The Influence of the physical underground workplace conditions on the production at a deep level gold mine

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ABSTRACT

The general aim of this research study was to determine whether the physical underground conditions have an influence on the production output at a deep-level gold mine. This type of study has never been conducted within this particular environment, and, as such, a valuable contribution could be made to ensure more effective performance results within this context.

A questionnaire was administered to test the responses of 150 employees. A response rate of 91% was obtained for the questionnaires.

The data showed a statistically significant, positive relationship between underground conditions and the production output. The data showed that there were some significant differences for the various demographic groups, as well as their perceptions of the factors.

Limitations within the study were identified and recommendations for future research were made.

Key Terms: Work place conditions, production, production output, deep-level mining, gold mining industry, unions, safety, workplace hazards, production parameters.

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CHAPTER 1 – NATURE AND SCOPE OF STUDY

1.1 Introduction

This study was executed to determine the influence that the physical underground workplace condition has on the production, at a deep-level gold mine. Towards the end of 2012 and the beginning of 2013, a number of very significant events in the mining industry, changed the way forward for mining in this county, which would prove irreversible for the foreseeable future.

According to De Waal (2012),

> Violent clashes continued in the mining sector, this time in Carletonville, where workers were allegedly shot at with live rounds and rubber bullets at Harmony Gold's Kusaslethu mine. With layoffs, union rivalry and mine bosses reneging on pay promises, 2013 looks set to be a torrid year for SA's mining sector.

During 2012, 50 people lost their lives as a result of violence at various mine. During this time, 34 people were killed during the Marikana Massacre. This happened when police opened fire on striking mineworkers at Lonmin's mine in Rustenburg. Today this is remembered as one of the greatest tragedies in the recent history of South Africa.

Bheki Sibya, the CEO of the Chamber of Mines (now known as the Minerals Council of South Africa), stated that:

> 2013 looks to be a challenging year for government, mine owners and workers in the sector, because when the sector gets back to work in January, the first thing on the agenda is the shedding of jobs (De Waal, 2012).

Kusasalethu mine operation is situated on the West Wits Line. Kusasalethu is situated 14 kilometres south of Carletonville, and 90 kilometres southwest of Johannesburg. The mine employs around 5000 people, including contractors. The mine has an average production profile of 13 500 m² of ore per month, an average of 58 650 tons of gold-bearing ore brought to the surface ('hoisted'). The former is then treated per month, at a recovered grade of 6.85 grams of gold per ton of ore, which produces an average of 400 kilograms of gold per month, at a Rand per ton cost of R3087 per ton (Unknown, 2019).

Kusasalethu has proven to be a very ‘temperamental beast’, with many technical challenges and a very volatile labour force. The impact of labour unions has played a significant role in the mine. Since the start of 2007, Harmony Gold has spent R4bn capital expenditure on the Kusasalethu operation, in an effort to turn the operation around, from a marginal producer to a world-class operation. Unfortunately, of an expected annual production of 415,806 ounces of gold per annum, only 124,198 ounces of gold had realised. (Ryan, 2016).

For an extended period of time, the mining department has not achieved its targets. This has resulted in below-benchmark gold production, which relates to lower revenue that is generated, as well as lower profits for the company. This is of great concern to the company’s executive management (Ryan, 2016).

The factors that could have an influence on the productivity of Kusaslethu Mine are as follows:

- Physical underground workplace conditions:
    - The distances travelled, from the shaft to the point where actual mining takes place, have increased to between three and six kilometres, which reduces possible available time to complete daily tasks at the point of production (referred to as ‘face time’).
    - An ageing infrastructure to support services, such as electricity, water and air.
    - The huge dimensions of mined-out areas limit the effectiveness of available ventilation.
- As older employees leave and/or retire, their skills and vast experience are lost.
- The morale of employees is often low (Gouws, 2015).

In a deep-level gold mine like Kusasalethu, the underground working environment is challenging. The conditions are normally hot, very humid and wet. As a result, the conditions are very dangerous. The air that the people have to breathe, has often been circulated through other working areas and has, therefore, also become hot. The workers travel vast distances underground, to reach their actual place of work.

These distances can be up to six kilometres, and workers often have to walk to cover these distances (Gouws, 2015).

It is evident that all these conditions could have a negative impact on a person who works in these conditions (Gouws, 2015). In this study, an attempt is made to establish whether a relationship exists between these underground conditions, and below-par production output.

1.2 Problem statement and core research question

The problem being investigated is that current production levels at Kusasalethu mine are low, and often do not meet the required production levels planned to sustain the operation. Lower production output tends to go hand in hand with increased safety risks, as well as with people exhibiting risky behaviour, which in turn results in an increase in injuries and fatal accidents (Long *et al*, 2015).

The lower production, on the other hand, has a negative impact on the final quantity of gold produced. This then results in lower earnings for the company, as well as reduced profit margins. Ultimately, this destroys value for shareholders, which poses the risk that shareholders would take their investment elsewhere (Zubac, 2019).

The severe underground working conditions are not conducive to high production levels (Gouws, 2015). This, in turn, could be demotivating to people who work under these conditions, and could have a detrimental effect on the morale of employees, which will further negatively affect mind-set production output (Gouws, 2015). The key question, therefore, is: What is the influence of the physical underground workplace conditions on the production achieved at Kusasalethu Gold Mine?

This research is intended to investigate the hypothetical relationship in the above research question.

1.3 Research objectives

1.3.1 Primary objective

The general objective of this research study is to determine the influence of the physical underground conditions on the production achieved at a deep-level gold mine.

1.3.2 Secondary objectives

The specific objectives of this study are to:

- provide an overview of deep-level mining;
- investigate workers' experience of the physical underground conditions;
- determine the reasons for low production at a deep-level mine; and
- quantify the influence of the physical underground workplace conditions on the production at a deep-level gold mine.

1.4 Scope of the study

The study was conducted, in order to test a theory that was formulated before the commencement of the current study. A quantitative research method was chosen, based on a positivist paradigm, where a self-constructed questionnaire was used for the collection of data. The data was coded in excel and statistically analysed (Wang, 2018). This approach is commonly used in empirical investigations of social phenomena. The study was conducted at a single mine, amongst non-unionised workers. The decision was made to only involve those employees in a supervisory capacity in the production/mining environment at the Kusasalethu mine, who work underground. The research involved all levels of supervisors – from junior management up to senior management. At the time of the study Kusasalethu employed 3979 employees, of which 360 are in supervisory positions.

The study population, to which the questionnaire was distributed, consisted of 148 supervisors from the production/mining department, the engineering department and the services departments. The sample size of 148 was based on the actual number of supervisors working in the various supervisory levels within the mining environment, at the point in time when this research was conducted, and based on the current labour planning that was done.

The numbers of people in the various supervisory job categories, that were included in the study, are as follows:

- 73 Mining personnel
- 10 Engineering personnel
- 60 Services personnel
- 5 Senior Managers

1.4.1 Assumptions

In the case of this research project, it was assumed that the questionnaire responses from all the participants were provided honestly, and that all the respondents are knowledgeable about the topic being researched.

1.5 Importance and benefits of the study

In 2007, the editor of Mining Weekly, Martin Creamer, stated that mining in South Africa is a deep, dark and dangerous business. He then continued to state that foreign companies are becoming increasingly apprehensive and fearful of the risks associated with South Africa's deep-level mines (Faul, 2007). In an ever-changing and increasingly challenging environment, which is dictated by legislation and prescriptive policies on creating value for shareholders, it has become progressively more imperative for gold mines to achieve set targets. As price takers are subject to fluctuating Rand-Dollar exchange rates, profit margins are constantly under pressure.

