Factors affecting mechanisation in the South African platinum mining industry

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ABSTRACT

Although mine mechanisation is not a new concept to the mining industry, the majority of platinum mines in South Africa are still using conventional methods to mine. Given the current South African economic climate, these conventional methods are not sustainable for the platinum industry. South African mining enterprises are faced with numerous challenges, some of which are: low labour productivity, increasing operational costs, and challenges associated with greater mining depths. These challenges are forcing platinum producers to rethink how they mine. In order for platinum producers to remain relevant and competitive, mechanisation of mines is a viable option that mining stakeholders must embrace.

Given this context, this research aims to provide insight into the factors that affect mine mechanisation in the South African platinum mining industry. A quantitative research methodology was adopted, whereby 142 online questionnaires were sent out to gather information from different mining stakeholders. The mining stakeholders comprised four groups, namely: mining house technical staff, mining house management staff, consultants, and mining equipment vendors. The data that was gathered was subsequently subjected to the following statistical analyses: descriptive statistics, exploratory factor analysis (EFA), and analysis of variance (ANOVA).

The findings of the research highlighted favourable and unfavourable factors that affect mine mechanisation in the South African platinum mining industry. Some of the factors, including mine safety and productivity, are perceived as very favourable, while skills shortages and job losses are viewed as unfavourable for mechanisation.

The exploratory factor analysis was instrumental in determining the underlying structure of the data and revealed that a four factor structure exists. These factors are: deciding elements of mechanisation, implementation of mechanisation, benefits of mechanisation, and impact of people on mechanisation. Finally, an ANOVA was conducted to identify differences in stakeholder views, and revealed that no significant differences in perceptions exist between the different stakeholder groups.

It is envisaged that this study will assist mining stakeholders to better grasp the factors that influence mechanisation, and enable them to effectively strategize when undertaking mechanisation projects. Further, the findings of this research contributes to the limited body of knowledge in the platinum mining sphere and provides a platform for further research on mine mechanisation.

Search words: mechanisation, mining, platinum, exploratory factor analysis, analysis of variance

DECLARATION

I, *Nishal Manilall,* declare that this research report is my own work except as indicated in the acknowledgements and references. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

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Nishal Manilall

Signed at …………………………………………………………..…

On the ………………… day of ……………………………... 2016

DEDICATION

This research is dedicated to my wife, Nadine Behari, and daughter, Miraya Manilall, for their continuous support and inspiration throughout my academic journey. With their unwavering support and continual encouragement, my research has finally come to fruition. I am very grateful for all the sacrifices made and am truly blessed to have such an amazing family.

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CHAPTER 1: INTRODUCTION

1.1 Purpose of the study

The purpose of this research was to identify favourable and unfavourable factors that affect mechanisation in the South African platinum mining industry. The research further went on to determine the extent to which these factors affect mine mechanisation. Different stakeholder perceptions were considered when identifying and evaluating the favourable and unfavourable factors that influence mechanisation.

1.2 Context of the study

The South African platinum industry is a major contributor to the global supply of platinum. According to Jones (1999) and Cawthorn (2010), more than 80% of the world's platinum reserves are located in South Africa, which is also the largest producer of Platinum Group Metals (PGM). South Africa's PGM production is primarily gathered from the Bushveld Igneous Complex (BIC) and comprises: platinum, rhodium, iridium, palladium, ruthenium, and osmium (Platinum, 2013). The three main ore deposits, Upper Group 2 (UG2), Merensky Reef and Platreef (Cawthorn, 2010), was identified by Hans Merensky in 1924 (Cawthorn, 1999). Numerous mining companies operated for many years in the Bushveld complex, leaving only four primary platinum producers. The four main platinum producers in South Africa are Anglo American Platinum (AMPLATS), Lonmin Platinum (LONMIN), Impala Platinum (IMPLATS), and Northam Platinum (Bell, 2015). PGM have a wide range of applications in technology and industry. The demand for platinum is driven mainly by the jewellery market and its use in auto catalysts, which regulates exhaust emissions from motor vehicles (Platinum, 2013). The remaining demand comes from petroleum, glass, medical, electronic and chemical technology applications (Platinum, 2013). The leading consumers of platinum are China, Europe and North America (Platinum, 2013).

Mine mechanisation is referred to as any machinery, which when used in a mine to either break or transport rocks, reduces human effort or labour (Willis, Dixon, Cox, & Pooley, 2004). Mechanisation is not a new concept. It has been implemented extensively for decades in the coal mining sector (Egerton, 2004). Mechanisation in the platinum mining sector is not as common as in the coal mines, therefore, conventional mining is adopted using drill rigs or jack hammers (Egerton, 2004). This is indeed a very labour intensive process (Egerton, 2004). Some of the mechanisation equipment implemented in platinum mining includes trackless equipment, conveyor belts and hydropower systems. (Willis et al., 2004).

An understanding of the factors that affect mechanisation will contribute significantly to improve its implementation in South Africa. Favourable factors are seen as any factors that make mechanisation possible, while unfavourable factors are those factors that inhibit successful mechanisation.

Some of the perceived positive factors influencing mine mechanisation are requirements for improved working conditions, higher standards for safety of mine workers, and increased productivity (Willis et al., 2004). Some unfavourable factors, on the other hand, are: mine workers lack of knowledge and expertise to adapt to the new technology, and high capital cost of mechanisation (Willis et al., 2004).

For many decades, production from South Africa's mines relied heavily on manual labour, resulting in compromising the safety of miners (Stoddard, 2014). Years of political initiatives and labour upheavals, in order to improve safety and uplift low wage miners, have set the scene to replace rock drillers with machines (Stoddard, 2014). The move towards mechanisation is underway despite geological challenges and capital constraints (Stoddard, 2014).

At Anglo American Platinum's Bathopele mine near Rustenburg, mechanisation has already made rock drillers obsolete by replacing them with hydraulic machines (Stoddard, 2014). This improvement has set the trend for many other platinum producers to follow, and as such, many platinum shafts have plans to roll out mine mechanisation (Stoddard, 2014). Impala Platinum, a rival to Anglo American Platinum, has recently sent a team to observe the mine layout and operation at Anglo American's Bathopele mine (Stoddard, 2014). This initiative is a clear example of co-operation between the mines to get mechanisation underway, which is contrary to the way things were in the past, i.e. competitive and secretive (Stoddard, 2014). The three leaders in platinum production, Anglo American Platinum, Impala Platinum and Lonmin Platinum, are also partnering with a mining technology firm, Joy Global, to develop technology for rock cutting (Stoddard, 2014).

According to SMedia (2014), the mining industry will now take on a transformational and noticeable route to mechanise in order for mines to be more feasible and productive. Mechanising mines has also been seen as a strong solution to creating a steady stream of revenue and could cut significant costs for mining companies, one of which would be through worker retrenchments. Job losses, however, could have a major impact on the country's unemployment percentage and spark fresh labour sector disputes. Although mechanisation will impact negatively on many, it will probably be better for the mining industry. Much of the mechanisation trends gained momentum after the protracted wage strikes in the platinum sector. The South African mining industry lost well over seven million work days during the strikes, while the three biggest platinum producers lost R24 billion.

1.3 Problem statement

1.3.1 *Main problem*

To identify and evaluate favourable and unfavourable factors that affect mine mechanisation in the South African platinum mining industry based on key stakeholder perceptions.

Arising from the main problem, the following sub problems have been derived:

1.3.2 *Sub-problems*

Sub-problem 1

To identify and evaluate favourable factors affecting mine mechanisation based on key stakeholder perceptions.

Sub-problem 2

To identify and evaluate unfavourable factors affecting mine mechanisation based on key stakeholder perceptions.

Sub-problem 3

To identify differences in stakeholder perceptions regarding mine mechanisation.

1.4 Significance of the study

In view of platinum producers transitioning to more mechanised operations, this research is aimed at providing guidance to them. People from various mining backgrounds are likely to benefit from this study, as it covers many aspects of operating in a South African mining environment. The favourable and unfavourable factors that influence mechanisation will be researched from a greater perspective, some of which being safety, employment, mining challenges, and technological innovations.

Since a relatively small number of platinum operations are mechanised, all positive and negative factors are unknown. Anglo American Platinum, the market leader in platinum production, has only one fully mechanised mine (Stoddard, 2014). Existing literature does not provide sufficient information regarding these factors and their extent of influence on mine mechanisation in the platinum industry. For the last two decades, mining research in South Africa has been deteriorating and stakeholders are realising the impact of this lack of research (Vogt, 2011). Therefore, a potential benefit of such a study is to supplement the existing database of mining research.

In general, executives, management, and technical staff from platinum mines may be able to benefit from this research by better understanding the main factors affecting mechanisation. This information will be used in management's strategic decision making and will allow them to direct their efforts and resources appropriately during the planning and execution of a mechanised mining project.

A stakeholder management plan, which is developed by the mining houses, generally considers the different stakeholders involved in mining. There is a possibility of differing stakeholder views regarding certain aspects in the mining industry that can result in failure of that particular aspect. This research will also provide information to the mining houses regarding stakeholder perceptions so that these perceptions can be proactively managed.

1.5 Delimitations of the study

The following delimitations apply to the research:

- This research only focused on the platinum mining sector
- Only factors relating to underground mining were considered. Any factors pertaining to ore processing and refining were excluded from this research
- The research does not consider any accounting benefits.

1.6 Definition of terms

Mine mechanisation is referred to as any machinery, which when used in a mine to either break or transport rocks, reduces human effort or labour (Willis et al., 2004).

Platinum Group Metals (PGM) encompasses platinum, rhodium, iridium, palladium, ruthenium and osmium (Platinum, 2013).

1.7 Assumptions

The following assumptions are applicable to this research:

- Respondents had sufficient knowledge regarding mine mechanisation in the South African platinum sector
- Respondents provided information to the best of their knowledge by reflecting on their professional experience in the industry
- Each stakeholder category sample is representative of the stakeholder category in the platinum industry
- The sample of stakeholders collectively is representative of the platinum mining industry as a whole.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of applicable scholarly literature pertaining to the problem and sub-problems as defined in Chapter 1.

While preparing this literature review, it was noticeable that there are scholarly literature articles available that identifies factors relating to mine mechanisation. However, the applicability of these theories have not been tested or explored in the South African platinum mining sector.

This chapter reviews literature pertaining to factors affecting mine mechanisation. The literature review also touches on the importance of the different stakeholders in the mining industry, and their different interests and perceptions.

2.2 Definition of topic or background discussion

2.2.1 *Definitions*

Definition of Mechanisation
"Mechanisation is the process of creating and deploying specialised equipment that increases the power of human operators by increasing the work outcome relative to the physical human input" (Priester & Trappeniers, 2010, p. 2).

2.2.2 *Platinum industry challenges*

Baxter (2014) emphasises that for many years the supply of platinum had outstripped the demand. With an increase in metal substitutions entering the market, PGM demand has further reduced. While the price of platinum has remained relatively flat since 2008, mining and inflations costs have increased by more than twice the inflation rate. Cost increases can be attributed to a number of factors, namely: energy costs, declining grade, fuel costs, hoisting costs, lower productivity, labour costs, and high ventilation costs due to greater mining depths. Costs for 2014 were 17% higher than in 2013.

For the last decade, production in the platinum sector has also been declining by 0.4% annually due to the following challenges: deeper mining depths, declining grades, less productive blasts, and a decrease in worker productivity (Baxter, 2014).

Platinum (2013) points out that AMPLATS, the industry leader in platinum production, produces 70% of South Africa's production. AMPLATS's value driven strategy is to move towards a greater degree of mechanisation. A decision was taken to convert the mines from conventional to mechanised, therefore, a full set of feasibility studies are underway in order to evaluate the merits of implementing mechanisation.

2.2.3 *Conventional mining*

According to Robbins (2000), some of the advances in mining include dynamites and explosives, which accounts for the small incremental improvements in the mining industry. Conventional mining currently uses the drill and blast method for mining hard rock. The drill and blast operation is a sequential process, which results in two critical issues. The first being the explosion, which results in violent shock waves leading to flying rocks that could potentially injure personnel and weaken the ground support systems. The second critical issue is ventilation, which is necessary for the removal of noxious gasses and replenishment of oxygen. In some cases, mineworkers are instructed to move to a safe distance away from the blast area. Other mines employ more stringent measures in terms of safety and don't allow miners underground during blasting operations. This cyclical or sequential nature of the drill and blast operation has a tremendous negative impact on the mining operation as a whole, resulting in a safety hazard and low productivity.

Unfortunately, conventional mining methods are entrenched in the South African mining industry after more than a century of operating (Willis et al., 2004). In order to change to a mechanised operation, a holistic approach encompassing all areas of mining is required (Willis et al., 2004).

2.3 Factors affecting mechanisation

Based on literature review findings, some of the important factors that influence mine mechanisation are:

2.3.1 *Mine safety*

A critical factor affecting mine mechanisation is mine safety, which is undoubtedly a very important objective for many mining enterprises. Mechanisation prevents mineworkers from being in potentially dangerous environments (Robbins, 2000). Willis et al. (2004) also confirms that automation has led to mineworkers being removed from the face, resulting in lower accident rates. Further agreement is provided by Hattingh, Sheer, and Du Plessis (2010) that improved levels of safety are achieved by minimising the quantity of mineworkers at the mine face through mechanising.

Robbins (2000) mentions that new mechanised technology is being developed to handle hard rock. The new technology will be able to tunnel through the rock continuously and productively, resulting in eliminating the drill and blast cycle, hence leading to a reduction in dangerous activities.

Extensive research conducted by Blank, Diderichsen, and Andersson (1996), on the effects of technological advancements on safety, revealed that there may be favourable effects on the number of injuries and general occupational well-being. The research further stated that technological changes are not a preventative factor; accident risks will also depend on the intrinsic characteristics of the technology implemented, the working environment, and human factors. In another study, conducted by Blank, Laflamme, and Andersson (1997) in the Swedish mining industry, relating to the relationship between technology development and occupational accidents, revealed that when technology development variables were analysed in isolation, then technology is the least potential determinant of occupational accidents. This study also indicated that when other factors were considered, then technology changes alone were insufficient to explain accident rates. Nevertheless, both the studies revealed that there are favourable results in terms of safety when mechanising.

The British coal mining industry reported a reduction in fatalities from 1947 to 1994 by a factor of 60 (Pickering, 2004). The South African gold mining industry reported a drop in fatalities by a factor of 3 from 1947 to 1993 (Pickering, 2004). These reductions are attributed to mine mechanisation (Pickering, 2004).

As indicated by Coleman and Kerkering (2007) in their paper, which looked at fatality incidence rates in the coal industry from 1966 to 2004, there has been a significant downward trend in fatalities. One of the factors attributing to the downward trend is increased level of mechanisation, whereby there has been significant improvement in design of mining systems. Improvements encompass underground mining technology, such as drill jumbos and load and dump vehicles, which display fewer hazards than some of the older methods and machines. It is apparent that the newer technology machines are generally made safer, therefore, results in fewer safety hazards.

The above studies reveal that mine safety is a critical factor when considering mechanisation for the mining industry. This is a common understanding among the authors and historical figures support the fact that safety is one of the most important factors in favour of mechanisation.

2.3.2 *Technology development*

There is a strong drive to develop mining technologies to handle hard rock such as platinum. Coal mining, on the other hand, is extensively mechanised due to the rock being relatively soft (Robbins, 2000). Coal is mined using drag bits or picks that easily penetrate the rock (Robbins, 2000). With harder rocks, machinery pick wear becomes a huge problem and machine downtime is inevitable (Robbins, 2000). In this case, the continuous maintenance of equipment makes the conventional drill and blast method more economical as compared to using mechanised machinery (Robbins, 2000).

Robbins (2000) also mentions that joint ventures between mining companies and Original Equipment Manufacturers (OEM) are fundamental to the success of mechanisation. Mining in hard rock environments will undergo a revolution when hard rock machines are commercialised, resulting in these machines tunnelling through hard rock continuously and productively. Some of the positive outcomes associated with these new technologies are: lower costs, quicker developments and improved safety. Some new mining technologies include raise drills and tunnel boring machines (TBM) with a practical disc cutter.

Although raise boring is used in many underground engineering applications, it is also applicable to the underground mining industry. The raise boring machine is an example of technology advancement in the mining sector (Liu & Meng, 2015). The new machine has completely changed the working conditions during raise construction; workers operate machines at a safe working distance from the face (Liu & Meng, 2015).

Willis et al. (2004) indicate that a major barrier to mechanisation is poor communication between technology providers and technology users. Hattingh et al. (2010) support this view that relationships between stakeholders are critical to the successful implementation of mechanisation. Further confirmation is evident from the implementation of trials at LONMIN, where one of the key elements to technology development was the trust exhibited between the OEM and mining houses (Pickering & Moxham, 2007).

During the implementation of extra low profile (XLP) series of equipment at AMPLATS, one of the major problems experienced was the long OEM technology development lead time (Harrison, 2008). These long lead times are inhibiting the successful implementation of mechanisation.

Technology development is an important factor that will aid mine mechanisation, provided that better lead times are achieved and good relationships between OEM and mining companies are maintained.

2.3.3 *Skills availability and training*

South Africa is currently experiencing a shortage of skilled technical people. The right skills set for mechanisation is a very important success factor. Willis et al. (2004) emphasise that employees have to be educated and informed about mechanisation. Training and development of employees in order to use new technologies is crucial to the successful implementation of mechanisation.

Harrison (2008) shows that during the implementation of the XLP technology range at AMPLATS, it was evident that availability of mechanised mining skills and artisan skills were major barriers to performance and productivity. The studies of Hattingh et al. (2010) also support the fact that skills availability and training is a pivotal success factor for the successful implementation of mechanisation.

LONMIN also experienced high costs due to equipment damage, which led to the focus on mechanised equipment operators (Webber, Van Den Berg, Le Roux, & Hudson, 2010). Operators were mainly trained theoretically on arrival at the mines, and were not able to add much value (Webber et al., 2010). Simulation based training was arranged in order to improve their practical skills (Webber et al., 2010). This initiative certainly reduced the amount of damages to mechanised machinery (Webber et al., 2010).

