Avoid the installation of radioactive instruments in the plant area.
Avoid the cost of installing conventional density meter (**R700 000**)
Zero incident of Out of spec slurry density from weekly incidents.
Zero dumping/spilling of Baryte Slurry (instead of dumping/spilling Baryte slurry 200 times)

Before and After Photos

Improving Structural Design to Prevent Downtimes

Idea Originator:	Idea Implementor:
David Riba	David Riba, Harry Mamogale & Riba's team

Problem Statement:

UG crushers have been in operation for over 20 years. Constant welding and metal fatigue on crushers cylinder brackets was the cause of serious down time (12 – 16 hours), production lost and fatigue to employees.

Solution:

Changed crushers cylinder structural design to 30mm plate with extra support brackets.

Value Created:

No breakage of cylinder bracket for more than a year since the new installation. Crushers team could now concentrate more on preventative maintenance. There is improved crushers availability leading to production tons increase.

Cost in the previous years: 2021= R1,547,454.21; 2022= R3,304,873.26 2023= R169,892.26 (significant reduction)

Before and After photo/s:

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Improve of life span of impeller blades

Idea Originator:

Simon Boloko

Idea Implementor:

Patrick Mawela, Jabulani Ntimana, Rito Khosa, Paul Mokoena, Armstrong Mathipa, Simon Boloko

Problem Statement:

Up-Cast fans were unable to run a full year in service due to excessive wear on the leading-edge of the impeller blades and bolts securing the hub and impeller. The excessive wear is caused by the sand grit which is mixed with the exhaust air from underground via the current ventilation shaft which does not have a concrete lining. The fan impeller blades were initially supplied with 2 mm thick stainless-steel leading-edge liners. The wear on these liners were excessive due to the orientation and thickness of the steel.

Solution:

Improvement of life span of impeller blades by modification of stainless-steel welded sheet plate wear resistance protection. Design review of the fan done by OEM with Site Manager to change orientation of stainless-steel shield. New liners(SAF 2205) were manufactured & installed on all up-cast fans. Deflection plates around the bolts

Value/ Benefit Created:

Prolong equipment life span from 6 to 18 months. Impeller repairs were costing R1.6M (R1.3= Refurbished impeller & R300K= labor)

Before and After

HBIS | PMC PALABORA VIP

Conversion milling circuit

Idea Originator: Hua Guo

Idea Implementor: Tshepo Malatji, Kabelo Machete, Koketso Mahlane, Bridget Mayayise

Problem Statement:

In 2022 to 2023, magnetite team demonstrated that the % Fe (Iron) can be upgraded from 62% to 65% by re-grinding. Current Magnetite from Underground is 1,5 Mtpa and its finer than current HiTi. In late December 2023, Concentrator Conventional Circuit was identified as an opportunity to test the concept of magnetite re-grind. Concentrator has got 6 conventional circuits. Whereby three are used for Cu tap off processing and the other three have been decommissioned.

Solution:

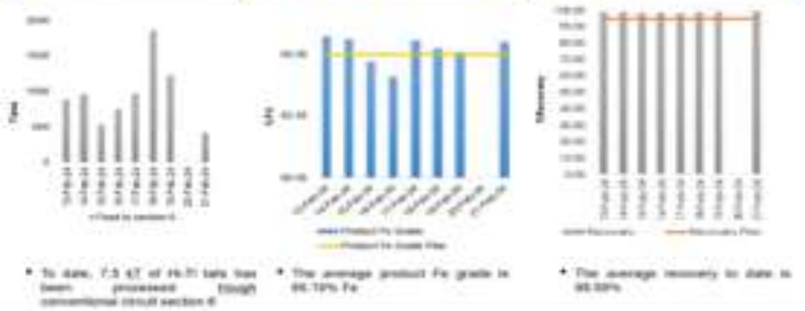
Key stakeholders' identification: Magnetite team, Concentrator team, & VIP Magnetite Regrind team. Stakeholder skills mapping: Identified skills within people who already knew the circuit. An alignment meeting was set up to clearly outline the objective of the project. Kick off meeting to ensure all stakeholders are aligned on the objective and value add to the business. Using the assembled team, followed by walkabout and defining options. Further aligned that this would be done in-house due to the timing and the fact that it was a POC trial

Value Created:

Improved grade. Conversion milling circuit repurposed for magnetite milling (also a Business Approach) Increases the value of the ore by removing gauge, minimize losses, Increase mining production & Overall increased profitability

Photos:

Magnetite Conventional Milling Results



HBIS | PMC VIP

Is this optimization approach adding value?

Performance Case Study

= R1,1b / R669m, = 1.65

Value Estimate= R 1.7b