Promises that are made to shareholders and forecasts, are carefully based on the production planning parameters that are determined through an elaborate and complicated system of simulations and scheduling methods. These parameters are compiled by inputs from all the different departments on the mine. The purpose of these plans is to determine the budgets that can be supported by the set production levels, and still be able to generate a profit (Garg, 2011, 29).

In an ideal and perfect working environment, a mine will achieve or surpass its targets, and realise a monthly profit. The variance between planned production levels and the actual production achieved, indicates that there is an obvious problem. In a publication by Lulea University of Technology in 2014, it is stated that research showed a lack of research, in regard to working conditions that relate to sustainable development in mining (Abrahamson, 2014).

When Harmony published its annual report, it stated and promised that the then Elandsrand mine (subsequently renamed to Kusaslethu mine), would produce 415,806 ounces of gold per year. However, up to the financial year-end of June 2016, they only managed to produce 124,198 ounces (Unknown, 2018). This is a clear indication that there is a problem with production.

The aim of this research endeavour is to determine whether or not the particular problem with production is due to the underground working conditions at Kusaslethu. In essence, if management can understand why there is a variance between the planned and actual production, and if they can identify the issues leading to the working conditions and address them, there should be increased production and, therefore, more profits.

Research methodology

1.6 Literature overview

According to Saunders and Bezzina (2015), one should always ensure that all the literature consulted and used must be relevant. The factors that should be considered, in order to ensure this are the following:

- How current is the relevant item being used?
- What is the likely hood that the item being used is out-dated?
- Is the context adequately different to ensure that it is marginal to the research question and the objectives?
- Whenever a reference to this item or its author have been found in other sources of literature, the assumption can be made that the source is reliable.

- One should always establish whether the item supports or opposes the argument. If it is in fact the case, additional studying of the topic could add value to the external validity of the study.
- It is important to establish if any bias exist in the source, and even if it is the case, it might still be applicable to one's critical review.

During the literature review of this research study, the abovementioned guidelines where used and consider. During the first phase, a complete literature review of the constructs that were researched, was conducted. The sources that were consulted and used include:

- The data base of the Ferdinant Postma library at the NWU in Potchefstroom, for the literature search.
- The internet was used to search for relevant articles and literature.

During the search phase, the keywords used for this study were: deep-level gold mines, mining industry, production, physical underground conditions, underground workplace, Chamber of Mines, factors that influence productivity, Harmony Gold, Ore body and Ore resources, ventilation, ground support, mining methods, occupational hazards, safety, productivity, gold price volatility, production costs, unions in mining, productivity measurements, and unit costs.

Empirical research

1.7 Research method

1.7.1 Research design

The purpose and intention of this study were to pursue a quantitative investigation, by implementing a cross-sectional field survey. This research study was carried out at Kusasalethu Gold Mine operation, which is part of the Harmony Gold group. This study is intended to provide understanding into the actual, physical underground conditions at the mine, as well as the influence that these conditions have on the underground production. This could assist the company in the possible improvement of the production results, if these influences can be understood and mitigated. A quantitative approach was followed in the study.

1.7.2 Research participants

The target population for this research study consists of the supervisors who work underground, on a daily basis, supervising and directing all work performed in the underground working places. The units of analysis will consist of the individual supervisors, on the different supervisory levels, and who are responsible for the health and safety of workers, as well as for achieving production targets.

From this target group, four distinct subgroups can be identified, which serve as the sample for the study. The sample consists of:

- 73 Mining personnel
- 10 Engineering personnel
- 60 Services personnel
- 5 Senior Managers

All of these categories of supervisor-level participants, at the Kusasaletu mine, work underground on a daily basis, in order to visit all their relevant working places, where they are responsible for health and safety issues, as well as for production output. The reason for selecting the particular sample is three-fold: First, they cover all the different working places on a daily basis, and are exposed to the physical underground conditions. Therefore, they understand the influence of the physical underground conditions on production levels.

Secondly, the respondents are regarded as a reliable source of information, as they all have a sufficiently high level of education – starting with grade 12 for the miners with a blasting ticket, all the way up to higher tertiary qualifications, as the ranks and levels increase and develop. Being literate has the additional advantage that it also simplifies and accelerates the data collection process, since survey documents can be distributed electronically (via e-mail), and the participants can complete it independently and at their leisure, and then return it to the researcher.

The third reason for selecting this group to participate in the study, is that they would be keen to cooperate and give honest feedback, as the research topic (and a solution to the problem being studied) is close to their hearts. It was easy to obtain the contact details of this group of individuals from the human resources department, and permission could easily be obtained for conducting the study amongst this group of respondents.

1.7.3 Measuring instrument

There is a number of commercially available, reliable, validated measuring instruments to test the constructs being measured in this study. The first choice was, therefore, to use one of these readily available instruments. Welman and Kruger (2001) state that, if the researcher intends to use such an instrument, the reliability coefficients reported in test manuals and past studies should be comparable to those found in the current study. It is also of utmost importance that the available instrument should be appropriate and valid for the purpose intended. In this study, no existing questionnaire could be found that would be able to test all the constructs of this study.

Due to this, a self-compiled questionnaire was used for the collection of data for the study. This questionnaire consisted of a demographic section and a section of 28, six-point Likert scale questions. The 6-point scale was constructed as follows: 1 (‘Not at all’), 2 (‘To a small extent’), 3 (‘To some extent’), 4 (‘To a moderate extent’), 5 (‘To a great extent’), and 6 (‘To a very great extent’).

1.7.4 Research procedure

Before the research was conducted, the first step was to obtain permission to conduct research in this organisation. This permission was obtained from the organisation’s management. Each of the target respondents was also approached individually, and asked to participate in the study. The questionnaire was explained to each participant and they were given clear instructions. Furthermore, the purpose of the research, as well as the survey was explained. Each participant was thanked for their participation.

Before each of the participants commenced with the questionnaire, their written consent was obtained. Each participant was given enough time and opportunity to complete the questionnaire. The participants were then requested to return the completed questionnaires to the researcher by placing it in a designated collection bin.

1.7.5 Statistical analysis

After compiling all the questionnaires, the statistical analysis was carried out, at the Statistical Consultation Services of the North-West University, using the Statistical Package for Social Sciences (SPSS), 23rd edition.

1.7.6 Ethical considerations

As part of the questionnaire, an explanation of consent was included in the introduction of the questionnaire. In this letter of consent, respondents were guaranteed that the process was anonymous and would be treated with the utmost confidentiality. They were also assured that they could withdraw from the study at any time. It was further explained that demographic information was purely requested for the purpose of statistical analysis. According to Welman and Kruger (2001), when conducting research, ethical considerations are important, and must be considered at three crucial stages of the research project:

- The first stage is when the actual participants are recruited to complete the questionnaires.
- The next stage is when the actual measurement procedure takes place, and the information is shared with the participants.
- The third stage is when the results are obtained and released.

All ethical principles were observed, including permission from the company where the study was carried out, as well as permission from the company to use their name in the study.

Welman and Kruger (2001) continued to state that there are other important ethical issues that need to be considered when conducting research, namely:

- Researcher competence – The researcher should be trained and have the skills required to conduct research. If this is not the case, he or she should not conduct the research.

- Literature review – In order to ensure that the proposed research study has not been conducted before, a thorough review of the literature must be performed by the researcher.
- The threat of plagiarism – Before a researcher can use the data or ideas of anybody else, one should get permission and give appropriate acknowledgement where it was due.
- Falsification of results – The altering and falsification of research results, and deceptive reporting will constitute unethical behaviour.