Further findings of Webber et al. (2010) points out that general engineering skills also provided a challenge at LONMIN. The practical skills and general knowledge of artisans were a major concern for LONMIN, specifically for the XLP equipment. Sandvik, an equipment vendor, had to arrange specialised training for artisans and maintenance supervisors.

Research conducted by Neingo and Cawood (2014) indicate that although mechanisation is perceived to increase productivity, this cannot be achieved on its own. In a study conducted at three of Anglo American Platinum mines, namely Bathopele, Kroondal and Mototolo, it was concluded that labour utilisation in conjunction with mechanisation is imperative for better profitability. One would expect that mine mechanisation would result in better profits, while productivity would depend on equipment utilisation, but labour skills availability was found to be critical to the success of the mines profitability.

A paper published by Webber et al. (2010) regarding mechanisation trials at LONMIN supports the general thinking that technical skills are a shortage. Many supervisors at LONMIN’s Hossy mine was found to have minimal mechanised mining skills. On the job training was specifically developed for supervisors by Sandvik and Trans4mine (mining equipment vendors). The training focussed on extra low profile (XLP) equipment.

Most of the authors are in agreement that availability of mechanisation skills is a major barrier to mechanisation, and training and development of mineworkers is a prerequisite for the successful implementation of mechanisation.

2.3.4 *Social issues*

According to Willis et al. (2004), unemployment is a serious and sensitive issue to be considered when mechanising. Mechanisation generally results in a reduction of low skilled workers. Mechanisation can also be a driver for investment in education, training and development. Although fewer people will be employed directly by the mine, many people will be employed by secondary industries, such as servicing and manufacturing of new technologies. Therefore, increased work opportunities could exist within the mining industry as a whole.

When new mechanised iron ore mines opened in Sishen and Phalabowra, there was a noticeable replacement of unskilled black labour by skilled white repair and maintenance workers. In the iron ore industry, between 1975 and 1978, the black to white worker ratio decreased from 4.56 to 2.24 (Spandau, 1980). Due to the requirement for skilled labour, unemployment increased (Spandau, 1980).

Research conducted by Ali and Hattingh (2014) revealed that labour unrest is a major deterrent to mining investment and sustainability. Labour unrest has a tremendous negative impact on mining operations. The number of work days lost in South African mining increased from 13% to 82% between 2011 and 2012. The labour unrest in 2012 resulted in a R12 billion decline in production. The strikes and work stoppages also resulted in a decline in GDP contribution from 5.7% in 2011 to 4.1% in 2012. Accordingly, the labour disputes has triggered more talks to mechanise (Dixon, 2014).

Unemployment is certainly an important factor affecting mechanisation. Historical figures indicate that more highly skilled labour is required and fewer low skilled labour for mechanised mines. Spandau (1980) findings lead to result that unemployment will result in fewer people being employed by the mine, but Willis et al. (2004) further states that secondary jobs will be created and there is a possibility of more jobs being created in the mining industry.

2.3.5 *Productivity*

Jones (1983) found that during the mechanisation of the coal mining industry, an interesting observation was made. Increase in productivity due to mechanisation was reduced due to set backs during the learning periods related to the implementation of new technologies. Productivity was only up when employees were familiar with the new technologies through training. Industry management did not anticipate the growth in spares and capital stock associated with equipment repairs. Lack of coordinated planning and preparedness were also factors that resulted in delayed productivity.

Willis et al. (2004) emphasise that productivity has been highlighted as one of the main drivers for mine mechanisation. Increased or improved productivity is a perceived result of mechanisation. This is achieved by reducing the number of mineworkers' underground, resulting in simpler transport logistics and lower labour overheads.

The British coal mining industry reported that mine mechanisation increased productivity from 260 tonnes per annum per employee in 1947 to 5810 tonnes in 1994 (Pickering, 2004). The South African gold mining industry reported an increase in productivity from 146 tonnes of rock per employee per year in 1947 to 333 tonnes per employee per year in 1993 (Pickering, 2004).

Based on the measure of productivity being production per employee (Pickering, 2004), an increase in production is due to an increase in productivity , provided that the number of employees does not increase. Generally, the number of employees at a mine doesn't increase when mechanising, as described in Section 2.3.4, therefore, an increase in production is attributed to an increase in productivity.

Historical figures indicate that mechanisation leads to higher levels of productivity. Organisations need to be aware that productivity doesn't increase immediately; there will be a lag before mine workers become familiar with the new technology and productive.

2.3.6 *Lifecycle cost*

The economics of mechanisation is severely impacted by the cost of labour (Priester & Trappeniers, 2010). Research that was conducted in different countries, namely Guyana, Sierra Leone and Brazil, confirmed that wage had a considerable effect on the level of mechanisation (Priester & Trappeniers, 2010). In some countries where labour is very cheap, it was not economical to mechanise (Priester & Trappeniers, 2010).

Robbins (2000) stresses that lifecycle cost (overall cost) associated with mechanisation is lower. Although initial capital outlay (CAPEX) may be substantial, but over a long period of time, cost will be lower. Lower lifecycle cost, which is achieved by faster mining, is one of the most important drivers for mechanisation.

It is evident that labour cost is a high proportion of the mines operating costs (OPEX). When mechanising, a smaller workforce is required, resulting in a reduction in costs over the life of the mine.

2.3.7 *Mining complexities and challenges*

When reefs are narrow, and not always conducive to mechanised mining techniques, then conventional mining methods are employed because mechanisation may not be feasible (Whittle & Burks, 2010).

According to research conducted by Nong (2011), mechanised mining generally leads to higher waste quantities or dilution. Dilution is the reporting of waste into the reef or mineralised rock stream. The reason for dilution could be poor waste management, but mechanised equipment also contributes to increased waste due to larger excavation sizes required. This would render mechanisation unsuitable or limiting for narrow ore body mining. Waste dilutes the grade of the mine and results in a higher production cost per tonne of ore, leading to lower revenues. Stewart (2013) findings also support the view that mechanised machines require massive stope widths, which necessitates large excavations of waste rock leading to grade dilution.

Complexities in the ore body remain an important factor when planning to mechanise. Compromised integrity of the rock or discontinuous reef (faults) makes mechanisation very difficult (Nong, 2011). Upfront geological studies must be conducted to confirm if a mechanised mining option will be feasible. In areas where a high frequency of faulting occurs, mechanised mining methods may not be viable (Nong, 2011).

As mentioned earlier in Section 2.3.2, with harder rocks like platinum, machinery pick wear becomes a huge problem and machine downtime is inevitable (Robbins, 2000). In this case, the continuous maintenance of equipment makes drill and blast more economical as compared to using machinery (Robbins, 2000).

The mining complexities generally affects a decision to mechanise unfavourably and leads to the adoption of conventional or hybrid methods.

2.3.8 *Mine design and planning*

Morin (2002) emphasises that the design of a mine is a very complex process. The design process is iterative and must consider the inter-related variables. Once the ore reserve determination has been finalised, the mine design or pre-production planning commences. This stage considers the technology to be used and its availability, the mining method applicable to the ore deposit, production rates, etc. The early mine planning project must consider the equipment to be used, as this could have a severe impact on mechanisation. Mine access design must allow for sufficient access to the ore body using mechanised methods and equipment. Equipment selection is also critical and must be integrated into the design process.

Many technology implementation projects have failed due to incorrect equipment selection, i.e. the equipment was either too advanced for the current mining infrastructure or the level of available skills for the machines was too low (Macfarlane, 2001). Therefore, it is necessary to take a holistic view when selecting technology.

.Advanced equipment alone will not produce a successful mine; thorough mine design and planning, correct equipment selection, and integrating the equipment with the mine's existing infrastructure will produce a successful mechanised mining operation (Willis et al., 2004).

2.3.9 *Organisational factors*

Hattingh et al. (2010) found that successful mine mechanisation is not just reliant on mine layout design and the actual mining technology; rather, there are several human factors that affect the success of mine mechanisation. Some of these factors include leadership, change management, mine management, and operation of the mine.

One of the biggest problems, as explained by Pulkkinen (1990), was the way of thinking which led to the low success rate of mine mechanisation. Willis et al. (2004) provide another view regarding organisational factors that play an important role in mechanisation. Senior managers in mines may be unwilling to implement mechanisation because of their short tenures, as they believe that they will not be present to reap the benefits. Change management is an important factor to address these issues.

Mechanisation is perceived to improve work conditions by providing more stimulating and satisfying work (Hattingh et al., 2010). Mechanisation will also facilitate workplace gender changes and lead to the employment of HIV positive workers (Hattingh et al., 2010). This is achieved through the use of machines to do physically demanding work. Priester and Trappeniers (2010) advocate Hattingh et al. (2010) findings that mechanisation leads to improved working conditions.

Numerous organisational issues tend to inhibit mine mechanisation. Management and leadership play an important role in making mechanisation successful. Mechanisation will also lead to a better workplace environment.

2.3.10 *Conceptual framework for research*

Figure 1 depicts a summary of all the factors that affect mine mechanisation derived from the literature review.

Figure 1: Summary of mechanisation factors

Figure 2 forms the conceptual framework for the research. The factors that were described in Figure 1 were grouped into three main categories and were the variables used to conduct the research, complete the analysis, and interpret the results in order to address the research questions. Mechanisation projects follow a logical process of deciding whether to mechanise and then implementing the project. Finally mechanisation will lead to certain outcomes, therefore, the three main categories used are; decision to mechanise, implementation of mechanisation, and outcomes of mechanisation.

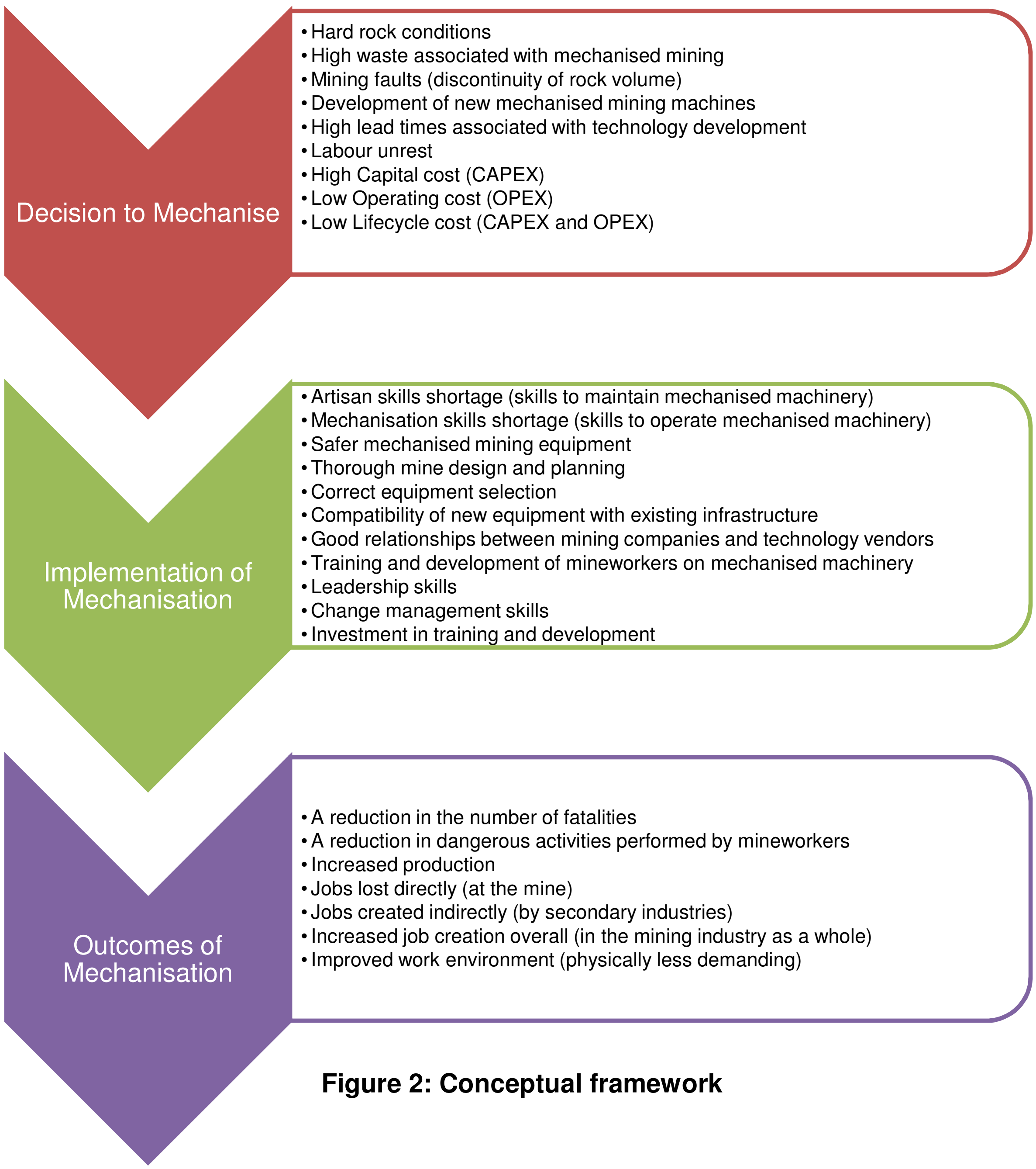

Figure 2: Conceptual framework

2.4 Stakeholder perception

Stakeholder theory states that firms have a responsibility to deliver value to their stakeholders instead of only delivering value to customers and shareholders (Mutti, Yakovleva, Vazquez-Brust, & Di Marco, 2012). Stakeholders are considered as people, groups or constituents that contribute to the organisations operations and wealth, either involuntarily or voluntarily (Mutti et al., 2012). Many enterprises currently operate using a stakeholder approach which is depicted in Figure 3.

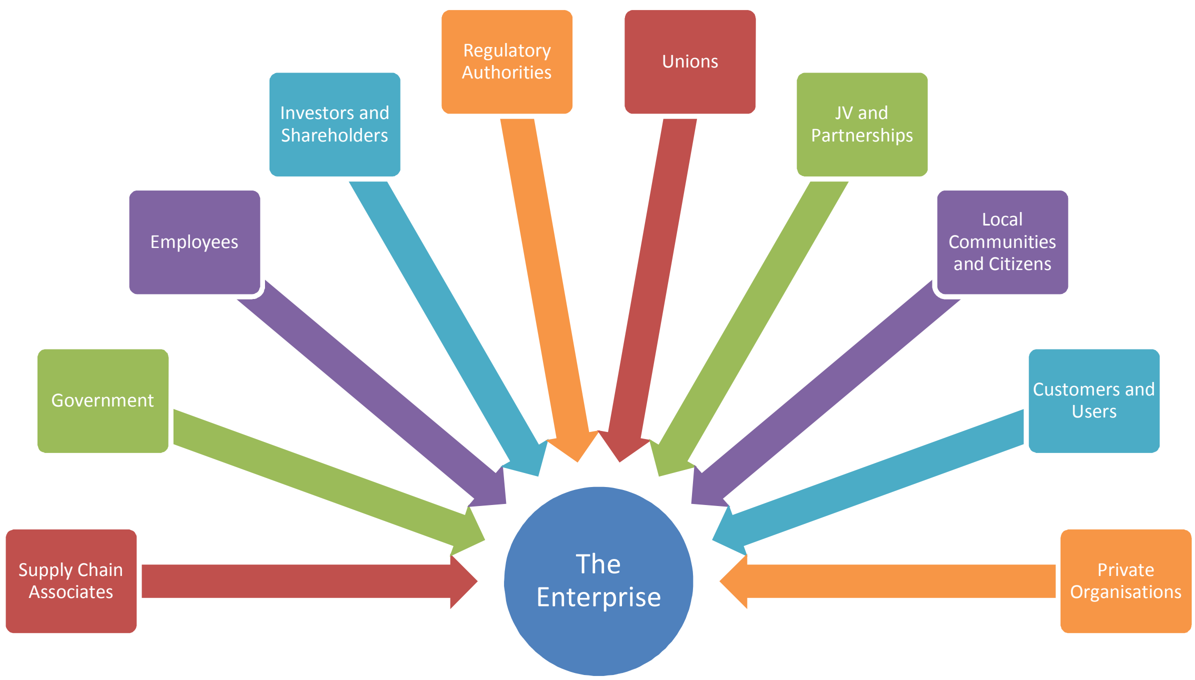

Figure 3: Stakeholder approach

According to Mutti et al. (2012), some of the important factors relating to stakeholder theory are:

- Benefits and threats associated with stakeholders and companies: Local communities can disrupt an organisation's operations if certain compensation is not provided, e.g. wage strikes.

- Varied interest of stakeholders: It is difficult for companies to satisfy the interest of all stakeholders. Due to the varying interests of stakeholders, it may be a case whereby one stakeholder may be satisfied at the expense of the other.
- Stakeholder network and roles: Companies do not respond to stakeholder queries on an individual basis. There are groups of stakeholders e.g. government, environmental, legal, etc.
- Stakeholder management: This is important because the interests of stakeholders are included in the process of business strategy development.

In a paper published by Stacey and Stacey (2009), an illustrative example regarding sustainable development in the mining and minerals industry revealed a number of stakeholders with differing interests and perceptions. The stakeholders engaged were shareholders, communities, civil society, employees, and government. The main aspects investigated were:

- Corporate social investment (CSI)
- Environmental management
- Financial performance of the mines
- Infrastructure development
- HIV/Aids
- Safety

The different stakeholders provided different perspectives on each of the aspects. Safety was rated very highly by shareholders and employees. Shareholders rated financial performance as a high priority, while communities rated it as the lowest priority. CSI spend received a high rating by only the communities.