To ensure ethical compliance, all these prerequisites were met by the researcher. The researcher was trained in research, and a literature study is included in this document, with the necessary acknowledgements. The questionnaires that were administered in this study are in safe storage and available for the verification of the data.

1.8 Limitations of the study

The only limitation to this study is that it was carried out on only one of the operations of the organisations, which means the results can, therefore, not necessarily be generalised to the whole organisation and industry.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

On 1 September 2017, the chairman of the Harmony board, Patrice Motsepe, stated:

> “We will not hesitate to shut down Kusasalethu mine if it is found to be unsafe for mining. Maybe we have to ask ourselves as an industry, are the days of deep-level gold mining in South Africa at an end?” (Nkosi, 2017).

This literature review is aimed to study mining, and more specifically, deep-level mining and the underground conditions in the workplace, in general. This relates to the South African deep-level gold mining industry in particular. This was done in order to provide some level of understanding about the low production rates achieved at the mine.

This literature review was conducted through thorough investigation of the information presented in relevant published articles, journals, textbooks, academic research papers, online web-based reports, as well as operation-specific information. From this review, the researcher aims to establish whether any existing research, on the relationship between production levels achieved and the physical underground working conditions, specifically relating to the South African deep-level mining industry, has been conducted.

Specific conclusions were drawn, from this literature review, as to what the basic causes are for poor production, and whether additional research is needed to further investigate the relationship between the low production levels and the physical underground working conditions.

2.2 What is mining?

Pickering (1996) defines mining as a process that would deplete any natural resource. It would start with the easily recovered resources, and then progressively move on to the more difficult part of the resources to recover (Pickering, 1996).

Wills and Finch (2016) define underground hard rock mining as the use of different underground mining methods and techniques, to excavate minerals that would contain metals. These would include ore containing iron, gold, copper, silver, lead, zinc, tin and nickel. This would also involve using the same techniques to excavate ore that would contain gems, such as rubies and diamonds.

Mining is considered to be an ancient activity, and the occupation of a miner has, for a very long time, been recognised as arduous and dangerous. Mining activities have always been associated with physical injuries and disease, often leading to death (Wills & Finch, 2016). Mining has a very clear and distinguishable life cycle, which consists of five consecutive steps. These steps would start with the exploration phase, followed by the mine development, which provides the foundation for the third step – the actual mine operation. After the completion and exhaustion of all viable ore and minerals, the decommissioning phase would follow. The final stage is the rehabilitation of land on the mining site (Wills & Finch, 2016).

Mining is a very labour intensive industry, drawing on a multitude of disciplines, professions, trades and highly specialised skill sets. As a general rule, mining can be divided and classified as metalliferous mining, or coal mining. It is often distinguished by mining underground, or mining on the surface. Metalliferous mining is always associated and classified with a specific commodity that will be mined. (Wills & Finch, 2016)

At most mine sites, where a specific metal or mineral is mined, a certain degree of mineral processing will take place, and in some instances, further processing will take place at a later stage, at a refinery that is situated on a different site. In the case of metalliferous mining and the metallurgical processes, there are many associated occupational health hazards (Wills & Finch, 2016).

2.2.1 Mine access

In order to access the ore underground, the mine needs to develop an access way. There are various ways to do this, depending on the depth of the ore. Typically, this is done with declines or ramps, and inclined or vertical shafts. In the case of deep-level gold mining, this is ordinarily achieved with multiple vertical shafts, where the first descend is through a vertical shaft, and then a second descend through a sub-shaft (Annels, 1991:82).

A shaft can be defined as a vertical excavation that is sunk near, or adjacent to an ore deposit. Typically, a shaft is sunk where the ore is deep, and where the haulage of the ore to surface, with trucks or other similar means, is not economically viable (Annels, 1991:84).

2.2.2 Ore access

As a vertical shaft is sunk, or developed towards the desired depth, levels are excavated at certain pre-determined depths. A level is a tunnel, which is horizontally off the shaft, and is used to access the ore body. A mine can have several different levels spaced approximately 100 to 150 metres apart, depending on how deep a mine is, in order to access the entire ore body. When a level reaches the desired depth into the mine, stopes are excavated perpendicular to the levels into the economically viable ore (Annels, 1991:85).

2.2.3 Development mining vs. production mining

At any new mine, there are two principal phases to underground mining. The two phases are development mining and production mining. Essentially, the two phases are very different; however, interdependent. The one cannot be done without the other (Annels, 1991:87).

Development mining is done with an excavation in the waste rock, which means that the excavation is in rock that has no economic value. However, it must be done to reach the ore body that will be mined. Each round of development blasting requires six steps to be completed. Step one is the cleaning and removal of the previously blasted material. Step two is the barring or scaling, which entails the removal of loose rock and slabs with a pinch bar, to ensure the hanging, or roof and sidewalls are safe, and that workers do not get injured and/or that equipment is not damaged (Gentry, 2002:9). The third step is the installation of support and the spraying of ‘shot crete’ (cement), to secure the roof and sidewalls. Step four is to drill holes in the excavation end, or rock face. The holes are drilled to a predetermined depth, and in a specific pattern, to ensure the best possible effective braking of the rock face. The following step, step five, is to load explosives into the drilled holes, and finally, step six is to set off the explosives and blast the face. These steps are repeated as often as possible, to achieve the best possible advance of the development end, in a month.

Before any blasting activities can commence it is essential to plan the various activities, from the supply of adequate power and water to the drilling arrangement, the installation of ventilation, the de-watering of the tunnels, as well as the broken rock withdrawal facilities and arrangements.

The process of production mining is almost identical to the process for development mining, and the steps are near identical. However, there is a difference where the production mining happens on the reef horizon, and the stope faces are generally between 25 and 30 metres long, and mined perpendicular or abreast to the development excavations, and following the reef.