Many organisations in South Africa, particularly the platinum mines, operate using a “stakeholder approach” as opposed to a “shareholder approach”. Due to the complexities of operating in contemporary South Africa, it is important that all stakeholders work together. For example, companies need the communities, and communities need companies to create a sustainable future. Mining companies also need technology development firms to implement new technologies, and vice versa. Some of the major stakeholders in the mining sector are the mine employees, unions, suppliers, technology partners and consultants. It is imperative that all stakeholders are aware of the mining organisations strategies and how they affect them. Based on the nature of stakeholders, and as stated in the theory, there is often varied interest, misunderstandings or disagreements between stakeholders that could result in failure of a particular project or initiative. Different stakeholders have differing perspectives and it is important to identify the differences and manage the different perceptions.

According to Sachs, Post, and Preston (2002), shareholders' role is to manage risk and cost, employees roles are focussed on team production and collaboration at work. Unions are responsible for workforce stability and conflict resolution. Private organisations seek to supplement their firm's own resources.

Based on stakeholder theory, management, who is driven by cost and risk management, will tend to rate productivity and lifecycle cost as more important factors. Unions, whose interest is the stability in the workforce, is likely to rate unemployment as one of the critical factors influencing mechanisation. Private organisations, specifically technology developers, whose interest is supplementing their own resources, are likely to rate technology development high. Consultants, who execute projects on behalf of clients, aim to maintain client relationships and act based on the instruction of the client (management). Consultants would, therefore, also tend to rate cost and productivity as more important factors.

2.5 Conclusion of the literature review

After reviewing the academic literature regarding mechanisation within the mining industry, certain conclusions are drawn pertaining to the factors that affect mechanisation. Conclusions regarding stakeholder perceptions are also drawn from the literature review. The findings from the literature review enabled the researcher to develop a conceptual framework for the research.

2.5.1 *Summary of literature*

After conducting the literature review, it is evident that the platinum industry has some major challenges. The current conventional drill and blast method for mining platinum has been shown to be labour intensive, dangerous and low in productivity. The platinum industry also faces numerous challenges, some of which are: mining challenges, rising operational costs, and low worker productivity. The necessity to mechanise mining operations is now a reality in order for mining organisations to be sustainable and competitive in both, local and global, markets. The key factors identified that influence mechanisation of mines are mine safety, social issues, technology development, productivity, skills and training, lifecycle cost, mining complexities, mine design and planning, and organisational factors. Some of these factors have a higher degree of influence, either positively or negatively, than some of the other factors. Stakeholder management is a critical aspect of the mining business. It is imperative to consider the different stakeholders and their perceptions when mechanising. Due to the differences in interests and perceptions of stakeholders, one can expect resistance to mechanisation from some stakeholders.

2.5.2 *Formulation of propositions*

Based on the literature review and research sub-problems, the following propositions have been drawn:

Sub-problem 1

To identify and evaluate favourable factors affecting mine mechanisation based on key stakeholder perceptions

Proposition 1

Some of the favourable factors affecting mine mechanisation are: mine safety, productivity, operating cost (OPEX) and lifecycle cost (overall cost), mine design and planning, employment, technology development, skills development, organisational factors and labour unrest. Three factors, namely: mine safety, productivity and lifecycle cost (overall cost) are very favourable factors.

Sub-problem 2

To identify and evaluate unfavourable factors affecting mine mechanisation based on key stakeholder perceptions

Proposition 2

Some of the unfavourable factors that affect mechanisation are: mining complexities, high technology development lead times, direct job losses, high capital cost (CAPEX) and skills shortage. Skills shortage seems to be a very unfavourable factor.

Sub-problem 3

To identify differences in stakeholder perceptions regarding mine mechanisation.

Proposition 3

The different stakeholders have different interests and perceptions regarding the factors that affect mine mechanisation. Management will tend to rate productivity and cost as more important factors. Unions are likely to rate unemployment as one of the critical factors influencing mechanisation. Technology developers are likely to rate technology development high. Consultants would also tend to rate cost and productivity as important factors. There are no differences in perceptions between the stakeholders in terms of mine safety.

CHAPTER 3: RESEARCH METHODOLOGY

This chapter describes the methodology that was employed to conduct the research. Firstly, the research method, the research design, and the research procedure are discussed. Other aspects, such as target population and sampling, data collection and storage, data processing and analysis are also discussed. Finally, validity, reliability, and limitations to the research are highlighted.

3.1 Research methodology/paradigm

There are three types of research methodologies, namely, quantitative, qualitative and mixed methods. This study will utilise a quantitative research methodology.

A quantitative method involves “methods used to understand variation in things, test causal relationships, and identify the prevalence or distribution of phenomena; also the use of statistical tools to interpret data” (Kalof, Dan, & Dietz, 2008, p. 204).

This study establishes the extent to which factors influence mine mechanisation within the platinum sector. The research goes further to identify differences in stakeholder perceptions regarding the identified factors. Therefore, to provide the ability to measure the extent and identify differences, the study employed a quantitative research methodology.

3.2 Research design

There are primarily five research designs, namely, experimental, cross-sectional, longitudinal, case study, and comparative. This research applied a cross-sectional research design.

A cross-sectional design is a research design that involves the collection of data on more than one case at a single point in time in order to collect quantifiable or quantitative data in connection with two variables, which are examined to see if there is any association (Bryman, 2012).

This study focuses on identifying and evaluating favourable and unfavourable factors that influence mechanisation at a particular point in time, and is not interested in determining trends over time. Experimental methods for this type of research require large amounts of capital investment. Case studies and comparative studies require organisational information which is not always accessible. Organisations are also not always willing to disclose their intellectual property due to the element of competition in the market. This research employs a cross-sectional design and is exploratory in nature, as the researcher aims to gain insights or themes from the research.

3.2.1 *An example of a similar study*

This research adopts a similar approach to a study conducted by Ghosh, Bhattacherjee, and Chau (2004), at the coal mines in Eastern India, where the researchers approached three underground coal mines to conduct the research. The research methodology was quantitative; the design was cross-sectional, and used questionnaires targeted at different stakeholders. The quantitative methodology was used to determine which factors played a significant role in occupational injuries.

3.3 Population and sample

3.3.1 *Population*

The population for this research comprise key stakeholders in the platinum mining industry. For this research, the following five stakeholder categories were initially considered: management employees of mining houses, technical employees of mining houses, mining equipment vendors, consultants, and trade union representatives. Unfortunately, many trade union representatives were not able to participate in the research. Numerous attempts were made to acquire information from the trade unions, but due to the sensitive nature of this research topic, trade union representatives were reluctant to participate in the research. The trade union representatives' response rate was extremely low. With only having 3 valid responses from the trade unions, generalisation is not possible within this stakeholder category; therefore, they are excluded from this research.

The final population for the research, therefore, includes four stakeholder groups. These stakeholders include people who are familiar with platinum mining in South Africa. The four different stakeholders make up the population. These are employees or ex-employees who have experience within the platinum mining sector. Below are details of the stakeholder groups:

- Mining house management staff (executives and management staff from the mining houses)
- Mining house technical staff (engineers, designers, production managers, etc. from the mining houses)
- Consultants (people who undertake studies and implementation projects for clients)
- Equipment vendors that supply mining equipment or develop new technologies.

The main reason for selecting this population is because of the wealth of knowledge that rests within this population. The target population is also diverse in order to get a representative and realistic view of mechanisation in the platinum industry.

3.3.2 *Sample and sampling method*

This research used an inferential approach. Survey research was performed on a sample to determine certain characteristics, and then inferred to the defined population (Kothari, 2011). This is a non-probabilistic sample, as every member of a population does not have an equal chance of being included in the sample (Kalof et al., 2008).

This study employed a web based survey and convenience sampling, as it is common to use a group that has email and internet access. Web based survey typically uses convenience sampling techniques (Kalof et al., 2008).

The final sample comprised a predefined quantity of respondents. The respondents were from the list of stakeholders mentioned, and the sample comprised:

- Employees (management and technical staff) from the mining houses, including AMPLATS, LONMIN, IMPLATS and Northam Platinum

- Consultants from HATCH, TWP Consulting and DRA, who execute many mining projects on behalf of the platinum mining clients
- Employees from equipment vendors involved in equipment supply and mining technology development, including: Sandvik, Joy Mining, FLSmidth and Atlas Copco.

Race, age, education or any other background limitations were not imposed on individuals. As long as they were categorised in one of the predefined stakeholder categories, it was acceptable.

Since this study employs a quantitative method of research, it was important to get an adequate quantity of respondents for the study to be reliable and valid. For the purpose of this study, a planned amount of 120 respondents were deemed sufficient. The breakdown of the sample for each stakeholder category is indicated in Table 1.

Table 1: Planned profile of respondents

Description of respondent type	Planned Number to be sampled
Mining house management staff	30
Mining house technical staff	30
Consultants	30
Vendors	30
Total	120

3.4 The research instrument

This research was carried out using a self-administered web based questionnaire; the actual questionnaire is shown in Appendix B. Web based research is popular and has extended beyond academic research to businesses, marketing and other industries (Kalof et al., 2008). This survey employed a set of predetermined questions administered in a designated order. The survey was designed specifically for this research and not based on any other studies in the past. The questions were designed from the information gathered in the literature review. One of the major downsides of online surveys is that there are people without internet access or computer skills (Kalof et al., 2008). Therefore, convenience sampling solved the problem of internet access issues (Kalof et al., 2008). The questionnaire was designed to be very simple such that the questions were easily understood by the sample population (Kalof et al., 2008).

The major sections of the questionnaire encompass:

- A cover letter
- Stakeholder category
- The main body comprising the subject specific questions.

The questionnaire, with a five point Stapel scale (as depicted in Table 2) ranging from very favourable to very unfavourable, was used to gather the data.

Table 2: Stapel scale divisions

Rating	Description
1	Very Unfavourable
2	Unfavourable
3	Neutral
4	Favourable
5	Very Favourable

One of the limitations associated with the Stapel scale is that one is unable to gauge by how much more or less a respondent is favourable or unfavourable towards a particular aspect of mechanisation (Kothari, 2011). There is also no basis that indicates that the scale is equally spaced between the ratings. The scale, however, supports the aim of the study to an extent, which is to determine whether the respondents are more or less favourable towards a particular factor (Kothari, 2011). The scale ordinate responses were also rescaled, as shown in Section 4.4.

The questionnaire structure comprised the following four parts:

- The first part pertains to stakeholder categories
- The second part relates to the decision to mechanise
- The third part pertains to the implementation of mechanisation
- The last part relates to the outcomes (results) of mechanisation.

Part 1

Select the category that reflects your position or role
Mining house technical staff (Engineer/Scientist/Designer/Machine Operator/Artisan)
Mining house management staff (Project Management, Engineering Management, Senior Management, Director)
Consultant
Vendor (Technology Developer, OEM (Original Equipment Manufacturer, Equipment Supplier)
Trade union representative

Part 2

How, favourably or unfavourably, do the following factors affect the decision to mechanise:
Hard rock conditions
High waste associated with mechanised mining
Mining faults (discontinuity of rock volume)
Development of new mechanised mining machines
High lead times associated with technology development
Labour unrest
High Capital cost (CAPEX)
Low Operating cost (OPEX)
Low Lifecycle cost (CAPEX and OPEX)

Part 3

How, favourably or unfavourably, do the following factors affect the successful implementation of mechanisation:
Artisan skills shortage (skills to maintain mechanised machinery)
Mechanisation skills shortage (skills to operate mechanised machinery)
Safer mechanised mining equipment
Thorough mine design and planning
Correct equipment selection
Compatibility of new equipment with existing infrastructure
Good relationships between mining companies and technology vendors
Training and development of mineworkers on mechanised machinery
Leadership skills
Change management skills
Investment in training and development

Part 4

To what extent are the following outcomes of mechanisation favourable or unfavourable:
A reduction in the number of fatalities
A reduction in the number of dangerous activities
Increased production
Jobs lost directly (at the mine)
Jobs created indirectly (by secondary industries)
Increased job creation overall (in the mining industry as a whole)
Improved work environment (physically less demanding)

3.5 Procedure for data collection and storage

Contact was made with the various stakeholders using email contact and social media. The message to respondents included an email cover letter (included in Appendix A) with a brief explanation, which informed the respondents about the topic being researched. A link to the online questionnaire was sent to the various respondents and data was gathered automatically using the online survey software. Data collected was backed up using an external hard disk and a server to minimise the risk of loss.

In total, the actual number of responses exceeded the planned number as can be seen in Table 3. The actual number of responses also exceeded the planned number of responses for all the stakeholder groups. As mentioned previously in Section 3.3.1, trade union representatives were excluded from the research.

Table 3: Actual number of responses

Description of respondent type	Actual responses
Mining House Technical Staff	35
Mining House Management Staff	37
Consultants	37
Vendors	33
Total	142

3.6 Data analysis and interpretation

Data analysis followed the process highlighted in Figure 4. Descriptive statistics was used to determine the response frequencies, response means and standard deviations. This enabled the researcher to identify which factors positively and negatively affect mine mechanisation. The descriptive statistics also allowed the researcher to be able to deduce the extent to which the factors affect mechanisation.

Figure 4: Data analysis process

An exploratory factor analysis (EFA) was used to establish latent factors that affect mechanisation. This research did not aim to confirm an existing theory, hence the use of exploratory factor analysis instead of confirmatory factor analysis (CFA) (Hair, Black, Babin, Anderson, & Tatham, 2006). The factors obtained for the research framework represent theoretical factors or variables. The factor analysis, which is a multivariate technique, was used to determine the structure underlying the variables, resulting in derived latent (empirical) factors (Hair et al., 2006). The EFA was also used to confirm the current structure used in the questionnaire and enable easy comparison of stakeholder perceptions.

Comparison between the different stakeholders or categories was done using analysis of variance (ANOVA). ANOVA was used to determine statistical significance of mean differences between the groups (stakeholders) (Pelham, 2012).

3.7 Limitations of the study

Some of the limitations of this research are as follows:

- The study depended on people answering the questions honestly and to the best of their knowledge through experience gained in the platinum industry
- This survey was not used in previous research, resulting in the study being exploratory in nature
- It was difficult to track and follow up on respondents who did not fill in the questionnaires

- If there is a question that was not well understood, the respondent did not have an opportunity to clarify the question
- This research is open to researcher bias, however, strict procedures were adopted in order to minimise the effect of this limitation (Kalof et al., 2008)
- This study is cross-sectional; the data was collected at a particular point in time. Any future trend prediction must be done with caution as stakeholder views change over time with new developments.

3.8 Validity and reliability

It is crucial that the research contains an acceptable level of validity and reliability. The research instrument must be able to measure what it was intended to measure (validity) and produce repeatability (reliability) (Kalof et al., 2008). Validity also means a 'goodness of fit' between the research details, the evidence, and the conclusions drawn from the research (Kalof et al., 2008).

3.8.1 *External validity*

External validity refers to the ability to generalise conclusions from the research to the larger (intended) population (Kalof et al., 2008). With reference to this study, the main issue is whether the findings will be able to be generalised to the platinum sector. The high number of responses achieved supports external validity. The various key stakeholders that were approached are a representative sample of the platinum industry and supports external validity.

The questionnaire design and questions were specific to the topic and simple to understand. The questionnaire was designed to include only 28 questions in order to maintain the respondent's concentration and accuracy of response to each question.

3.8.2 *Internal validity*

Internal validity relates to the appropriate conclusions being drawn from the collected data (Kalof et al., 2008). The variables in the study must measure what they are intended to measure (Kalof et al., 2008). It is very important that content validity, which measures the extent to which the instrument covers the topic, is maximised (Kothari, 2011). Content validity is achieved by a thorough literature review where information on each factor was gathered through several variables or theoretical factors.

A pilot study was conducted using a few respondents. The pilot study was aimed to help address any misconceptions or weaknesses regarding the questions, and improve internal validity (Kothari, 2011). The questionnaire was updated taking into account the pilot study findings before being sent out to the actual respondents.

Details of the pilot study are as follows:

- The pilot study included 7 people
- Changes were made to stakeholder categories to avoid ambiguity
- The main questions were simplified, as the original questionnaire was found to be difficult to interpret

After making changes to the questionnaire, the pilot study respondents felt that the changes did remove ambiguity and was simpler to understand.

Apart from construct validity as described by a well-defined set of variables from literature and the pilot test, the researcher found it necessary to further check convergent and discriminant validity.

Convergent validity means that the theoretical factors (variables) grouped under a latent factor are highly correlated (Hair et al., 2006). This is evident from the factor loadings in Table 9. Generally, smaller sample sizes require larger factor loadings (Hair et al., 2006). The researcher used a sample size that was adequate and not classified as small (less than 50) (Hair et al., 2006). Williams, Brown, and Onsman (2012) indicate that a minimum value of 0.3 is acceptable for factor loadings; therefore, the researcher used a cut-off factor loading of 0.3. The result of the factor analysis revealed that all retained factors had loadings of greater than 0.4; thus, indicating a high degree of convergent validity.

Discriminant validity refers to the extent to which the factors are uncorrelated (Hair et al., 2006). Variables must relate more to their own factor than the other factors, and load significantly on only one factor (Hair et al., 2006). The researcher examined the matrix for cross loading, and since there was no evidence of cross loading, a high degree of discriminant validity prevailed.

3.8.3 *Face validity*

Face validity effectively means that the research “on the face of it” makes sense to a lay person (Greener, 2008). Finally, the researcher checked the results for face validity and the results do make sense.

3.8.4 *Reliability*

Reliability regarding research is about being consistent. A research or study is deemed reliable if similar findings are found after repeated application of the research (Kalof et al., 2008). Even if a perfect instrument is designed for a survey, there will still be some challenges in the sense that people’s responses are not always the same for the same questions. Various factors can affect the responses, namely the time of day, mood, behaviors, attitudes, etc.

The relevance of reliability in this study is the ability of the instrument to provide similar results when the research is carried out. Reliability was achieved by receiving a substantial number of respondents resulting in a representative sample. The sample size of 142 is deemed acceptable and supports reliability.

Sample size also has an impact on reliability of factor analysis results (Yong & Pearce, 2013). Generally, the larger the sample size, the better. Costello and Osborne (2011) highlight the fact that most factor analyses (63.2%) have been done with a subject to item ratio of 10:1 or less. Majority of factor analysis have been done using a subject to item ratio between 2:1 and 5:1. The subject to item ratio for this research is 5.25 and is deemed acceptable.

Reliability also means that the variables will consistently load on the same factor. One way to check for this is using Cronbach’s alpha (Hair et al., 2006). A value of 0.7 is generally accepted as the lower limit (Hair et al., 2006). The computed Cronbach’s alpha coefficients are 0.879, 0.799, 0.777 and 0.634 for Factor 1, Factor 2, Factor 3 and Factor 4 respectively (as shown in Table 4). Although Cronbach's alpha for Factor 4 is slightly lower than the generally accepted lower limit, this value may decrease to 0.6 for exploratory research (Hair et al., 2006). The computed Cronbach's alpha coefficients revealed that there is an acceptable level of reliability. More details regarding Cronbach's alpha is included in Appendix D.

Table 4: Cronbach's alpha

Cronbach's alpha	
Factor	**Value**
Factor 1	0.879
Factor 2	0.799
Factor 3	0.777
Factor 4	0.634

Another aspect of reliability is equivalence. Equivalence was attained through the use of only one method of data collection. Further to this, multiple questions were asked on the same factor in order to improved reliability (Kalof et al., 2008). The number of questions was also kept to a minimum to prevent fatigue and capture accurate data.

CHAPTER 4: PRESENTATION OF RESULTS

4.1 Introduction

The preceding chapter laid the foundation for the collection and analysis of the data. This chapter presents the research results. No attempt is made to interpret the results in this chapter, as the interpretation will be addressed in Chapter 5 of the research report.

The presentation of the results follows the process described in Figure 4, which is depicted in the methodology chapter of this report. The research results are presented in the following order:

- Descriptive statistics
- Exploratory factor analysis
- Analysis of variance (ANOVA)

The online questionnaires were sent out with 28 questions and the responses were evaluated using a 5 point Stapel scale ranging from very unfavourable to very favourable.

Data gathered from the questionnaires were subjected to statistical analyses. Descriptive statistics highlighted the profile of the respondents, frequency of responses, means and standard deviations. The exploratory factor analysis revealed the underlying structure of the data and finally the ANOVA indicated if there are significant differences in the means of the stakeholder groups'.

4.2 Sample profile

The total sample size is 142. Of the total sample, the number of responses for each stakeholder category is very similar; each stakeholder category responses contribute to approximately a quarter of the total as depicted in Figure 5.

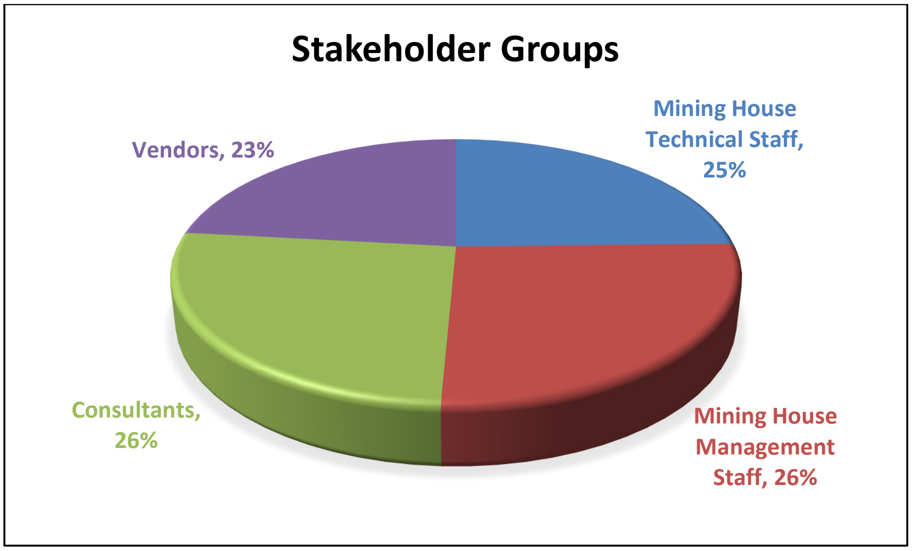

Figure 5: Sample profile

4.3 Frequency distribution

Frequency refers to the number of occurrences of data values that fall within a class or rating (Isotalo, 2001). The frequencies of responses are depicted in Table 5 with the highest frequencies (modes) being highlighted. This table depicts responses to each question in terms of the actual percentage of responses (of the total number of responses) for each rating.

After examining the frequency table, there are no frequencies for a single factor within close proximity of any two ratings. The minimum difference between the highest and second highest frequency for the factors is 7%. There were no factors present where most of the respondents responded very unfavourable or neutral.

Unfavourable, favourable and very favourable responses can be seen in Table 5. The frequency response table shows that most of the respondents selected unfavourable for 7 factors, favourable for 16 factors and very favourable for 4 factors. Some of the factors that received unfavourable responses were skills shortages, job losses and capital cost (CAPEX). Most of the respondents selected very favourable for 4 factors, namely, a reduction in the number of fatalities, a reduction in dangerous activities, increased production, and labour unrest.

Table 5: Frequency table

	Theoretical Factor	Very Unfavourable	Unfavourable	Neutral	Favourable	Very Favourable
Q2.1	Hard rock conditions	8%	23%	27%	34%	8%
Q2.2	High waste associated with mechanised mining	17%	39%	30%	11%	3%
Q2.3	Mining faults (discontinuity of rock volume)	19%	35%	26%	17%	3%
Q2.4	Development of new mechanised mining machines	4%	9%	10%	55%	22%
Q2.5	High lead time to develop mining technology	10%	45%	21%	17%	6%
Q2.6	Labour unrest	19%	13%	11%	19%	38%
Q2.7	High capital cost (CAPEX)	13%	49%	20%	10%	8%
Q2.8	Low operating cost (OPEX)	3%	7%	10%	48%	32%
Q2.9	Low lifecycle cost (CAPEX and OPEX)	3%	9%	23%	42%	23%
Q3.1	Artisan skills shortage (skills to maintain mechanised machinery)	24%	45%	11%	10%	9%
Q3.2	Mechanisation skills shortage (skills to operate mechanised machinery)	18%	51%	16%	10%	5%
Q3.3	Safer mechanised mining equipment	1%	3%	7%	50%	38%

	Theoretical Factor	Very Unfavourable	Unfavourable	Neutral	Favourable	Very Favourable
Q3.4	Thorough mine design and planning	0%	4%	19%	49%	28%
Q3.5	Correct equipment selection	0%	4%	12%	52%	32%
Q3.6	Compatibility of new equipment with existing infrastructure	8%	23%	13%	42%	13%
Q3.7	Good relationships between mining companies and technology vendors	1%	4%	26%	51%	17%
Q3.8	Training and development of mineworkers on mechanised machinery	3%	16%	15%	43%	22%
Q3.9	Leadership skills	2%	11%	17%	47%	24%
Q3.10	Change management skills	3%	15%	21%	40%	22%
Q3.11	Investment in training and development	3%	14%	11%	50%	21%
Q4.1	A reduction in the number of fatalities	1%	2%	4%	27%	66%
Q4.2	A reduction in the number of dangerous activities	1%	2%	5%	37%	55%
Q4.3	Increased production	0%	0%	8%	34%	58%
Q4.4	Jobs lost directly (at the mine)	21%	42%	21%	10%	6%
Q4.5	Jobs created indirectly (by secondary industries)	2%	6%	24%	58%	10%

	Theoretical Factor	Very Unfavourable	Unfavourable	Neutral	Favourable	Very Favourable
Q4.6	Increased job creation overall (in the mining industry as a whole)	2%	12%	30%	45%	10%
Q4.7	An improved work environment (physically less demanding)	1%	0%	9%	49%	41%

4.4 Mean and standard deviation

The raw data was rescaled in order to establish a common scale and enable comparison of the different factors. The rescaling of the ordinal responses was carried out using the normal distribution fitting algorithm (Stacey, 2005). The new rating scale is shown in Table 6. This table also enables classification of the different factors into ratings. The ratings are defined by the scale range. A factor is assigned to a rating, based on its mean and where the mean lies on the scale range.

Table 6: Adjusted rating scale

Ratings	Scale Range
Very Unfavourable	Less than - 1.468
Unfavourable	Greater than -1.468, but less than -0.653
Neutral	Greater than -0.653, but less than -0.183
Favourable	Greater than -0.183, but less than 0.713
Very Favourable	Greater than 0.713

Unfavourable, neutral, favourable and very favourable factors can easily be extracted by using the ratings scale in Table 6 and the means from Table 7. The means indicate that there are no very unfavourable factors, 7 unfavourable factors, 2 neutral factors, 15 favourable factors, and 3 very favourable factors.

Table 7: Means and standard deviation table

	Theoretical Factor	Mean (μ)	Standard Deviation (σ2)
Decision to Mechanise			
Q2.1	Hard rock conditions	-0.34	0.56
Q2.2	High waste associated with mechanised mining	-0.76	0.52
Q2.3	Mining faults (discontinuity of rock volume)	-0.76	0.60
Q2.4	Development of new mechanised mining machines	0.17	0.64
Q2.5	High lead time to develop mining technology	-0.66	0.56
Q2.6	Labour unrest	0.17	3.31
Q2.7	High capital cost (CAPEX)	-0.70	0.68
Q2.8	Low operating cost (OPEX)	0.35	0.69
Q2.9	Low lifecycle cost (CAPEX and OPEX)	0.14	0.60
Implementation of Mechanisation			
Q3.1	Artisan skills shortage (skills to maintain mechanised machinery)	-0.86	0.98
Q3.2	Mechanisation skills shortage (skills to operate mechanised machinery)	-0.85	0.62

	Theoretical Factor	Mean (μ)	Standard Deviation (σ2)
Q3.3	Safer mechanised mining equipment	0.52	0.49
Q3.4	Thorough mine design and planning	0.32	0.39
Q3.5	Correct equipment selection	0.42	0.38
Q3.6	Compatibility of new equipment with existing infrastructure	-0.19	0.77
Q3.7	Good relationships between mining companies and technology vendors	0.11	0.40
Q3.8	Training and development of mineworkers on mechanised machinery	0.09	0.70
Q3.9	Leadership skills	0.18	0.58
Q3.10	Change management skills	0.06	0.68
Q3.11	Investment in training and development	0.12	0.64
Outcomes of Mechanisation			
Q4.1	A reduction in the number of fatalities	1.12	0.91
Q4.2	A reduction in the number of dangerous activities	0.82	0.66
Q4.3	Increased production	0.84	0.51
Q4.4	Jobs lost directly (at the mine)	-0.83	0.72
Q4.5	Jobs created indirectly (by secondary industries)	0.01	0.37
Q4.6	Increased job creation overall (in the mining industry as a whole)	-0.08	0.39

	Theoretical Factor	Mean (µ)	Standard Deviation (σ2)
Q4.7	An improved work environment (physically less demanding)	0.56	0.49

(dark green)	-	Very favourable factors
(light green)	-	Favourable factors
(grey)	-	Neutral factors
(red)	-	Unfavourable factors

The following are factors with the highest mean or average (> 0.8):

- A reduction in the number of fatalities
- A reduction in the number of dangerous activities
- Increased production

The following are factors with the lowest mean or average (< -0.8):

- Artisan skills shortage (skills to maintain mechanised machinery)
- Mechanisation skills shortage (skills to operate mechanised machinery)
- Jobs lost directly (at the mine)

The standard deviation indicates the variance (spread) in the responses (Isotalo, 2001). The standard deviation for most of the factors is low (less than 1). The only factor that has a high standard deviation (3.31) is labour unrest, as shown in Table 7.

4.5 Exploratory factor analysis (EFA)

Exploratory factor analysis is a multivariate technique involving many variables from questionnaires, which can eventually be reduced to a significantly smaller set of factors so that an underlying concept can be established (Yong & Pearce, 2013). It is also much easier to focus on fewer important factors rather than numerous variables, which could be trivial (Yong & Pearce, 2013). An exploratory factor analysis was conducted using SAS Enterprise Guide 5.1.

The factor analysis was very informative in terms of determining the underlying structure of the data. The factor analysis also proved to be very valuable in terms of reducing dimensionality of the problem to enable easy comparison between the different categorical data.

4.5.1 *Extraction method and factor selection*

Table 8 shows the factor extraction details in terms of the extraction method, number of factors extracted, and factor loading criterion employed in the EFA of this research.

Table 8: Factor extraction details

Parameter	Method
Extraction method	Principal component analysis (PCA)
No of factors	Eigenvalue greater than 1/Scree test/Parallel analysis test
Factor loading criterion	Greater than 0.3

Williams et al. (2012) show that there are many methods for factor extraction. Some of these methods are:

- Principal axis factoring (PAF)
- Principal component analysis (PCA)
- Unweighted and Least squares.
- Alpha and Image factoring.

The most common methods are PCA and PAF, with PCA generally being the default method (Williams et al, 2012). When there isn't an existing model or when preliminary solutions are required, then PCA is suggested (Williams et al., 2012). Conway and Huffcutt (2003) emphasise that the main difference between the two methods is in their purpose. PAF is to understand the unobserved factors among the variables, whereas PCA is to reduce the quantity of variables. This study set out to identify favourable and unfavourable factors without an existing model and reduce dimensionality, therefore, PCA was utilised.

The researcher felt that the suitability of the respondents' data for factor analysis was important to check. The test that was used was the Kaiser–Meyer–Olkin (KMO) test (Williams et al., 2012). An acceptable KMO value is greater than 0.5; the KMO value computed in the analysis is 0.719 as indicated in Appendix C for reference (Williams et al., 2012).

4.5.2 *Number of factors extracted*

The criteria used for factor extraction is very important when conducting factor analysis. There are three main criteria used for factor extraction:

- Cumulative percentage of variance and eigenvalue greater than 1
- Scree Test
- Parallel Analysis (Williams et al., 2012).

Williams et al. (2012) found that multiple decision criteria are desirable. This research used the three criteria listed above. The EFA was conducted using principal component analysis with the Kaiser's eigenvalue-greater-than-one criterion, which revealed that there are 9 factors as shown on the Scree plot in Figure 6.

Costello and Osborne (2011) highlight that eigenvalue greater than 1 is one of the least accurate methods and a Scree test is one of the better methods. Just by examining the Scree plot shown in Figure 6, it can be seen that only 2 factors need to be extracted. This is determined by drawing a line through the smaller eigenvalues and observing the point of departure between the Scree plot and line (Williams et al., 2012). The downside with extracting only two factors, as explained by the Scree plot, is that the cumulative variance is too low (only 33%) as indicated in Figure 7.

Finally, parallel analysis was used to extract the factors. This method is not widely mentioned in literature. The reason for its limited use is due to the fact that the method is not available in conventional statistical programs like SAS and SPSS (Williams et al., 2012). This method is regarded as one of the best methods by some authors, including Conway and Huffcutt (2003). The parallel analysis involved creating a random dataset with the same number of variables and observations as the original dataset (Ledesma & Valero-Mora, 2007). A correlation matrix was then computed using the random data. Eigenvalues were computed from this correlation matrix. Eigenvalues from the parallel analysis that were higher than that of the PCA were retained and eigenvalues that were below the parallel analysis curve, as indicated in Figure 6, were ignored, as they are generally random noise (Ledesma & Valero-Mora, 2007). The parallel analysis did reveal that four factors are adequate, which explains 46% of the variance. The factor analysis conducted made use of multiple decision criteria, which is in line with best practise.

The researcher also thought that the cumulative percentage of variance was also very important to check. Generally, factors are stopped when 95% variance is explained when doing research in the natural science field (Williams et al., 2012). Humanities can be as low as 50 to 60 % (Williams et al., 2012). Kootstra (2004) indicates that factors should be kept such that 70-80% of the variance is explained. The cumulative variance explained in this research is 46% as depicted in Figure 7 (with 4 empirical factors extracted) and is deemed adequate for this research, as it is exploratory.