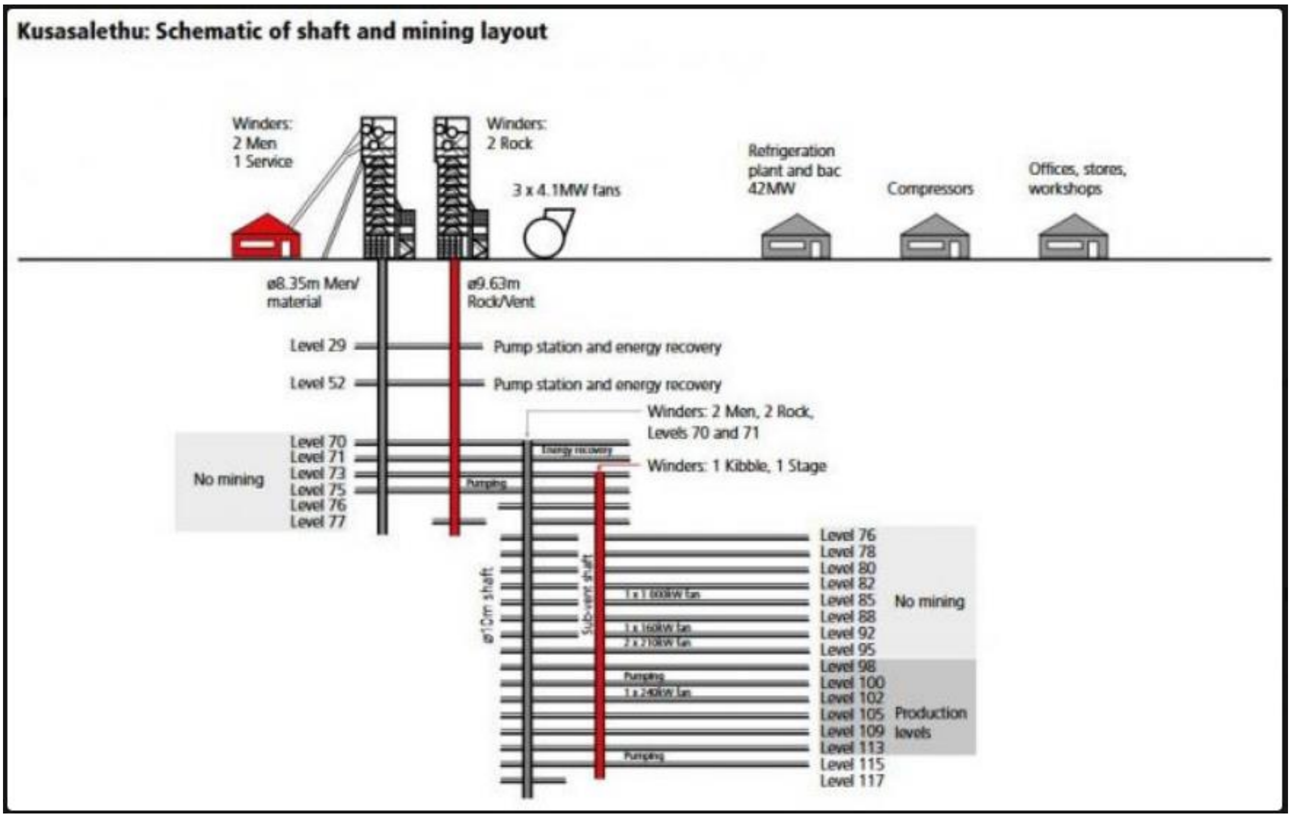

Figure 2.1: Typical deep-level gold mine layout

2.3 Underground conditions

2.3.1 Ventilation

Adequate ventilation is one of the most important parts of any deep-level underground mine. In fact, without ventilation, no mine can exist. Essentially, ventilation is the movement of air down the mine, circulating the air through the entire mine and then returning the used air back to the surface.

Ventilation is important, as it is the primary method of clearing the underground excavations of dangerous gases and dust, which are liberated by the mining activities. Drilling and blasting activities produce noxious gasses and fumes, which are hazardous to human health. These must be removed before the workers can enter working areas. In many mines, natural gasses exist, and emanate from the surrounding rock into the working areas (Gentry, 2002:42).

Another very important function of the ventilation system is to manage and control underground temperatures. In very deep mines, the ventilation is used to cool down the working places, to humanly acceptable levels, for work to commence. Heat is a big danger to the workers, and, if not controlled, excessive heat can easily lead to heat-related illnesses, such as fatigue and heat stroke, which, if not treated immediately, can be fatal (Jones, 2018).

In the deep-level mines, the primary source of heat is the actual heat that emanates from the virgin rock, which heats up the surrounding air. The deeper a mine goes down, the hotter the virgin rock becomes. Other factors that contribute to the increased temperatures in deep-level mines are machinery, heat from hot fissure water, and automatic compression. To a lesser extent, blasting activities and human body heat could also contribute to the heat underground (Jones, 2018).

2.3.2 Ground support

As the mining process entails the opening up of excavations in the virgin rock, supports (stays) maintain these excavations and keep them from collapsing – some form of support is, therefore, needed. This support could be in the form of local support and/or area support. Area ground support can be in the form of rock bolts, where long holes are drilled into the back area roof, and the long steel rods are installed, to secure the area (Kaiser *et al*., 2000).

Another form of area support is the building of timber packs, to support the local area. These packs are spaced on a pre-determined grid, as specified by the local rock engineering department. The last form of area support is the installation of backfill support. This entails the filling of big backfill bags, with the recycled tailings from the plant, after the gold has been extracted. As the mud dries, it forms a permanent support structure in the area.

Local ground support is the support of smaller localised areas, to prevent the falling of smaller rocks. This kind of support could take the form of welded wire mesh – a metal screen secured to the roof with anchor bolts. Another form of local ground support would be to spray affected areas with 'Shot Crete'. Shot Crete is concrete in a liquid form, enforced by fibres that coat the affected roof and sidewalls. This kind of support is very popular in development tunnels (Kaiser *et al*., 2000).

2.3.3 Mining methods

The method selected to mine a specific ore body, will differ for each type of commodity, and will be dictated by size, orientation and the natural shape of the ore body. In the Witwatersrand area, which includes Kusasalethu, the ore body is a narrow gold-bearing vein. The size of the ore body is determined by the grade and the natural distribution of the ore. The 'dip' (direction) of the ore body will help determine the suitable mining method that should be implemented, in order to mine that ore body successfully. In the case of the deep-level gold mines, a preferred method would be the long-wall method, where a number of panel faces, next to each other in a sequence, would be mined at the same time (Alford *et al.*, 2007:561-577).

2.3.4 Occupational hazards in mining

The topic of occupational hazard is closely related to the underground conditions that are found in the actual workplaces of deep level mines. Today, this is regarded as one of the most important topics related to mining. In this section the researcher will examine a number of different types of hazards that are related to mining.

2.3.4.1 Physical hazards

In deep-level mining, physical hazards and traumatic injuries remain two of the biggest problems impacting production. These can range from small injuries and scratches, to injuries resulting in fatalities. The most common incidents that could cause a fatal accident, would be uncontrolled rock falls, underground fires, unplanned explosions, rail-bound equipment accidents, falling from a height, inundation from mud, and electrical electrocution (Tadesse & Admassu, 2006).

A less common cause of fatalities, but a reality, is unexpected underground flooding of underground workings and tunnels. In recent years there has been a major drive towards the application of risk management techniques, and new legislation has also contributed to the effort to reduce risks and accidents. This has had a positive impact in decreasing injury frequency rates, in the gold mining sector in South Africa (Tadesse & Admassu, 2006).

However, in safety management, one can never claim that all targets have been met, and further improvement is a desirable outcome to this issue. Another major hazard that is associated with deep-level mining, is noise. Noise is generated from day to day activities, such as drilling the rock faces, cutting with equipment like grinders, material handling, the flow of ventilation and the fans associated in assisting ventilation flow, the crushing of broken ore, and the conveyance of broken ore (Tadesse & Admassu, 2006).

Controlling noise remains a challenge but the introduction of hearing protection systems like Noise Clippers™ has helped to prevent or limit hearing loss induced by mining activities. Recently, implemented legislation has forced companies to take more steps to reduce noise and protect the workers. However, in certain instances the implementation and convincing the workers to actually wear the hearing protection has proven less successful (Tadesse & Admassu, 2006).

Heat and humidity play a major role in deep-level mines, and remain a major risk. As one descends, the virgin rock temperatures and the air temperature increase with depth. This is due to the geothermal gradient of the rock, and the auto-compression in air columns. There are several heat illnesses that can be associated with the high temperatures in the mines. These illnesses differ in degree of seriousness. Illnesses can start with the onset of heat exhaustion; however, if left undetected and untreated, they can quickly progress to heat stroke – which could prove fatal (Van Eldik, 2006).

As mining activities are associated with the operation of mobile equipment, which results in whole-body vibration, such activities could lead to, or exacerbate, spinal injuries and disorders. Poorly maintained equipment and work surfaces could also pose an increased the risk to mine workers. The use of vibrating tools, such as air leg rock drills, could cause hand-arm vibration syndrome (Van Eldik, 2006).