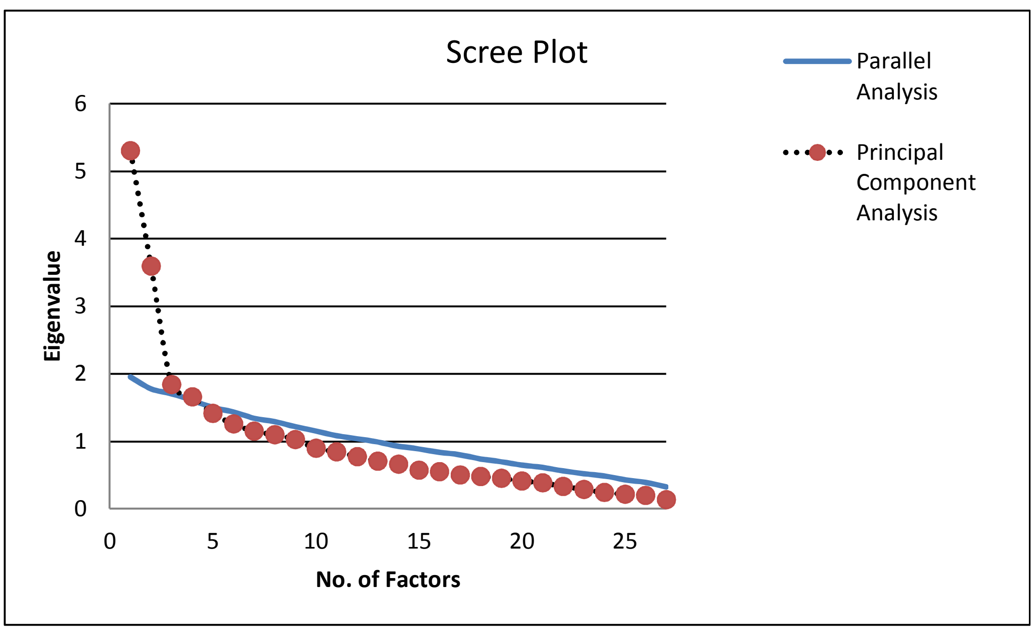

Figure 6: Scree plot

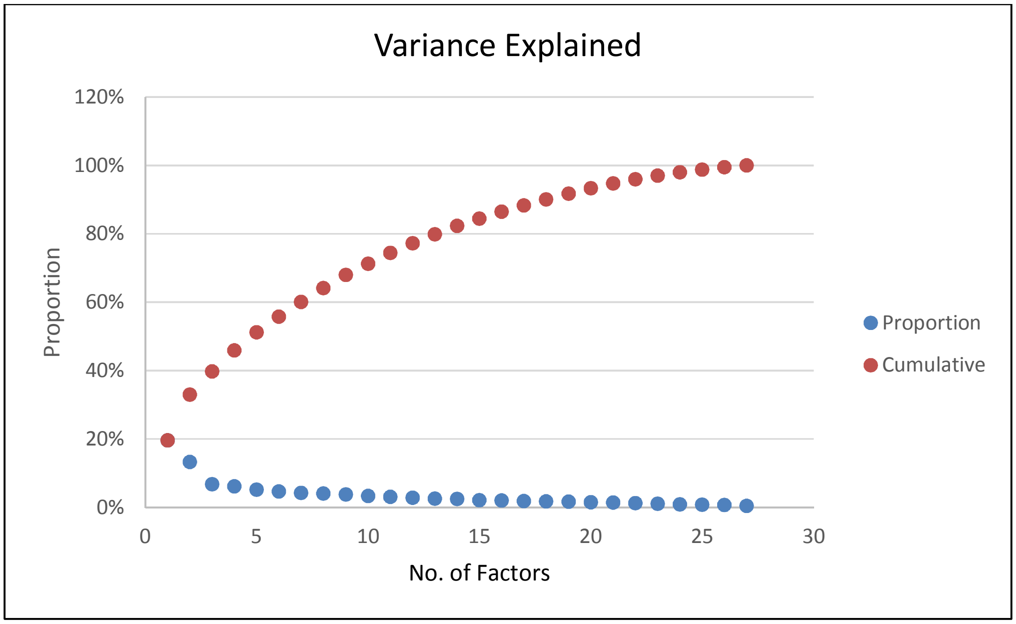

Figure 7: Variance explained

Table 9 shows the factor loadings for the 4 empirical (latent) factors. Williams et al. (2012) indicate that a minimum value of 0.3 is acceptable for factor loadings. This figure of 0.3 is also supported by Costello and Osborne (2011). The researcher decided to use a factor loading cut-off of 0.3; therefore, the variable “Jobs lost directly (at the mine)” was discarded.

Table 9: Rotated factor pattern

	Theoretical Factor	Factor1	Factor2	Factor3	Factor4
Q2.1	Hard rock conditions	-0.013	0.5853	0.0573	0.2355
Q2.2	High waste associated with mechanised mining	-0.01	0.5532	-0.191	-0.107
Q2.3	Mining faults (discontinuity of rock volume)	-0.016	0.6168	-0.065	0.0895
Q2.4	Development of new mechanised mining machines	0.0291	0.3375	0.1131	0.2658

	Theoretical Factor	Factor1	Factor2	Factor3	Factor4
Q2.5	High lead time to develop mining technology	0.1146	0.6748	-0.195	0.0046
Q2.6	Labour unrest	0.0733	-0.04	0.0786	0.5024
Q2.7	High capital cost (CAPEX)	0.1748	0.5878	-0.134	0.3289
Q2.8	Low operating cost (OPEX)	0.2989	0.1106	0.0566	0.6861
Q2.9	Low lifecycle cost (CAPEX and OPEX)	0.243	0.0234	0.0178	0.7282
Q3.1	Artisan skills shortage (skills to maintain mechanised machinery)	-0.093	0.7314	0.0482	-0.133
Q3.2	Mechanisation skills shortage (skills to operate mechanised machinery)	0.0761	0.7604	-0.039	-0.112
Q3.3	Safer mechanised mining equipment	0.0864	0.0717	0.3439	0.5053
Q3.4	Thorough mine design and planning	0.4123	-0.102	0.1053	0.3705
Q3.5	Correct equipment selection	0.5564	-0.079	0.1103	0.1869
Q3.6	Compatibility of new equipment with existing infrastructure	0.6477	0.2127	-0.057	0.0482
Q3.7	Good relationships between mining companies and technology vendors	0.5707	0.13	0.2538	0.0985
Q3.8	Training and development of mineworkers on mechanised machinery	0.672	0.1019	0.1062	0.0617
Q3.9	Leadership skills	0.7374	-0.124	0.1172	0.2501
Q3.10	Change management skills	0.7727	-0.002	0.0826	0.1968

	Theoretical Factor	Factor1	Factor2	Factor3	Factor4
Q3.11	Investment in training and development	0.7288	0.1143	0.2082	0.0271
Q4.1	A reduction in the number of fatalities	-0.017	-0.007	0.7536	0.2757
Q4.2	A reduction in the number of dangerous activities	0.0629	0.0208	0.7595	0.1771
Q4.3	Increased production	0.2126	0.0043	0.4691	0.2433
Q4.4	Jobs lost directly (at the mine)	0.1421	0.2674	0.1471	-0.138
Q4.5	Jobs created indirectly (by secondary industries)	0.3478	-0.232	0.5659	-0.168
Q4.6	Increased job creation overall (in the mining industry as a whole)	0.2972	-0.008	0.5325	-0.218
Q4.7	An improved work environment (physically less demanding)	0.1321	-0.226	0.6398	0.097

4.5.3 *Empirical factor names*

Despite the difficulty of naming the factors, as described by Yong and Pearce (2013), the researcher named the 4 final empirical factors. Generally, at least two to three variables must load a factor to be meaningful (Williams et al, 2013). This view is also supported by Preacher and MacCallum (2003). The minimum number of variables loaded on a factor for this research is four, which is deemed acceptable. These empirical factors and their comprising theoretical factors (variables) are shown below.

Empirical Factor 1: Implementation of Mechanisation

- Thorough mine design and planning
- Correct equipment selection
- Compatibility of new equipment with existing infrastructure
- Good relationships between mining companies and technology vendors

- Training and development of mineworkers on mechanised machinery
- Leadership skills
- Change management skills
- Investment in training and development

Empirical Factor 2: Deciding Elements of Mechanisation

- Hard rock conditions
- High waste associated with mechanised mining
- Mining faults (discontinuity of rock volume)
- Development of new mechanised mining machines
- High lead time to develop mining technology
- High capital cost (CAPEX)
- Artisan skills shortage (skills to maintain mechanised machinery)
- Mechanisation skills shortage (skills to operate mechanised machinery)

Empirical Factor 3: Benefits of Mechanisation

- A reduction in the number of fatalities
- A reduction in the number of dangerous activities
- Increased production
- Jobs created indirectly (by secondary industries)
- Increased job creation overall (in the mining industry as a whole)
- An improved work environment (physically less demanding)

Empirical Factor 4: Impact of People on Mechanisation

- Labour unrest
- Low operating cost (OPEX)
- Low lifecycle cost (CAPEX and OPEX)
- Safer mechanised mining equipment

4.6 Analysis of variance (ANOVA)

An ANOVA was conducted to identify differences in perception between the four stakeholder groups pertaining to the 4 empirical factors. The analysis was conducted using SAS Enterprise Guide 5.1 as the analysis tool.

The independent variable is the stakeholder group (with four levels indicating the different stakeholders) and the dependent variables are the four empirical factors derived from the exploratory factor analysis. The null hypothesis for ANOVA is that the means (average values for the dependent variables) are the same for all stakeholder groups (Seltman, 2012). If the ANOVA test procedure produces a p value of < 0.05, the null hypothesis is rejected, indicating that the averages for the groups are not the same.

Depicted in Table 10 are the p-values from the results of the ANOVA analysis.

Table 10: Table of p-values: Stakeholder differences (mechanisation)

Dependent Variables	p-value (Prob>F)
Implementation of mechanisation	0.8618
Deciding elements of mechanisation	0.1036
Benefits of mechanisation	0.3406
Impact of people on mechanisation	0.0741

All p-values are greater than 0.05, which means that the null hypothesis can be accepted. More details regarding the ANOVA analysis is included in Appendix E for reference.

Figure 8 shows the box-and-whisker plots for the 4 factors and four stakeholder groups, illustrating the means and distributions. With reference to the box and whisker plots and the means in Table 11, it can be seen that consultants display the least standard deviation for all the factors except benefits of mechanisation. Vendors display the least standard deviation for benefits of mechanisation.

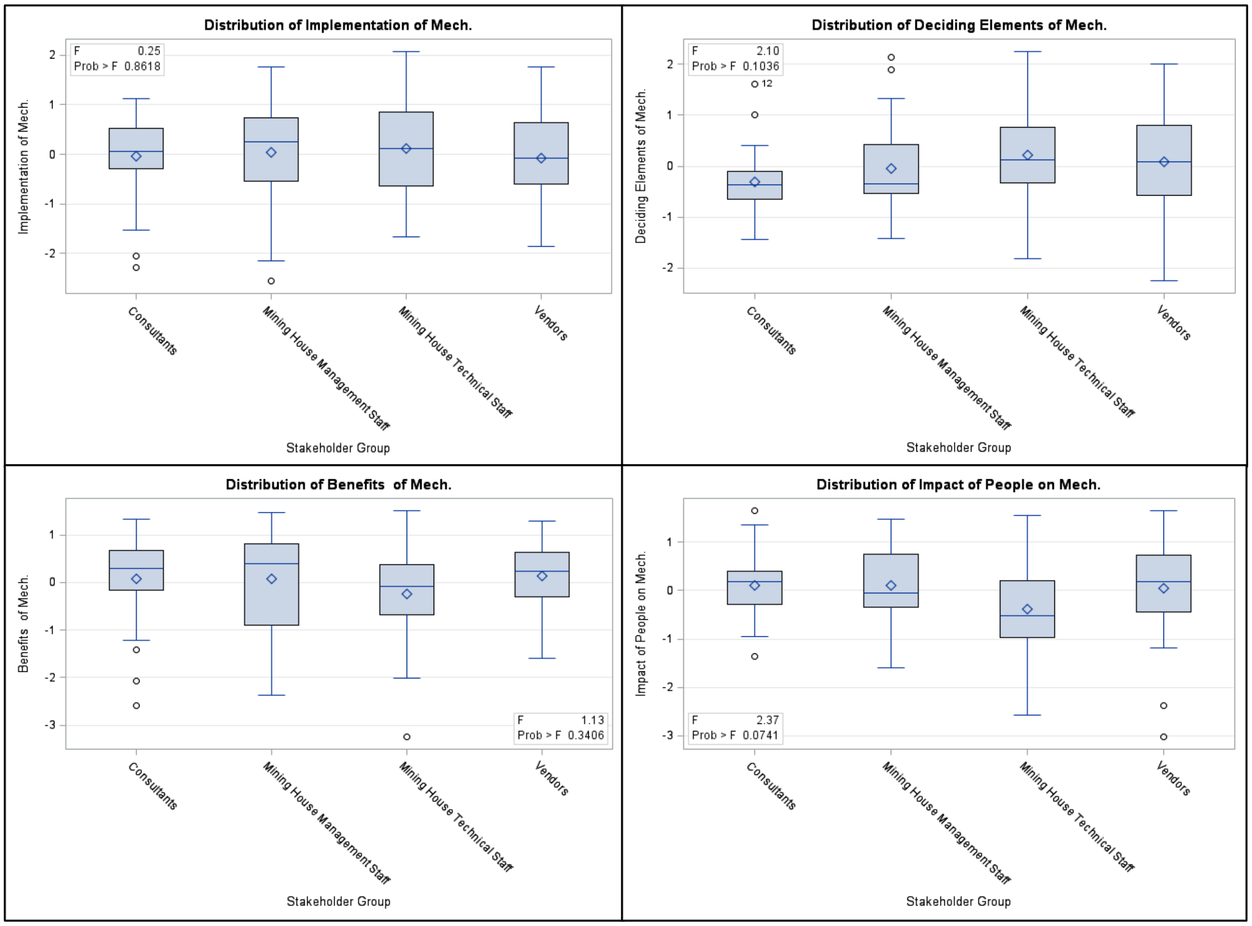

Figure 8: Distributions: Mechanisation empirical factors

Table 11: Means and std. deviations: Stakeholder differences (mechanisation)

Stakeholder Group	N	Implementation of Mech.		Deciding Elements of Mech.		Benefits of Mech.		Impact of People on Mech.	
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Consultants	34	-0.031	0.812	-0.317	0.636	0.085	0.923	0.116	0.671
Mining house management staff	32	0.037	1.121	-0.046	0.865	0.073	0.984	0.098	0.827

Stakeholder Group	N	Implementation of Mech.		Deciding Elements of Mech.		Benefits of Mech.		Impact of People on Mech.	
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Mining house technical staff	31	0.123	0.912	0.214	0.951	-0.247	1.020	-0.385	0.899
Vendors	32	-0.068	0.932	0.092	1.110	0.130	0.696	0.040	1.034

Safety comprises three factors. The ANOVA analysis regarding mine safety indicates that there are no significant differences among the stakeholders for two of the factors relating to mine safety, namely, reduction in the number of fatalities, and reduction in the number of dangerous activities; however, there is a slight difference in stakeholder views regarding the third factor, i.e. safer mechanised mining equipment. This can also be seen by the p-values indicated in Table 12.

Table 12: Table of p-values: Stakeholder differences (mine safety)

Dependent Variables	p-value (Prob>F)
Safer mechanised mining equipment	0.041
A reduction in the number of fatalities	0.110
A reduction in the number of dangerous activities	0.499

With reference to the box and whisker plots in Figure 9 and the means in Table 13, it is evident that consultants display the highest standard deviation for a reduction in fatalities and a reduction in dangerous activities, but the lowest standard deviation for safer mechanised equipment. On the other hand, vendors display the lowest standard deviation for a reduction in fatalities and a reduction in dangerous activities, but the highest standard deviation for safer mechanised equipment.

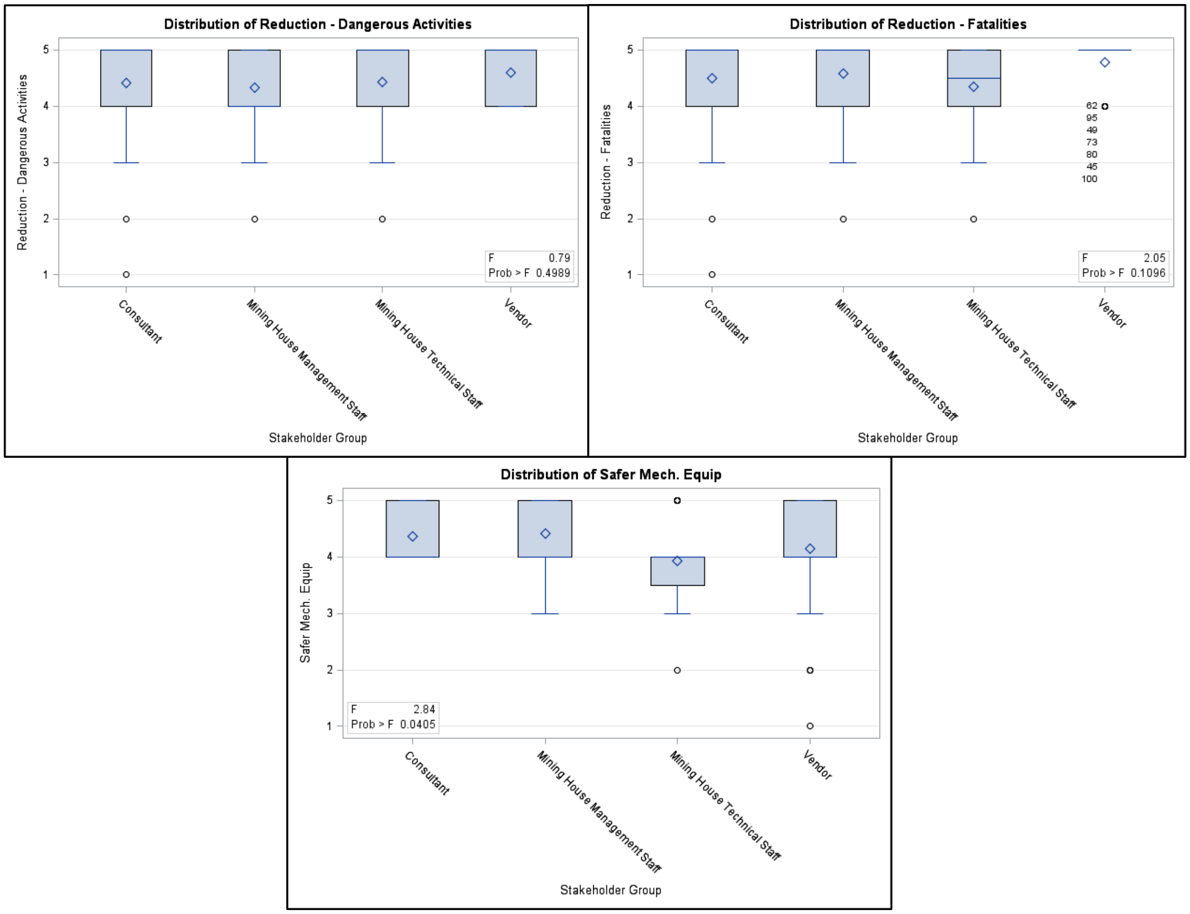

Figure 9: Distributions: Mine safety factors

Table 13: Means and std. deviations: Stakeholder differences (mine safety)

Stakeholder Group	Safer Mech. Equip.		Reduction in Fatalities		Reduction in Dangerous Activities	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Consultant	4.361	0.487	4.500	0.941	4.417	0.906
Mining house management staff	4.417	0.554	4.583	0.692	4.333	0.756
Mining house technical staff	3.938	0.759	4.344	0.787	4.438	0.759
Vendor	4.152	1.093	4.788	0.415	4.606	0.496

4.7 Conclusion

The research results were presented in this chapter. Descriptive statistics showed that there is an equal split in terms of responses from the four stakeholder groups. Based on frequency of responses, more favourable responses were received from the respondents, with 20 factors receiving favourable responses and 7 factors receiving unfavourable responses. Of these favourable responses, there were 4 factors that received very favourable responses.