2.3.4.2 Chemical hazards

According to Colinet (2010), one of the biggest risks associated with deep-level mining, is the exposure of workers to crystalline silica, which increases the risk of contracting silicosis. Silicosis has emerged as one of the most investigated mine-related illnesses. To a large extent, and with great success, silicosis can be controlled and even eliminated, through the implementation of measures that incorporate the addition of water to working places, and the suppression of dust

The use of water-fed rock drills, wet mining techniques, adequate ventilation supply and the wearing of respiratory protection (dust masks), can control dust and prevent silicosis. In a country with a very high HIV-positive workforce, this problem is increased with the presence of silico-tuberculosis, which affects many of the mineworkers and is highly contagious. In some cases, silicosis can be accelerated in rheumatoid arthritis, and can cause obstructive pulmonary disease, and ultimately lead to lung cancer (Colinet, 2010).

The presence of methane gas can pose a serious threat and danger in deep-level gold mine, as this gas is highly flammable, and at the correct percentage – mixed with the surrounding air – can be explosive. Many mineworkers have been killed in methane explosions, which, in many instances, could have been avoided (Colinet, 2010).

2.3.4.3 Ergonomic hazards

Deep-level gold mining has always been associated with a large amount of manual labour and material handling. As a result, the mining industry has one of the highest numbers of cumulative trauma disorders, and is ranked as the largest contributor to the industry's occupational disease. In many cases, prolonged disability can be the result, and has an impact on the production of the industry as a whole (Stuckler *et al*., 2015)

Common underground work practices are the installation of support in workplaces, the suspension of water and air pipes, as well as the suspension of all electrical cables. All of these include overhead work that could cause or exacerbate shoulder injuries and disorders. The underground environment is uneven and littered with broken ground and rocks, which is a major contributor to knee and ankle injuries (Stuckler *et al*., 2015)

Most mines are in operation for 24 hours a day, and 7 days a week throughout the whole year. This would necessitate the implementation of shifts. Shift work is often associated with fatigue. A study by McPhee (2007) showed that, when people experience sleep deficits, it can impair their cognitive and motor skills, as well as their performance.

2.3.4.4 Psychosocial hazards

Very often, the people working in the mining industry have been known to be prone to drug and alcohol abuse (Lauriski, 2018). Most, if not all, the major mining companies have procedures and policies in place to deal with such issues. There is an ongoing debate on the best way to test or measure psychosocial impairment (Lauriski, 2018).

Common practice, at most mining operations, is to measure breath-, or blood alcohol levels before engaging in work, and after accidents. In some instances, companies would implement the measurement of urinary drug metabolites, to test for impairment caused by the intake of drugs. Often mines are located in remote areas, away from major cities and communities. In some cases, this will justify the establishment of a so-called mine village, to house the mine workers (Lauriski, 2018).

In most cases, the workers would have to work away from their families, which often means working in foreign countries, as expatriates. The true psychological impact of these practices, is not yet fully understood. Mining practices are often associated with fatal accidents, and severe traumatic injuries. These tend to have a profound impact on the morale of those, in the workplace, who are left behind after such an incidence (Lauriski, 2018).

Many of the workers, colleagues and managers who have witnessed such an accident, could later develop post-traumatic stress disorder (PTSD). Often, managers of the people involved, would feel personally responsible, even when no negligence is proven, or when they are required to face inquiries from governmental departments and legal proceedings.

2.3.5 Work conditions in mining

In the field of humanities, research on the work conditions related to the mining industry, has always been a popular field of inquiry. According to Reilly (1998), studies of the mining industry and the work done there have played a significant role in the development of the socio-technical theory. This theory was developed as part of an analysis to investigate the effect of the introduction of new technology into coal mines in England.

At the centre of this study is the concept of rational production flow. In addition, the approach of the workers (people), the organisation, and the technology implemented are influenced and characterised by their work surroundings. The basic outcome and approach are that all organisations consist of both social and technical aspects. The theory suggests that these aspects are, in many instances, interrelated (Reilly, 1998)

The stronger this relation, the better and more effective the organisation will function. Therefore, the socio-technical theory recommends that any organisation should implement and optimise both the technical and social systems at the same time, in order to be an optimally functioning organisation.

2.3.5.1 Physical work environments

> The physical work environment in mining is a large research area and it includes research on dirt, dust, radiation, gasses, chemical exposure, ventilation, heavy lifts, transport, noise, vibration, darkness, lighting, musculoskeletal workload, work time, information / alarm systems and man-machine interaction (Friis, 2014).

Typically, companies focus on workplace safety and the physical work environment, in an attempt to ensure the safety of workers, while performing their duties. It is very important for companies to focus on creating a work environment, based on good occupational health and ongoing safety, to be sustainable. Work-related illness is the result of the interaction between factors related to the organisation, the environmental conditions in the workplace, the psychological behaviour of people, and the physical factors present in a work environment (IFC, 2014).

2.3.5.2 Safety

Safety is one of the most important issues relating to the mining industry and the physical working environment. In order for any company to be sustainable, safety must be key. In this regard, the safety training of mine workers is very important. Although safety training can be very expensive, its effectiveness in reducing accidents, far outweighs the cost. At most companies, basic safety training is mandatory, and commonly conducted in-house and on-site, by the company itself (IFC, 2014).

If any more specialised safety training is required, outside sources can be used. The type of job done and the level of specialisation, will determine the level of safety training required. An effective way to achieve good safety, is through the implementation of personal protective equipment (PPE). This is especially relevant and important for deep-level mining, where the work environment has more risks (IFC, 2014). These risks include higher temperatures and humidity, traffic of ore handling, nature of air supplied, and blasting operations. Most mining companies will measure and track safety performance, by using key indicators. These indicators would include number of fatalities, lost time injury (LTI) frequency rate, numbers on occupational diseases, and the use of sick leave. These indicators are all reactive in nature, and only give an indication of past performance.

It is far more beneficial when companies implement a proactive safety system, that would help with the prevention of accidents and incidents. Such proactive systems would include the implementation of action plans and monitoring progress.

2.3.6 Deep-level mining in South Africa

> It is another world – dark, cramped, unbearably hot, the air laden with harmful dust, earth tremors an ever-present threat, and the normal world of safety and sunlight a barely imaginable four or more kilometres above, well beyond reach in a moment of crisis. This is the dangerous world of South Africa's deep-level mining (Morris, 2017).

Some key facts and figures about the South African gold mining sector (Morris, 2017) include the following:

- The Witwatersrand Gold Basin is the world's largest source of gold.
- Between 2016 and 2017, the gold price went down by more than 8%.
- From 2016, gold production went down by 3.6%; however, gold sales went up by 33%.
- With the current prevailing gold price, more than 50% of the South African gold mines are marginal.
- On a global scale, South Africa only contributes 4.2% of the world's gold.
- In 2017, companies that produce gold, paid R1.6 billion in taxes.
- Over the past couple of years, employment in the gold mining sector has reduced.
- Gold mines employ 112,200 people.
- The earnings of employees, who work on gold mines, have increased from R14.7 billion in 2007 to R29.5 billion in 2017.

The gold mining sector is still relevant in the South African economy. In 2016, the mining sector held a share of 6.8% of the national, overall gross domestic product (GDP). This was after a decline of 4.3% in 2016. The aforementioned turned around with a 4.6% gain in 2017, with a contribution of R312 billion towards the GDP. Currently, the gold mining sector employs around 112,200 people. This figure has continued to decline since 1980 (Morris, 2017).

In this same period, the overall production at the mines has decreased, while the wages have increased. Gold mines remain the main source of income in many communities, with every person working on a mine, and supporting between five and ten dependants. Furthermore, for every job on a gold mine, two indirect jobs are created outside the mining sector (Morris, 2017).

2.4 What is gold mine productivity?

> "South Africa dominated the world as the number one gold producer until 2009 when China took that position, and today South Africa ranks fifth after China, Australia, Russia, and the USA" (Neingo & Tholana, 2016).

Neingo & Tholana (2016) define productivity as, "measured in various ways, including unit cost, output per employee, and output per unit capital equipment".

In the global mining industry, companies are experiencing major financial and economic challenges. The South African mining industry, in particular, has to deal with a unique set of challenges, that is specific to the South African industry. This comes amidst the global challenges, and puts this industry under severe strain to survive these conditions, and still perform well. The factors that have the most impact on the company's profit margins, are the rapidly increasing costs associated with mining practices, as well as the unstable and decreasing commodity prices. At the same time, the influences of unions and ongoing labour unrest is negatively affecting the labour productivity (Neingo & Tholana, 2016).

2.4.1 The major productivity challenges in the South African gold sector

Is has been estimated that South Africa currently has around 30 years of gold production left o its current gold resources. This figure is subject to change, as modifying factors are updated and/or changed. This means the South African gold industry is still very relevant in the global market, and has a clear comparative advantage in terms of mineral deposit endowment (Neingo & Tholana, 2016).

The challenge is to overcome the local factors that infringe on the translation of the comparative advantage into a competitive advantage, and realise value for the industry. The gold industry needs to address the challenges, in order to stay in business or risk closure. The major productivity challenges are the ever-increasing and escalating cost of mining practices, the availability of labour, and how labour can be effectively applied in the gold mining industry (Gankhuyag & Gregoire, 2018).

One fact remains: companies will have to increase productivity to recover from the slump. A number of technical, economic, social and operational problems and challenges confront the gold mining sector. These factors erode the South African gold mining industry’s competitiveness in the global gold market. Apart from the global pressure and competitiveness, the South African gold industry faces a number of challenges that are unique to this country, and its gold industry (Gankhuyag & Gregoire, 2018).

2.4.1.1 Gold price volatility

The one thing that all gold mining companies have in common, is that they have no control over the price they receive for their product or commodity. This makes all mining companies price takers, instead of price makers. The declining economic growth in China has had a major impact on the mining industry. These global economic conditions have severely influenced the local industry, and companies find it difficult to plan strategically, in order to composite for these unexpected changes (Neingo & Tholana, 2016).

In the South African gold mining industry, the gold price is a very important value driver. If the price drops, the impact is severe and negative on generated revenue. Furthermore, it adversely affects cash flows, which impacts on the profitability, which causes a decline in the value of the mineral assets. To add to the volatile gold price, there has been a steady decline in the gold price over the last 10 years. The price has dropped by 30% from a price of US$1826.80 per ounce in September 2011, to proximately US$1280 per ounce at the current stage, as is illustrated in Figure 2.2.

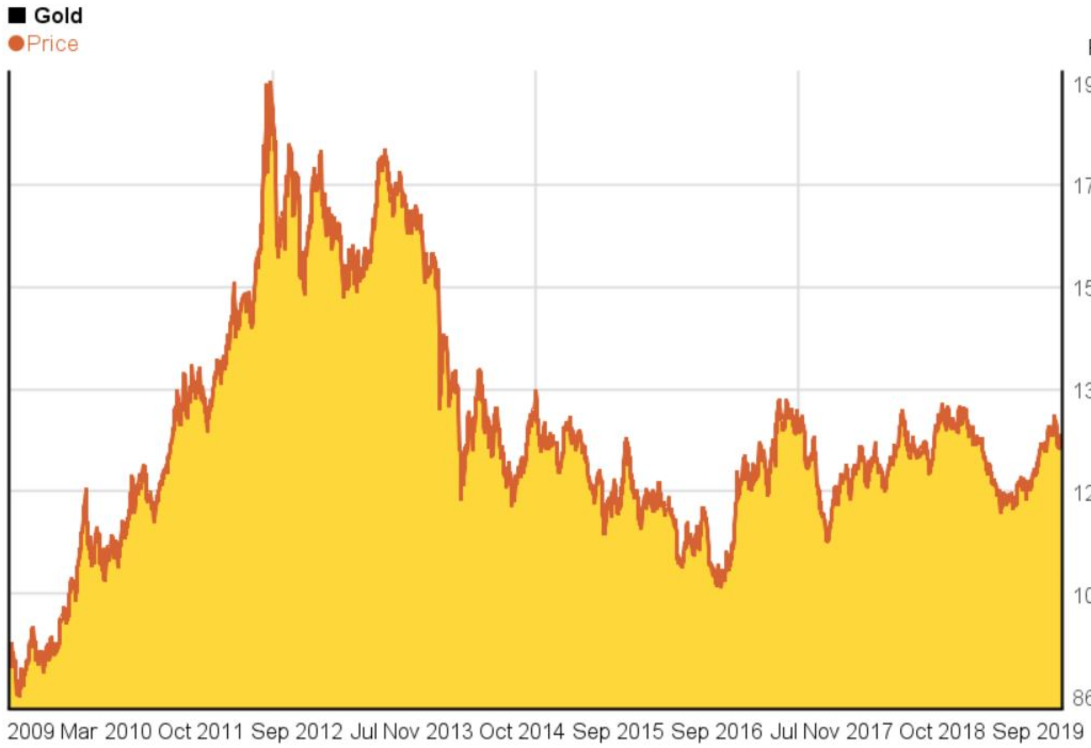

Figure 2.2: Gold 10 year chart of performance

The gold price volatility, as illustrated by Figure 2.2, combined with the steady price decrease, has put many mines under pressure, as well as with the risk of closure, as these operations are no longer viable.

2.4.1.2 High production costs

In the mining industry, there is a clear relationship between the ore grade mined, and the energy required to process the ore. Generally, in gold production, the lower the grade mined, the higher the energy, water consumption per ton of rock broken, reagents needed, and other consumables used for every unit of gold produced (Calvo *et al.*,2016).

The South African gold mining sector is faced with the unique problem of unprecedented, escalating electricity costs from Eskom, every year. From the graph presented in Figure 2.3 below, it is clear that these price hikes, coupled with erratic and unpredictable electricity supply, have definitely increased gold production costs, and consequently reduced production. Apart from the electricity crises, all the other major input costs have also increased steadily with time.