The means and standard deviations were presented in Table 7. There are 3 factors with a high mean score and 3 factors with a low mean score. Factors relating to mine safety and productivity have high means, while skills shortage and job losses are factors with low means. Table 7 also reflects that one factor, labour unrest, has a high standard deviation.

The exploratory factor analysis was conducted using PCA and parallel analysis and revealed an underlying structure to the dataset. The number of empirical factors that was extracted is four. These empirical factors were then named by the researcher. More details regarding the naming of the empirical factors is discussed in Chapter 5.

An ANOVA was finally done to identify differences in stakeholder groups 'perceptions of the four empirical factors and revealed that there are no significant differences between the groups.

CHAPTER 5: DISCUSSION OF RESULTS

5.1 Introduction

This chapter focuses on interpreting the results that was presented in Chapter 4. The progression of the discussion follows the same process as in the previous chapter. Firstly, the frequencies, means, and distributions are discussed. Secondly, the factor analysis is discussed followed by the ANOVA. Finally, the results pertaining to the propositions are discussed.

5.2 Frequency distribution

As discussed in the previous chapter, most of the respondents responded very favourable to 4 factors, favourable to 16 factors and unfavourable to 7 factors. The frequency responses are grouped in the three categories and shown graphically in Figure 10, Figure 11 and Figure 12. Most of the favourable responses are specific to the implementation of mechanisation instead of decision to mechanise or outcomes of mechanisation. The 7 factors that received unfavourable responses are mainly related to the decision to mechanise. It is also evident that the factors that received very favourable responses are mainly related to mine safety and productivity, which are outcomes of mechanisation. Based on the responses, most of the respondents are inclined to mechanise because they believe that productivity will increase and it would be safer for employees. Labour unrest also mostly received very favourable responses. As described earlier by Ali and Hattingh (2014), labour unrest has a tremendous negative impact on mining operations, therefore, by mechanising, the workforce is reduced and generally more skilled, hence reducing the chances of labour unrest. Strikes and work stoppages also resulted in a decline in GDP contribution from 5.7% in 2011 to 4.1% in 2012. Further to this, Dixon (2014), points out that labour disputes has triggered more talks to mechanise.

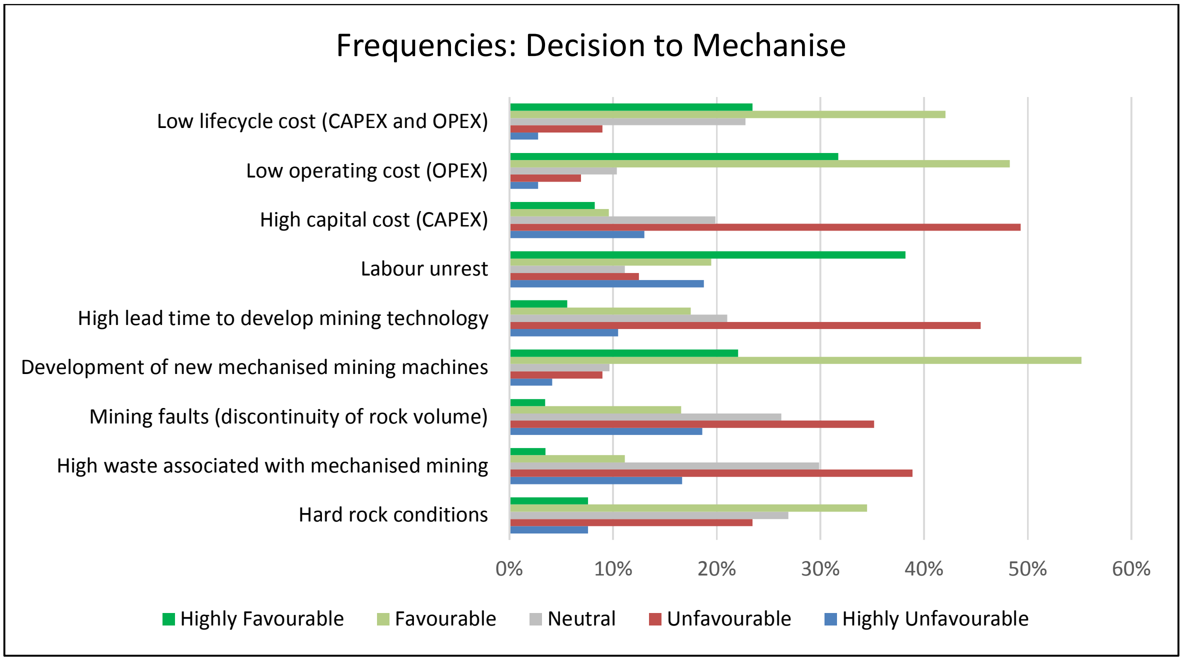

Figure 10: Frequency response: Decision to mechanise

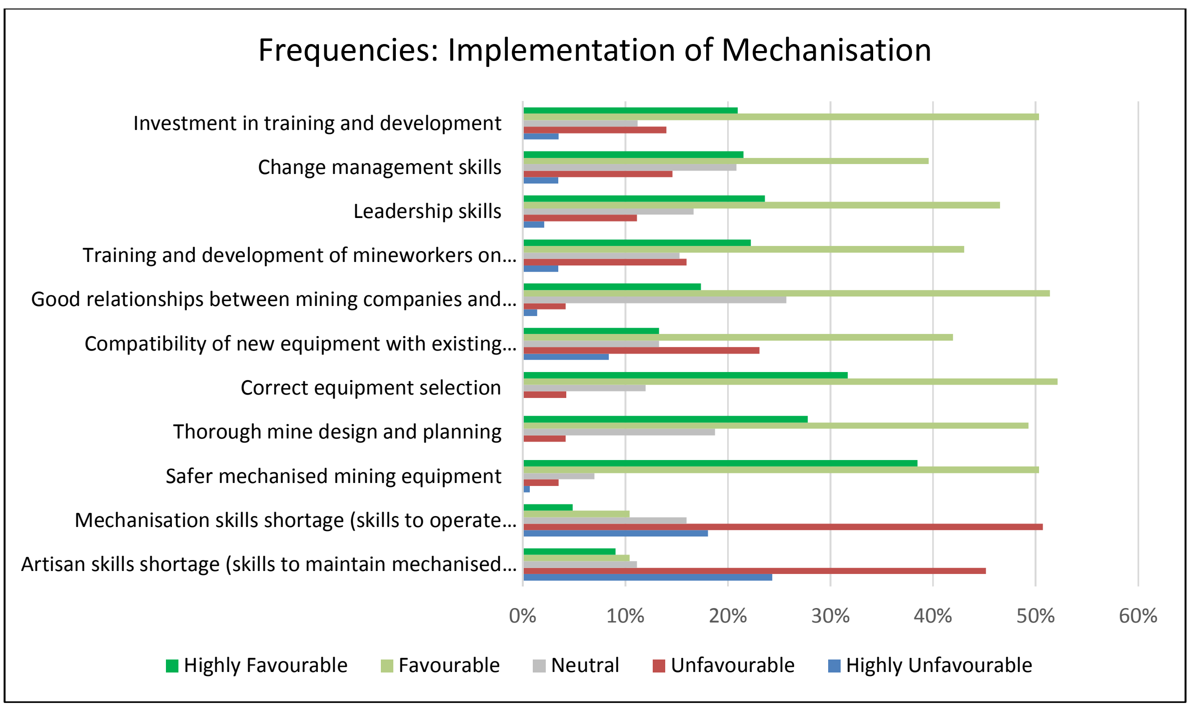

Figure 11: Frequency response: Implementation of mechanisation

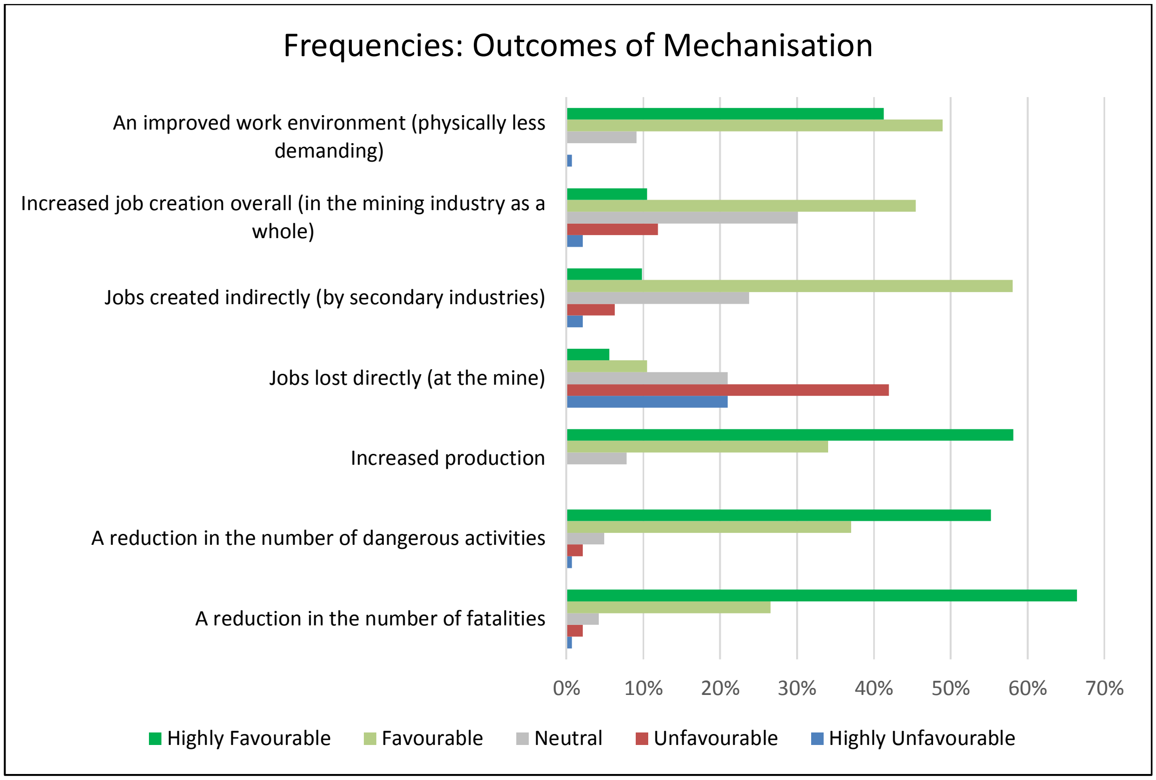

Figure 12: Frequency response: Outcomes of mechanisation

5.3 Mean and standard deviation

The means of responses for all the respondents were analysed and are displayed in Table 7. Based on these means, Figure 13 was created to easily view the rated factors. The means indicate that there are 3 very favourable factors, 15 favourable factors, 2 neutral factors and 7 unfavourable factors.

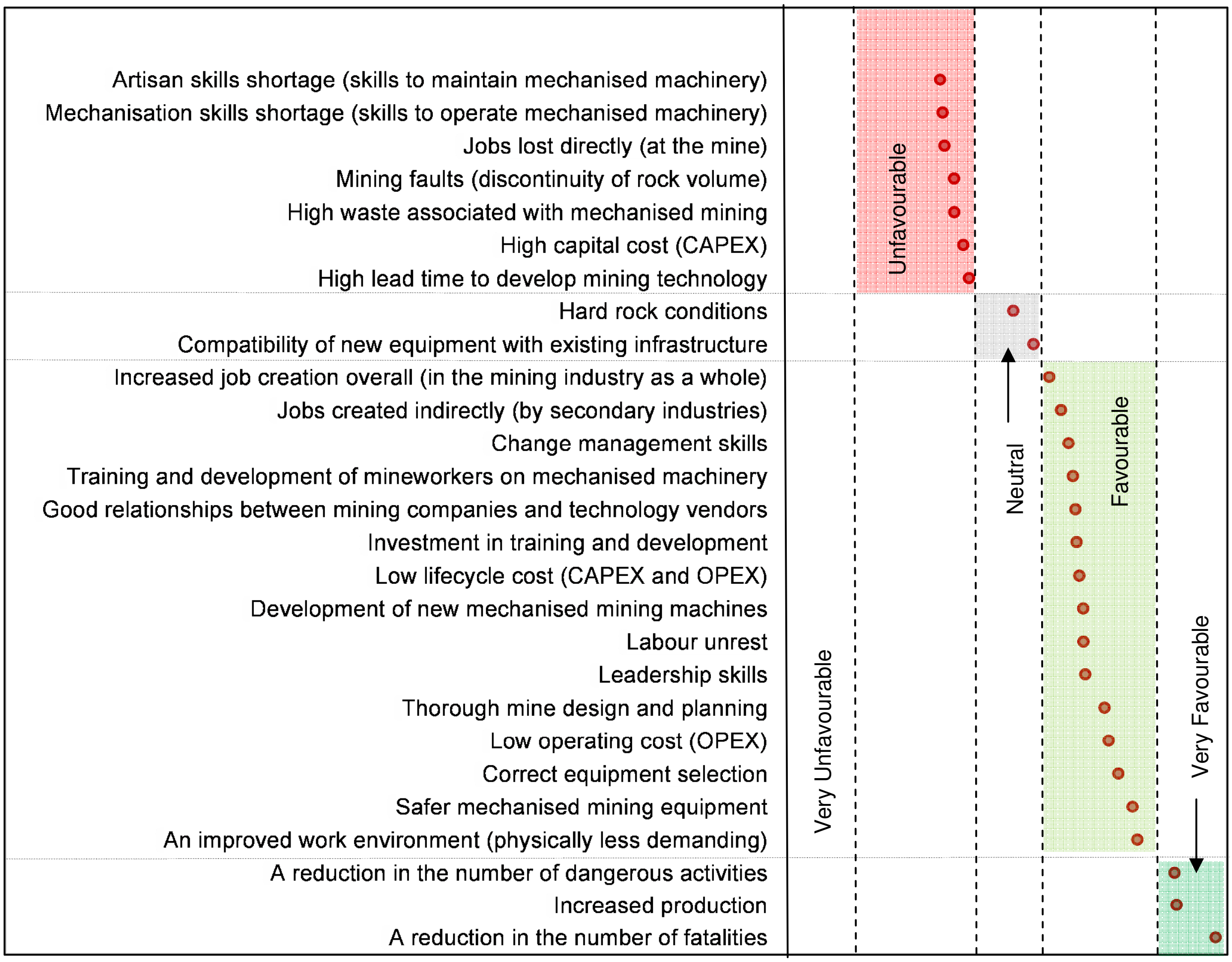

Figure 13: Factor ratings

The following 7 factors are perceived as unfavourable:

- High waste associated with mechanised mining
- Mining faults (discontinuity of rock volume)
- High lead time to develop mining technology
- High capital cost (CAPEX)
- Artisan skills shortage (skills to maintain mechanised machinery)
- Mechanisation skills shortage (skills to operate mechanised machinery)
- Jobs lost directly (at the mine)

The breakdown of the factors that are perceived as unfavourable are:

- 4 out of the 7 factors pertain to the decision to mechanise
- 2 out of the 7 factors pertain to the implementation of mechanisation
- 1 out of the 7 factors pertain to the outcomes of mechanisation

Based on these results, most of the unfavourable factors are related to the decision to mechanise. If the perceptions of the stakeholders towards most of the factors regarding the decision to mechanise are unfavourable, mechanisation projects may not go head. These decisions are generally made upfront during concept and pre-feasibility stages of a project. Although there are no factors rated as very unfavourable, mechanisation skills shortage, artisan skills shortage and jobs losses at the mines are perceived as the most unfavourable factors influencing mechanisation. Factors perceived as least unfavourable are high capital cost (CAPEX) and high lead times to develop technologies. It is surprising that high capital cost isn't perceived as one of the more unfavourable factors, but rather more towards neutral. One of the possible reasons for this perception is that most companies realise the capital cost intensive implications of mechanising and are mandated to cut expenditure where possible, resulting in them using existing infrastructure to support mechanisation projects (Joubert & Liebenberg, 2010). The use of existing infrastructure can reduce capital cost to an extent. Due to the absence of factors rated as very unfavourable, mining companies can expect little resistance from stakeholders when undergoing mechanisation projects.

The means also show that most of the factors are perceived as favourable. The following 15 factors are perceived as favourable:

- Development of new mechanised mining machines
- Labour unrest
- Low operating cost (OPEX)
- Low lifecycle cost (CAPEX and OPEX)
- Safer mechanised mining equipment
- Thorough mine design and planning
- Correct equipment selection
- Good relationships between mining companies and technology vendors

- Training and development of mineworkers on mechanised machinery
- Leadership skills
- Change management skills
- Investment in training and development
- Jobs created indirectly (by secondary industries)
- Increased job creation overall (in the mining industry as a whole)
- An improved work environment (physically less demanding)

The breakdown of the factors that are perceived as favourable are:

- 4 out of the 15 factors pertain to the decision to mechanise
- 8 out of the 15 factors pertain to the implementation of mechanisation
- 3 out of the 15 factors pertain to the outcomes of mechanisation

Factors perceived as favourable are mostly related to the implementation of mechanisation. This is indicative of stakeholders' perception that there are many factors that can enable mechanisation during the implementation phase. Seeing that 67% of all the factors are perceived as favourable or very favourable, this is a good sign for mechanisation projects, as these are the factors that will make mechanisation successful. Some of the perceived least favourable factors are job creation, change management skills, and training and development, while some of the most favourable factors are correct equipment selection, safer mechanised machinery, and an improved workplace environment.