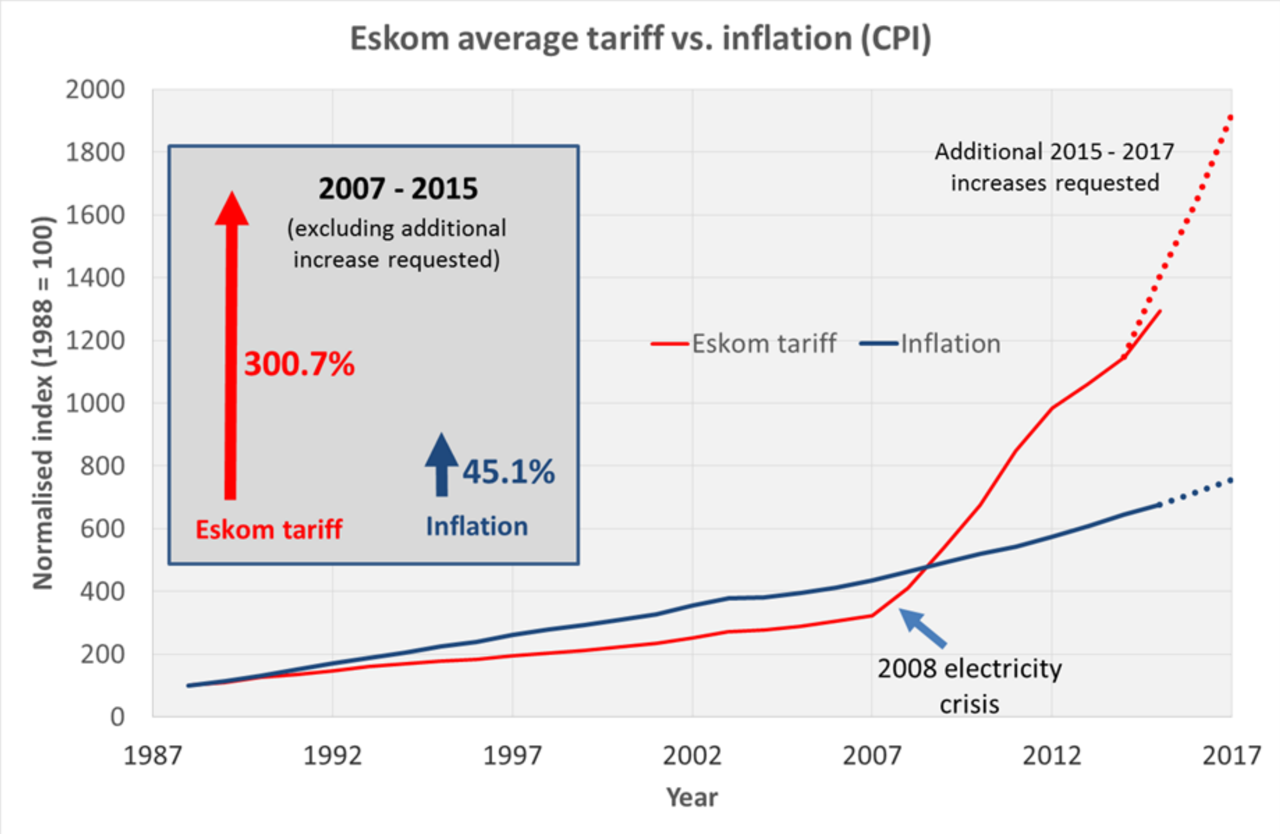

Figure 2.3: Eskom average tariff increases vs. CPI

2.4.1.3 Lower resource grade

The South African gold industry came into existence more than 100 years ago, in the Witwatersrand Goldfields. The easier, higher grade deposits were exploited first, and soon depleted This left the lower grade, which are more difficult to recover, deposits that are currently being mined. These remaining deposits can be found at great depths, and optimisation is required to optimally and viably exploit these deposits (Musingwini, 2014).

The lower ore grades are a worldwide phenomenon that is evident in all gold mining countries. If the average gold grade continues to decline at the current rate, many of the current operations will not be able to function economically by 2050, which would place the future of gold mining at risk, for future generations. The only way to prolong the current gold production, is if new higher-grade ore bodies are discovered and exploited in more remote areas of the world (Musingwini, 2014).

In the local South African context, ore grade is a very significant factor. Ore grade is a key value driver in the South African gold industry. Together with the declining gold price and increasing costs, the competitiveness of the South African gold industry is severely, negatively impacted. On top of these value drivers, the ever-increasing depths of mines, further increases production costs (Musingwini, 2014).

2.4.1.4 Mining method at great depth

In South Africa, 95% of all the gold that is produced comes from underground mines. South Africa has the world's deepest gold mine, at depths of over 4 kilometres. The ore bodies in these deep-level mines, are narrow in nature and disrupted by geological intrusions and discontinuities. These characteristics prevent the successful use and implementation of mechanised mining methods (Malehmir *et al*, 2014).

The Minerals Council of South Africa, previously known as the Chamber of Mines of South Africa, attributes the ability to mine at greater depths, to a lower geothermal gradient, compared to the rest of the world (Jones, 2015). Due to virgin rock temperatures that reach 60 °C at these depths, extensive ventilation and refrigeration are required to lower temperatures to acceptable standards for humans to work in, in these areas (Jones, 2015).

As the mines get to ultra-deep levels, the cost associated with ventilation, escalates significantly. The biggest cost driver at these depths is ventilation, along with this, is the cost of rock support systems, to stabilise and support the working areas to make it safe for people to enter these areas. One of the factors that directly affects productivity is seismicity and seismic events – also referred to as 'bumps' in the mining industry (Jones, 2015).

Current mine designs and mining methods ensure that mines are bound by these methods, and, in most cases, mines are producing near to full capacity. Current mining methods are non-continuous and cyclic, and are bound by currently available technology and equipment, with limited capacity, as well as limited efficiency for mines (Malehmir *et al*, 2014).

In theory, it should be possible to improve productivity in the South African mining industry with the current technology and mining methods. However, to have major improvements, new research is needed in mine planning methods, mine designs, optimisation of scenarios, as well as new mining methods to ensure better productivity. Due to depth, and the lack of mechanisation, the gold mining industry is very labour intensive, and relies on a large labour force.

2.4.1.5 Unions and labour-related issues

The South African gold mines are technically constrained, due to factors like the stoping, which dictates the height of the mining excavations. Equipment and processes must align with these technical constraints. The nature of the equipment and processes is highly labour-intensive, and requires a large labour force. Due to the nature of labour availability and labour utilization, and since labour is becoming a sought-after commodity, unions are highly active in this sector.

With the conventional deep-level mining methods, factors like travelling time to get to workplaces, coupled with the efficiency of labour to operate the availability of equipment and face preparation, mostly affect labour productivity. In some mines, people can travel up to an hour, or more, to reach their workplaces. The actual availability of people at work, can severely affect a crew's performance, as some jobs are specialised – and, an absent crew member can mean the face is not blasted.

In the South African context, issues like HIV and AIDS have a huge impact on labour availability at the mines. In some instances, managing sick leave has become a full-time HR function, in order to ensure enough labourers at work. As mentioned earlier in this literature review, in 2011 and 2012, widespread industrial action – in the form of strikes – crippled the mining industry, which resulted in a significant loss in revenue, in the form of remuneration and profits (Sonnenberg *et al.*, 2010).

This labour unrest is a clear indication of the lack of trust between unions, employees and the management of mining companies. Employees need to be aligned with the company strategy, to avoid disrupting labour issues. These, and other human factors, need to be taken into account when productivity parameters are established. Employees' lack of education, contributes significantly to these labour issues, and mining companies have strived to address this with adult learning (ABET), with the aim of raising employees' standard of education and understanding (Quain, 2018).

Employees with low, or no education, can be an obstacle to reach good productivity levels. The low literacy rates of some employees results in a low skill base, and little or no understanding of business principles. If an employee does not understand how they fit into a business or their role in productivity, they function disconnectedly from the rest of the business (Quain, 2018). The diverse culture base, found among mine employees, can also be an obstacle for productivity, as different cultures perceive values and good working principles, differently (Quain, 2018).

2.4.1.6 Political, social and environmental issues

Productivity in the gold mines is severely affected by the safety actions taken by the Department of Mineral Resources (DMR), in the form of forced safety stoppages, with the issuing of Section 54 and Section 55 notices of the Mine Health and Safety Act (29 of 1996). Any sub-standard safety issues need to be rectified. Once rectified, mining activities can only be resumed with further DMR approval (Ntsuxeko, 2017).

Work delays, such as safety meetings, are essential to the wellbeing and safety of employees, and cannot be compromised. Avoiding injuries and safety stoppages can, in the long term, improve productivity and avoid production losses (Ntsuxeko, 2017).

In the current political arena, some of the more radical groups, like the Youth League of the African National Congress, proposed and called for the nationalisation of all the South African mines and mineral resources (Ntsuxeko, 2017). This has caused major concerns for investors and, particularly, for foreign investors, who fear the loss of their investments, as well as the inability to recuperate from losses.

As recent as 2019, a number of ‘xenophobic attacks’ took place in the county, which provoked worldwide outcries and condemnation. This is significant to the mining employees, as a large number of workers originate from neighbouring countries. This put a severe strain on work relations between employees. On a wider front, these attacks weakened the Rand, and foreign investors lost confidence in the country as a possible investment opportunity.