The 2 perceived neutral factors are:

- Hard rock conditions
- Compatibility of new equipment with existing infrastructure

The breakdown of the 2 neutral factors is as follows:

- 1 out of the 2 factors pertain to the decision to mechanise
- 1 out of the 2 factors pertain to the implementation of mechanisation

Stakeholders perceive that these two factors are neither favourable nor unfavourable implying that these factors will not affect mechanisation.

Based on the literature review, compatibility of new equipment with existing infrastructure is portrayed as a favourable factor. Macfarlane (2001) highlights failed attempts to implement new technology due to equipment being too advanced for current mine infrastructure, hence the need for compatibility. The respondents have a different view; they perceive compatibility of new equipment with existing infrastructure as neither favourable nor unfavourable. Although respondents may be aware of potential cost savings by using existing infrastructure, a possible reason for the different perception could be that they still feel that a substantial cost, effort and risk is associated with modifying existing infrastructure in order to achieve compatibility (Scheding, Dissanayake, Nebot, & Durrant-Whyte, 1999).

Finally, the means revealed that the following factors are perceived as very favourable:

- A reduction in the number of fatalities
- A reduction in the number of dangerous activities
- Increased production

The breakdown of the very favourable factors is as follows:

- 3 out of 3 factors pertain to outcomes of mechanisation

It is evident that two of the mine safety related factors emerged as very favourable, indicating that safety is a very favourable result of mechanisation. In addition to mine safety, productivity is viewed as a favourable result of mechanisation. Based on the fact that all of the very favourable factors are related to the outcomes of mechanisation, it is clear that the outcomes (benefits) of mechanisation are very important to the mining stakeholders. The two most important aspects, in order of importance, to most of the stakeholders are mechanisation will lead to fewer fatalities and an increase in productivity.

Most of the standard deviations are acceptable (less than 1) indicating unanimity. The only factor with a very high standard deviation (3.31) is labour unrest. This implies that there is a variance or spread of responses across the rating scale and signifies very different perceptions among the respondents.

5.4 Exploratory factor analysis (EFA)

5.4.1 *Factor analysis interpretation*

The interpretation of the exploratory factor analysis is very important. The theoretical factors (variables) with the highest factor loading were allocated to the corresponding empirical (latent) factor, as indicated in Table 9. The researcher identified four empirical factors with the following details:

- Factor 1 contains 8 variables
- Factor 2 contains 8 variables
- Factor 3 contains 6 variables
- Factor 4 contains 4 variables.

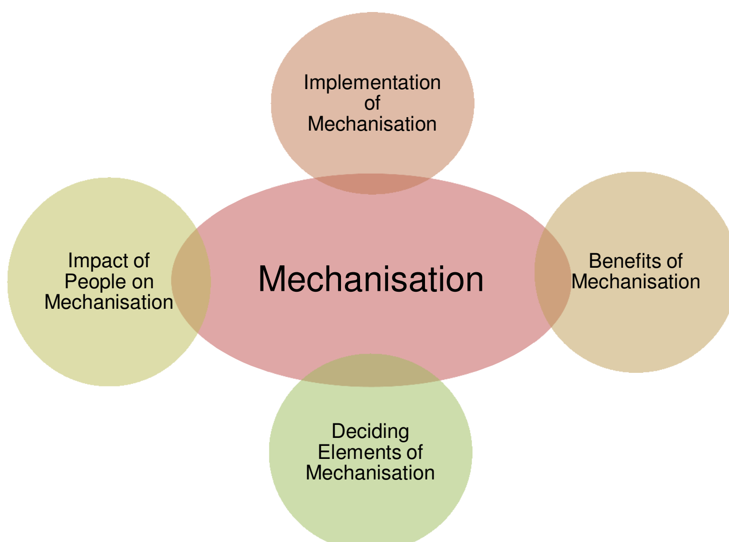

Figure 14: Empirical factors

The researcher also found factor names, as indicated in Figure 14, that adequately describe the variables associated with each of the empirical factors. Below is the rationale for deriving the names of the empirical factors:

Factor 1: Implementation of mechanisation encompasses variables that are all related to implementation of mechanisation. As implementation refers to the execution of a plan or strategy, the variables grouped under this factor will play an important role in ensuring the success of implementation.

Factor 2: Deciding elements of mechanisation contains variables that must be considered when deciding to mechanise. Prior to the commencement of mechanisation implementation, the variables grouped under this factor must be considered. These variables will enable stakeholders to make a decision whether to mechanise or not.

Factor 3: Benefits of mechanisation includes variables that are positive outcomes of mechanisation. The variables grouped under this factor are clearly the benefits of mechanising.

Factor 4: Impact of people on mechanisation contains variables that are a direct result of either people demands or a reduction of people. People demands can lead to strikes due to several reasons like wage increase, unsafe working conditions, etc. Reduction of people can lead to lower operating and lifecycle cost due to lower wage bills for the mines.

The factor analysis also confirmed the predetermined structure (framework for research) used in the research as shown in Figure 2, with the exception of an additional empirical factor, i.e. Factor 4: Impact of people on mechanisation. Three interesting observations were made in relation to the existing structure; firstly, the factor analysis revealed that skills shortages are more related to deciding elements of mechanisation than implementation of mechanisation; secondly, operating cost, lifecycle cost and labour unrest is more related to the new factor (impact of people on mechanisation) than the decision to mechanise. Finally, safer mechanised mining equipment is more related to the new empirical factor than implementation of mechanisation.

5.5 Analysis of variance (ANOVA)

The ANOVA indicates that there are no significant statistical differences in each of the group's (stakeholder) perception of the four empirical factors. This can also be seen in the box and whisker plots in Figure 8. Further discussion regarding the ANOVA results is covered in Section 5.6.3.

5.6 Results pertaining to propositions

The results pertaining to the propositions are discussed. The propositions are re-stated for ease of reference.

5.6.1 *Favourable factors affecting mine mechanisation (Proposition 1)*

Some of the favourable factors affecting mine mechanisation are: mine safety, productivity, operating cost (OPEX) and lifecycle cost (overall cost), mine design and planning, employment, technology development, skills development, organisational factors and labour unrest. Three factors, namely: mine safety, productivity and lifecycle cost (overall cost) are very favourable factors.

From the literature review, there were a number of factors identified as favourable. Table 14 will include the literature review findings and the research findings in terms of the favourable factors identified.

Table 14: Results pertaining to Proposition 1 (favourable factors)

Favourable factors identified in the literature review	Favourable factors identified from the research
Mine safety	The research confirmed that mine safety is a favourable factor. All three of the safety related factors, namely, safer mechanised mining equipment (affecting the implementation of mechanisation); a reduction in fatalities, and a reduction in dangerous activities (outcomes of mechanisation) were identified as favourable.

Favourable factors identified in the literature review	**Favourable factors identified from the research**
Productivity	The research confirmed that productivity was identified as a favourable outcome of mechanisation.
Operating cost (OPEX) and lifecycle cost	Low operating cost and lifecycle cost was identified as a favourable factor.
Mine design and planning	Two factors pertaining to mine design and planning, namely, thorough mine design and planning, and correct equipment selection were identified as favourable factors affecting the successful implementation of mechanisation. Note: Compatibility of new equipment with existing infrastructure is perceived as a neutral factor.
Employment	Secondary job creation (through industries other than the mine) and overall job creation is perceived as favourable outcomes of mechanisation.
Technology development	The research indicated that the two technology development factors identified as favourable were: development of new mechanised mining machines (affecting the decision to mechanise) and good relationships between mining companies and technology vendors (affecting the implementation of mechanisation).
Skills development	The research indicated that training and development of mineworkers on machinery was identified as a favourable factor that affects the implementation of mechanisation.

Favourable factors identified in the literature review	Favourable factors identified from the research
Organisational factors	All four organisational factors were identified as favourable: investment in training and development, change management skills, leadership skills (affecting implementation of mechanisation), and improved work environment, which is a favourable outcome of mechanisation.
Labour unrest	The research also confirmed that labour unrest is perceived as a favourable factor when deciding to mechanise.

Generally, the research findings and literature review findings convey the same message in terms of favourable factors.

The degree to which these factors are favourable was also determined. As indicted previously in the literature review, the very favourable factors affecting mechanisation are:

- Mine safety
- Productivity
- Lifecycle cost

Mine safety and productivity is perceived as very favourable outcomes of mechanisation as indicated in Figure 13. This is strongly supported by the literature review in Sections 2.3.1 and 2.3.5.

Lifecycle cost, however, is not perceived as a very favourable factor, but merely as favourable. This does vary with the literature findings. As mentioned earlier, lifecycle cost (overall cost) associated with mechanisation is low and is one of the most important factors affecting mechanisation (Robbins, 2000). The research findings affirmed that lifecycle cost is perceived as favourable, but not very favourable. One of the possible reasons for lifecycle cost not being perceived as very favourable is that stakeholders are aware that although labour costs will be lower due to the reduction of mineworkers, there will be other costs that could offset this saving. Some of the additional costs associated with mechanisation are due to higher skilled workforce, large amounts of strategic and operational spares and intense maintenance systems required to maintain and operate the mechanised mining equipment (Nong, 2011). Hattingh and Govender (2014) also point out that the use of technology in mining environments has definitely led to the more highly skilled personnel and an increase in equipment maintenance costs.

With reference to Figure 13, the research has also showed that the following factors are in close proximity to being very favourable:

- Correct equipment selection
- An improved work environment (physically less demanding)

As discussed earlier in Section 2.3.8, Morin (2002) highlights the importance of correct equipment selection. A possible reason for correct equipment selection being one of the more favourable factors is that more mining stakeholders are realising the importance of selecting the right machines for mechanisation. There are still numerous technical and operational challenges faced with mechanisation (Musingwini, Cruise, & Phillips, 2013). In 2012, LONMIN, who was at the forefront of mechanisation, suspended the mechanisation operation and reverted back to conventional operations (Musingwini et al., 2013). This failed mechanisation implementation has also sparked interest and triggered thorough design and planning in terms of correct equipment selection.

An improved workplace is also an important factor that was uncovered in the research as one of the more favourable factors. A possibility for this is the importance of promoting a physically less demanding environment. This means creating equal opportunity for male and female. Generally tools and equipment have been designed for men (Hermanus, 2007). Furthermore, bearing in mind that the physical demands of the harsh mining environment is matched to a physiology of a selected group of men, women are faced with an increased risk of injuries (Hermanus, 2007).

5.6.2 *Unfavourable factors affecting mine mechanisation (Proposition 2)*

Some of the unfavourable factors that affect mechanisation are: mining complexities, high technology development lead times, direct job losses, high capital cost (CAPEX) and skills shortage. Skills shortage seems to be a very unfavourable factor.

Based on the literature review, there were a number of factors identified as unfavourable. Table 15 includes the literature review findings and the research findings.

Table 15: Results pertaining to Proposition 2 (unfavourable factors)

Unfavourable factors identified in the literature	**Unfavourable factors identified from the research**
Mining complexities	The research uncovered two factors relating to mining complexity as unfavourable, namely, high waste associated with mechanised mining and mining faults (discontinuity of rock volume). These factors negatively affect the decision to mechanise. Note: Hard rock conditions was identified as a neutral factor when deciding to mechanise.
High technology development lead times	The current high lead time associated with development of mining technology is perceived as unfavourable when deciding to mechanise.
Direct job losses	Jobs lost directly (at the mines) is an unfavourable factor and was confirmed in the primary research.

Unfavourable factors identified in the literature	Unfavourable factors identified from the research
Skills shortage	It is also evident from the primary findings that artisan and mechanisation skills shortages are unfavourable factors affecting the decision to mechanise. Although skills shortage has also been flagged as the most unfavourable factor affecting mechanisation in the literature, it has not emerged as a very unfavourable factor in the research.
Capital cost (CAPEX)	The research findings confirmed that high capital cost (CAPEX) was identified as an unfavourable factor when deciding to mechanise.

Generally, the literature review and research findings provide the same conclusions in terms of unfavourable factors. Although there are no factors rated as very unfavourable in the research, skills shortage and direct job losses are perceived as the most unfavourable factors. This is slightly different to the literature review, where skills shortage was identified as a crucial (very unfavourable) success factor. The reason for this difference could be that mining stakeholders are now realising that the shift towards mechanisation is a reality and are taking steps to minimise the effects of skills shortages through training and development. This is evident by the substantial investment in people development initiatives and artisan training (Moodley, 2013).

Hard rock conditions was identified as an unfavourable factor in the literature due to the difficulty of machines cutting through hard rock. Machines will have to undergo frequent maintenance resulting in conventional drill and blast being more economical as compared to using machinery (Robbins, 2000). The research identified hard rock conditions as a neutral factor affecting the decision to mechanise. A possible reason for hard rock conditions not being viewed as unfavourable is that mining technology (low profile equipment) is being developed and some of them are already being tested on site and underground. Stakeholders are more optimistic that the new technology will be able to mine hard rock more effectively (Van Den Berg, 2014). Van Den Berg (2014) further states that rock cutting technology is also a possibility for the future of platinum mining.

5.6.3 *Differing stakeholders interests and perceptions (Proposition 3)*

The different stakeholders have different interests and perceptions regarding the factors that affect mine mechanisation. Management will tend to rate productivity and cost as the more important factors. Unions are likely to rate unemployment as one of the critical factors influencing mechanisation. Technology developers are likely to rate technology development high. Consultants would also tend to rate cost and productivity as important factors. There are no differences in perceptions between the stakeholders in terms of mine safety.

The research revealed that there are no significant differences in perceptions between the different stakeholder groups. The research findings are different from the stakeholder theory described in the literature review. The main reason for this could be that stakeholder engagement is frequent; goals and objectives are more aligned among the different stakeholders, through stakeholder management plans, resulting in no significant differences in perceptions. Mining stakeholders are also aware of the fact that mines will not be economically viable without effective stakeholder engagement, as can be seen by the recent protests (Lane & Kamp, 2013). This is good news for mining houses, as it can be assumed that there is consensus amongst the stakeholders regarding mechanisation; hence, there will not be a need for intense stakeholder management initiatives. It is also evident that consultants are more in agreement with each other than the other stakeholders regarding most of the empirical factors.

It was anticipated that all stakeholders will perceive mine safety in the same way. Mine safety comprises the following three factors:

- Safer mechanised mining equipment
- A reduction in the number of fatalities
- A reduction in the number of dangerous activities.

The ANOVA revealed that there are no differences in perceptions among the various stakeholders regarding reduction of fatalities and reduction of dangerous activities. However, there is a slight difference in perception regarding safer mechanised machinery, where the perception of technical staff varies from the other three stakeholders. Technical staff views this factor as a marginally less favourable factor relative to the other three stakeholders. Overall, the results can be interpreted as there are no significant differences in mine safety among the different stakeholders. It is also evident that vendors have a higher level of agreement with each other than the other stakeholders in terms of reduction in fatalities and reduction of dangerous activities. Consultants, on the other hand, have a higher level of agreement with each other regarding safer mechanised equipment.

5.7 Conclusion

The current research attempts to provide empirical evidence on the favourable and unfavourable factors uncovered in the literature. The research conducted shows that there is sufficient evidence that supports Proposition 1, Proposition 2 and part of Proposition 3. This evidence has been illustrated through detailed statistical analyses and the literature review.

Descriptive statistics provided valuable insight in terms of identifying and evaluating favourable and unfavourable factors that affect mechanisation in the South African platinum mining industry.

The exploratory factor analysis provided insight into the underlying structure of the dataset. The factor analysis results confirmed the initial structure used with the exception of one additional factor. Finally, the ANOVA showed that there were no differences in perceptions of the different mining stakeholders.

Proposition 1 is supported by the research findings with a few minor exceptions. Lifecycle cost is perceived as favourable as opposed to very favourable; compatibility of new equipment with existing infrastructure is perceived as neutral as opposed to favourable.

Proposition 2 is also supported by the research, with a few minor exceptions. Hard rock conditions are perceived as neutral as opposed to unfavourable; skills shortages are perceived as unfavourable as opposed to very unfavourable.

Proposition 3 comprises two parts. The first part relates to stakeholder perceptions of mechanisation as a whole and the second part relates to stakeholder perceptions of mine safety. The first part of the proposition is not supported by research, as the research findings contradict the literature review findings. The second part of the proposition is supported by the research.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter discusses conclusions and provides recommendations based on the research that was conducted. This chapter also offers areas for further research possibilities.

This research set out to identify and evaluate favourable and unfavourable factors that affect mechanisation in the platinum industry. The research further intended to identify differences in stakeholder perceptions. The findings and conclusions are discussed below.

6.2 Conclusions of the research

As identified earlier, since mining research in general has been deteriorating for the past two decades (Vogt, 2011), it provides an opportunity to undertake further research. The literature has uncovered the main factors that influence mechanisation in the mining industry. This research attempted to identify and evaluate factors affecting mechanisation, with specific reference to the South African platinum mining industry. The main conclusions drawn from both, the primary and secondary, research findings show that there are many commonalities and similarities pertaining to favourable and unfavourable factors.

It is also not surprising that factors relating to mine safety and productivity emerged as very favourable, as these factors were highlighted distinctly in the literature. Some of the other factors identified in the research that are on the border of being classified as very favourable are mine design and planning (correct equipment selection) during the implementation of mechanisation and an improved work environment, which is a direct result of mechanising. The stakeholders perceive job creation, change management and training and development as the least favourable factors.

It was also uncovered that hard rock conditions and compatibility of new equipment with existing infrastructure are perceived as neither favourable nor unfavourable.

The unfavourable factors influencing mechanisation are: mining complexities, i.e. mining faults and high waste, high lead times to develop new mining technologies, high capital cost, skills shortages and job losses. Although there were no factors rated as very unfavourable, the most unfavourable factors identified are skills shortages and direct job losses.

The research showed that stakeholder perceptions were the same regarding mine safety and mechanisation as a whole.

Conclusions regarding the propositions are captured in Table 16, Table 17 and Table 18. The propositions are re-stated for ease of reference.

Table 16: Proposition 1 conclusion (favourable factors)

Proposition 1	Result	Conclusion
The favourable factors affecting mine mechanisation are: mine safety, productivity, operating cost (OPEX) and lifecycle cost (overall cost), mine design and planning, employment, technology development, skills development, organisational factors, and labour unrest. **Three factors, namely:** mine safety, productivity and lifecycle cost (overall cost) are very favourable factors.	**Exceptions to Proposition 1 are listed below:** Compatibility of new equipment with existing infrastructure (mine design and planning) is perceived as neutral as opposed to favourable. Lifecycle cost is perceived as favourable as opposed to very favourable.	**Generally Accepted**

Table 17: Proposition 2 conclusion (unfavourable factors)

Proposition 2	Result	Conclusion
The unfavourable factors that affect mechanisation are: mining complexities, technology development lead times, direct job losses, capital cost (CAPEX) and skills shortage. **Skills shortage** seems to be a very unfavourable factor.	**Exceptions to Proposition 2 are listed below:** Hard rock conditions is perceived as a neutral factor as opposed to unfavourable. Skills shortage is perceived as unfavourable as opposed to very unfavourable.	**Generally Accepted**

The exploratory factor analysis confirmed the initial structure used to conduct the research. The factor analysis showed empirically that the three factors: decision to mechanise, implementation of mechanisation and outcomes of mechanisation do exist. The analysis also uncovered a new factor, namely, impact of people on mechanisation.

There are also some new insights provided from the research regarding stakeholder perceptions. What is surprising is the fact that all stakeholder perceptions regarding mechanisation are not significantly different. Due to a lack of research of stakeholder perceptions of mechanisation, the stakeholder model was adopted. Stakeholder theory states that stakeholders would act based on their interests. Different perceptions were expected from the various stakeholders, but the research results were vastly different to what is implied by stakeholder theory. However, as expected, stakeholder perceptions regarding mine safety are the same.

Table 18: Proposition 3 conclusion

Proposition 3	Result	Conclusion
The different stakeholders have different interests and perceptions regarding the factors that affect mine mechanisation. Management will tend to rate productivity and cost as the more important factors. Unions are likely to rate unemployment as one of the critical factors influencing mechanisation. Technology developers are likely to rate technology development high. Consultants would also tend to rate cost and productivity as important factors. **There are no differences in perceptions between the stakeholders in terms of mine safety.**	The first part of the proposition is rejected as there are no significant differences in perceptions of mechanisation. The second part of the proposition is accepted as the perceptions of the stakeholders regarding mine safety are the same.	**Partially Accepted**

6.3 Recommendations

Recommendations are based on the current research findings. For mechanisation to be successful, barriers or unfavourable factors must be addressed. Some of the recommendations are listed below:

- Job losses at mines due to mechanisation can be viewed as a threat. Although it has been stated that secondary jobs will increase, stakeholders need to cooperate and find ways in order to minimise direct job losses.
- Mechanisation and artisan skills shortages in the country remain unfavourable for mechanisation. Mechanisation and artisan skills are mainly developed through

Further Education and Training (FET) colleges and on the job training at mine site training facilities. Organisations need to invest in training and development of employees in order to address the skills gaps.

- High capital cost of mechanisation is still a negative factor affecting the decision to mechanise. Further development of cost effective machinery is encouraged through innovation. Effective mine planning through prefeasibility studies and feasibility studies is also recommended in order to find alternatives to minimise initial capital outlay (CAPEX). It is also beneficial for mines to use existing infrastructure as much as possible to minimise capital cost.
- The time taken to develop new technologies for mining is relatively long. New strategies need to be developed by mining houses and technology development vendors jointly in order to shorten the lead times. Investment in research and development of these new technologies will also play a pivotal role in the success of mechanisation. A proactive stance needs to be adopted to mine mechanisation research and development. The investment in new technologies must take place in good time in order to have mechanised equipment available when required.
- Mining faults and high waste associated with mechanised mining are also major challenges. Mining houses and technology vendors must also collaborate and develop equipment that is small enough in order to minimise waste and be flexible enough to encounter complex geological constraints. Although hard rock was identified as a neutral factor, it is still imperative that continuous rock cutting research and development continue with urgency. This will improve safety levels and enable continuous mining, which eliminates the risky drill and blast cycle.

6.4 Suggestion for further research

This research looked at the platinum industry in South Africa, where favourable and unfavourable factors that influence mechanisation were identified and evaluated. This research is exploratory in nature, and there is no doubt that there is substantial work still needed to be done in order to understand all facets of mechanisation comprehensively. Based on the literature review and research conducted, below are some further research suggestions.

6.4.1 *Confirmatory factor analysis (CFA) study*

A confirmatory factor analysis is generally used to test an existing model. This existing model is based on research that has already been conducted. The exploratory factor analysis conducted in this research revealed the underlying structure of the data and sets a platform for further research. This new structure can be confirmed by conducting a confirmatory factor analysis study. The measurement tool, which is the questionnaire, can be updated to incorporate the results of the exploratory factor analysis. This updated questionnaire can then be administered to a second sample in order to confirm the current identified exploratory factor model.

6.4.2 *Qualitative research*

A qualitative research on mechanisation would be beneficial, as this will allow researchers to uncover details regarding specific issues in terms of why some factors are more favourable or unfavourable than others. By understanding why some factors are more favourable or unfavourable than others, mining stakeholders can focus their attention and resources on any critical issues that may arise.

This research showed that some of the soft skills, such as leadership and change management, are less favourable than some of the other factors, namely, correct equipment selection and mine design. These soft skills are important to create a common vision, drive change, inspire, and lead people to achieve project goals. It would be useful to understand why these soft skills are perceived as less favourable than some of the other factors highlighted in the research.

Now that the unfavourable factors have been identified, it is imperative to determine why these factors are unfavourable. Unfavourable factors are seen as resistance or barriers to mechanisation. Mining companies have to devise action plans in order to minimise resistance or eliminate potential barriers to mechanisation. This can be done by conducting a qualitative research in order to determine all possibilities of why these factors are perceived as unfavourable.

6.4.3 *Labour unrest research*

As mentioned in the research, the impact of labour unrest is potentially devastating for platinum mining producers. The cost impact of any future labour unrest could be devastating to the South African economy. Although the research highlights the fact that there will be less unskilled labour in a mechanised mine, labour unrest can still affect a mechanised mine very unfavourably. Therefore, it is still important to understand why there is such varied perceptions (as uncovered in the research) relating to this factor. A comprehensive list of stakeholders can be generated; these stakeholders can then be interviewed to establish all aspects pertaining to labour unrest. A thorough understanding of labour unrest will assist mining houses to proactively manage labour disputes.

6.4.4 *Retrospective case study research*

As identified in this research, coal and gold mines are extensively mechanised. The research further indicated that many trials regarding mechanised mining methods have been implemented at some of the platinum mines. This provides an opportunity to investigate specific aspects of mechanisation. Recent trials at some of the platinum mines can reveal important information regarding many aspects of mechanisation. Some of the important information that can be gathered through a case study can divulge new insights such as technology performance and challenges, skills development challenges, mine design constraints, and safety improvements.

By tapping into other industries that are extensively mechanised, such as coal and gold, other critical information can be uncovered. Due to the fact that the coal and gold mining industries have been through the full cycle of mechanisation, broader issues can be identified. Although the platinum industry may have some differences to coal or gold; there may be many commonalities between the different industries. It will be beneficial to determine what the effects of these mechanised projects on certain factors were. It will also be very valuable to uncover some of the implicit challenges experienced during the life of these mechanisation projects.

6.4.5 *Inclusion of other stakeholders*

The research showed that many stakeholders exist within the platinum mining industry. The importance of taking into consideration these stakeholders perceptions is vital. This research was initially planned for a sample that includes five stakeholders, but one stakeholder, the union representatives, was discarded due to a poor response rate. Future research should include union representatives, as they are an important stakeholder and could have strong opposing views relating to mine mechanisation. If they have strong opposing views, this can then be proactively managed.

Generally, the union representative's perceptions are shared with employees of the mine (union members), resulting in a possibility of these employees adopting a similar perception to the union representatives. If union representatives have a negative perception of mechanisation, then there is a possibility that the employees will also have a negative perception, which can be detrimental to mechanisation projects. These employees that are represented by unions can also be a separate stakeholder. This will enable researchers to determine the employees' perceptions and assess the influence of union representatives on these employees.

6.5 Conclusion

Mine mechanisation is one of the disruptive innovations that the South African platinum mining industry is faced with. This field is still topical, multifaceted and complex.

The research results obtained were informative and uncovered a few aspects that were not present in current literature. The first two propositions relating to favourable and unfavourable factors were generally accepted with a few minor exceptions, but the third proposition regarding stakeholder perceptions was only partially accepted. It is hoped that the findings of this research will assist mining companies to better understand their stakeholders perceptions and the factors that influence mechanisation, which, will in turn help them in future planning and strategizing. It is also desired that the research findings add to the body of knowledge of mine mechanisation in the platinum sector.

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APPENDIX A

Request Email to Participants

Dear Participant,

I am a student at Wits Business School and conducting research in the mining industry. The title of my research is **"Factors affecting mechanisation in the South African Platinum Mining Industry".** This research aims to identify and evaluate favourable and unfavourable factors that influence mechanisation. I would be very grateful if you could kindly spend 10 minutes of your time to answer a few questions. You are under no obligation to take this survey. You are free to discontinue the survey at any point.

Kindly provide answers to the best of your ability. Your responses will remain anonymous.

Thank you in advance for your participation.

Yours sincerely

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APPENDIX B

Online Survey Using Qualtrics

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Q1.
Select the category that reflects your position or role

- ◯ Mining House Technical Staff (Engineer, Scientist, Designer, Machine Operator, Artisan)
- ◯ Mining House Management Staff (Project Management, Engineering Management, Junior Management, Senior Management, Director)
- ◯ Consultant (EPCM, Management Consultants)
- ◯ Vendor (Equipment Supplier, Equipment Manufacturer, Technology Developer)
- ◯ Trade Union Representative

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Q2.
How favourably or unfavourably do the following factors affect the decision to mechanise:

	Very Unfavourable	Unfavourable	Neutral	Favourable	Very Favourable
Hard rock conditions	◯	◯	◯	◯	◯
High waste associated with mechanised mining	◯	◯	◯	◯	◯
Mining faults (discontinuity of rock volume)	◯	◯	◯	◯	◯
Development of new mechanised mining machines	◯	◯	◯	◯	◯
High lead time to develop mining technology	◯	◯	◯	◯	◯
Labour unrest	◯	◯	◯	◯	◯
High capital cost (CAPEX)	◯	◯	◯	◯	◯
Low operating cost (OPEX)	◯	◯	◯	◯	◯
Low lifecycle cost (CAPEX and OPEX)	◯	◯	◯	◯	◯

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Q3.
How favourably or unfavourably do the following factors affect the successful implementation of mechanisation:

	Very Unfavourable	Unfavourable	Neutral	Favourable	Very Favourable
Artisan skills shortage (skills to maintain mechanised machinery)	○	○	○	○	○
Mechanisation skills shortage (skills to operate mechanised machinery)	○	○	○	○	○
Safer mechanised mining equipment	○	○	○	○	○
Thorough mine design and planning	○	○	○	○	○
Correct equipment selection	○	○	○	○	○
Compatibility of new equipment with existing infrastructure	○	○	○	○	○
Good relationships between mining companies and technology vendors	○	○	○	○	○
Training and development of mineworkers on mechanised machinery	○	○	○	○	○
Leadership skills	○	○	○	○	○
Change management skills	○	○	○	○	○
Investment in training and development	○	○	○	○	○

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Q4.
To what extent are the following outcomes of mechanisation favourable or unfavourable:

	Very Unfavourable	Unfavourable	Neutral	Favourable	Very Favourable
A reduction in the number of fatalities	○	○	○	○	○
A reduction in the number of dangerous activities	○	○	○	○	○
Increased production	○	○	○	○	○
Jobs lost directly (at the mine)	○	○	○	○	○
Jobs created indirectly (by secondary industries)	○	○	○	○	○
Increased job creation overall (in the mining industry as a whole)	○	○	○	○	○
An improved work environment (physically less demanding)	○	○	○	○	○

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APPENDIX C

Kaiser's measure of sampling adequacy

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.71903406		
Q2.1	Hard rock conditions	0.68679598
Q2.2	High waste associated with mechanised mining	0.71131368
Q2.3	Mining faults (discontinuity of rock volume)	0.73379376
Q2.4	Development of new mechanised mining machines	0.61281686
Q2.5	High lead time to develop mining technology	0.73372006
Q2.6	Labour unrest	0.75663705
Q2.7	High capital cost (CAPEX)	0.68380303
Q2.8	Low operating cost (OPEX)	0.68480332
Q2.9	Low lifecycle cost (CAPEX and OPEX)	0.59334651
Q3.1	Artisan skills shortage (skills to maintain mechanised machinery)	0.65366436
Q3.2	Mechanisation skills shortage (skills to operate mechanised machinery)	0.73972055
Q3.3	Safer mechanised mining equipment	0.75295113
Q3.4	Thorough mine design and planning	0.79134411
Q3.5	Correct equipment selection	0.74968826
Q3.6	Compatibility of new equipment with existing infrastructure	0.7121597
Q3.7	Good relationships between mining companies and technology vendors	0.84298792
Q3.8	Training and development of mineworkers on mechanised machinery	0.74801182
Q3.9	Leadership skills	0.76550374
Q3.10	Change management skills	0.71338875
Q3.11	Investment in training and development	0.75868714
Q4.1	A reduction in the number of fatalities	0.6648037
Q4.2	A reduction in the number of dangerous activities	0.71614196
Q4.3	Increased production	0.76960944
Q4.4	Jobs lost directly (at the mine)	0.50771231
Q4.5	Jobs created indirectly (by secondary industries)	0.77007691
Q4.6	Increased job creation overall (in the mining industry as a whole)	0.59939972
Q4.7	An improved work environment (physically less demanding)	0.79796057

APPENDIX D

Cronbach's alpha

Cronbach's alpha with missing variable		
Factor 1 Cronbach's alpha = 0.879		
Q3_4	Thorough mine design and planning	0.871
Q3_5	Correct equipment selection	0.865
Q3_6	Compatibility of new equipment with existing infrastructure	0.873
Q3_7	Good relationships between mining companies and technology vendors	0.863
Q3_8	Training and development of mineworkers on mechanised machinery	0.879
Q3_9	Leadership skills	0.848
Q3_10	Change management skills	0.847
Q3_11	Investment in training and development	0.857
Factor 2 Cronbach's alpha = 0.799		
Q2_1	Hard rock conditions	0.781
Q2_2	High waste associated with mechanised mining	0.785
Q2_3	Mining faults (discontinuity of rock volume)	0.777
Q2_4	Development of new mechanised mining machines	0.797
Q2_5	High lead time to develop mining technology	0.754
Q2_7	High capital cost (CAPEX)	0.766
Q3_1	Artisan skills shortage (skills to maintain mechanised machinery)	0.763
Q3_2	Mechanisation skills shortage (skills to operate mechanised machinery)	0.753
Factor 3 Cronbach's alpha = 0.777		
Q4_1	A reduction in the number of fatalities	0.761

Cronbach's alpha with missing variable		
Q4_2	A reduction in the number of dangerous activities	0.740
Q4_3	Increased production	0.721
Q4_5	Jobs created indirectly (by secondary industries)	0.746
Q4_6	Increased job creation overall (in the mining industry as a whole)	0.800
Q4_7	An improved work environment (physically less demanding)	0.760
Factor 4 Cronbach's alpha = 0.634		
Q2_6	Labour unrest	0.745
Q2_8	Low operating cost (OPEX)	0.508
Q2_9	Low lifecycle cost (CAPEX and OPEX)	0.476
Q3_3	Safer mechanised mining equipment	0.592

APPENDIX E

ANOVA Outputs

Dependent Variable: Implementation of Mechanisation					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	0.673155	0.224385	0.25	0.8618
Error	125	112.5944	0.9007549		
Corrected Total	128	113.2675			
R-Square	**Coeff Var**	**Root MSE**	**Mean**		
0.005943	7069.2	0.949081	0.013426		
Source	**DF**	**ANOVA SS**	**Mean Square**	**F Value**	**Pr > F**
Stakeholder Group	3	0.673155	0.22438497	0.25	0.8618

Dependent Variable: Deciding Elements of Mechanisation					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	5.136709	1.7122362	2.1	0.1036
Error	125	101.9095	0.8152757		
Corrected Total	128	107.0462			
R-Square	**Coeff Var**	**Root MSE**	**Mean**		
0.047986	-4365	0.902926	-0.020686		
Source	**DF**	**ANOVA SS**	**Mean Square**	**F Value**	**Pr > F**
Stakeholder Group	3	5.136709	1.71223624	2.1	0.1036

Dependent Variable: Benefits of Mechanisation					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	2.82317	0.9410565	1.13	0.3406
Error	125	104.3201	0.8345608		
Corrected Total	128	107.1433			
R-Square	**Coeff Var**	**Root MSE**	**Mean**		
0.026349	6655.9	0.913543	0.013725		
Source	**DF**	**ANOVA SS**	**Mean Square**	**F Value**	**Pr > F**
Stakeholder Group	3	2.82317	0.94105655	1.13	0.3406

Dependent Variable: Impact of People on Mechanisation					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	5.310502	1.77016724	2.37	0.0741
Error	125	93.49908	0.74799265		
Corrected Total	128	98.80958			
R-Square	**Coeff Var**	**Root MSE**	**Mean**		
0.053745	-3089.6	0.864866	-0.027993		
Source	**DF**	**ANOVA SS**	**Mean Square**	**F Value**	**Pr > F**
Stakeholder Group	3	5.310502	1.77016724	2.37	0.0741