2.4.2 Productivity measurements

For the purpose of this paper, unit costs and labour productivity will be explored as productivity measurement parameters.

2.4.2.1 Unit costs

Cost curves can be used to analyse cost behaviour and cost trends for any particular mine, over time, and as the mine matures (Gentry, 2002). At the same time, cost curves can be used as a benchmark, to compare performance against oneself, or other companies, in the same industry. As most of the mines in the South African Gold industry are at a mature life-cycle stage (Gentry, 2002), cost curves can be used to make an accurate comparison between the performance of the different mines, relative to the rest of the industry (Gentry, 2002).

In this case, the principle of economies of scale applies, where higher mine production translates to lower unit cost of production (Gentry, 2002). The reason for this is that, in the gold mining industry, every mine has a very big percentage fixed cost that must be paid, regardless of whether the mine is producing or not. These fixed costs consist of costs, such as ventilation costs, water pumping costs, electricity, and a very large portion for employees' salaries.

On the other side of the scale are the mines that have a lower rate of production, but they mine a much higher ore body grade. Therefore, for less effort, they produce the same amount of gold, and still manage to have a viable business (Gentry, 2002).

2.4.2.2 Labour productivity

The process of mining gold moves along a value chain, with consecutive steps and increasing value, up to the end product. This value chain can be affected by various factors along the way. These factors include the accuracy of drilling and blasting the stope faces, effective planning, quality issues and grade control, and effective processes to minimise the loss of ore up until the final product (Mitchell *et al.*, 2014).

Typically, labour productivity is measured in ounces per total employee cost (TEC). According to the Minerals Council of South Africa (2018) productivity in the South African gold mining industry has decreased, especially over the last 10 years. As stated before, the gold industry is heavily reliant on a large labour force, and the lack of mechanisation and new technology has a severe impact on productivity.

2.5 Conclusion

In this chapter, the effects of the underground working environment on employees, as well as the understanding of Gold Mine productivity and its measurements, were investigated, in terms of how they have manifested in the South African deep-level mining industry.

From this literature study, it can be concluded that the South African mining industry is a very complex industry, with extremely difficult underground conditions. The general environment is apprehensive, with all role players viewing each other with suspicion. Low production rates are a general phenomenon in the industry, due to logistical challenges and factors. The literature study serves to satisfy the first secondary research objective, namely a description of the mining environment.

In Chapter 3 the results of the empirical research are reported and discussed, in terms of the quantitative results.

CHAPTER 3 – EMPIRICAL STUDY

3.1 Introduction

In this chapter, the results of the empirical study are reported and discussed. The results of the questionnaire will be discussed and the interpretation of the data, from the instrument used to measure, will be presented. Finally, the hypotheses are tested and the results reported on.

The hypotheses that was tested in this study, is the influence of the physical underground conditions on the production output, at a deep-level gold mine.

Figure 3.1: The research hypotheses

3.2 Descriptive statistics

Descriptive statistics is a tool used in research to describe the basic features of the data in a study. Descriptive statistics provide summaries about the samples used and the measure employed. Combined with graphics analysis descriptive statistics form the basis of almost all quantitative analysis of data. Descriptive statistics describes what die data is or what the data shows (Trochim, 2020).

The questionnaire that was used for this research endeavour was designed to determine the influence of the physical underground conditions, on production at a deep level gold mine.

In October 2019, 148 employees from the Kusasalethu operation, a division of Harmony Gold were approached to be part of this research study. A total of 136 people responded and successfully completed the questionnaire (response rate of 91.2%). The sample group consisted of employees from four different departments at the operation. The group consisted of employees from the production (mining) department, the services departments, the engineering department and senior management.

When the survey was conducted, and the questionnaires were distributed, a cover letter formed part of the questionnaire. The latter stated that the survey was for academic research; to study the influence of the physical underground conditions on the production at a deep level gold mine. All the participants were guaranteed that their participation was anonymous, and all the responses would be handled with the utmost confidentiality.

The first part of the questionnaire (Section A) included a number of demographic questions that yielded the following information: 90% of the respondents were male, which corresponded with the gender composition of the operation. On average the age of employees was represented throughout all the ages groups, with the age groups 30-39, 40-49 and 50-59 similarly representing around 30% each. The majority of employees, 36%, had less than ten years of experience.

56% of the employees were from junior management. A total of 44% of the respondents have a national certificate (matric), with 56% who have some form of higher education. Overall, 60% of employees worked in the production department, followed by 31% in the services department, and 10% in the engineering department. On average, the majority (44%) indicated they go underground between 3 and 5 shifts per week, followed by 30% who reported that they go underground as many as 6-7 shifts per week. 19% reported to only go underground 1-2 shifts per week.

Table 3.1: Demographical profile of the respondents

Item	Category	Frequency	Percent
Gender (A1)	Male	123	90.4
	Female	13	9.6
Age group (A2)	20 – 29	12	8.8
	30 – 39	39	28.7
	40 – 49	44	32.4
	50 – 59	36	26.5
	60 and older	5	3.7
Number of years of service within the organisation (A3)	0 – 10 years	49	36.0
	11- 20 years	40	29.4
	21 – 30 years	30	22.1
	31 - 40 years	15	11.0
	41 and more years	2	1.5
Indicate your managerial level (A4)	Junior management	77	56.6
	Middle Management	47	34.6
	Senior Management	12	8.8
Qualification level? (A5)	National Certificate (Matric)	60	44.1
	Higher Certificate	16	11.8
	Advanced Certificate	21	15.4
	National Diploma	14	10.3
	Diploma	5	3.7
	Post-Graduate Diploma	4	2.9
	Degree	10	7.4
	Honours Degree	5	3.7
	Master's Degree	1	0.7
	PhD	0	0
Department? (A6)	Service Departments	42	30.9
	Engineering Department	13	9.6
	Mining Department	81	59.6
Number of underground shifts per week (A7)	0	9	6.6
	1 - 2	26	19.1
	3 - 5	60	44.1
	6 - 7	41	30.1

The demographical questions were limited to, and focused on those that could have a possible impact on the study and its conclusions. The questionnaire, available in

Appendix A, contains the items that tested the respondent's perception of the influence of the physical underground conditions on the production.

3.3 Validity and reliability

The validity was established through a factor analysis. This was done, in order to establish whether or not the questionnaire is a valid and reliable instrument to measure the two constructs: underground conditions and production. The questionnaire was subjected to a factor analysis.

The factor analysis was conducted through the use of the SPSS program. The first exploratory analysis was conducted without grouping the data. For the second analysis, the data was grouped within the seven constructs, according to the questionnaire, and analysed to determine the conformity results.

3.3.1 Exploring validity through exploratory factor analysis

The questionnaire contains the items testing the respondents' perceptions of the following factors: underground conditions and the production output. As well as, perceptions regarding colleagues, incidents, supervisor, availability, contribution, production impact, health and safety.

The questions were subjected to an exploratory factor analysis. As a result, seven factors with Eigenvalues greater than one were extracted. This explains the cumulative variance of 71% from the SPSS analysis.

Table 3.2: Factor loading: Exploratory factor analysis

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.379	19.210	19.210	5.379	19.210	19.210	4.324
2	4.813	17.189	36.399	4.813	17.189	36.399	3.354
3	2.608	9.313	45.712	2.608	9.313	45.712	4.099
4	2.349	8.391	54.103	2.349	8.391	54.103	3.395
5	2.173	7.762	61.865	2.173	7.762	61.865	2.595
6	1.400	4.999	66.865	1.400	4.999	66.865	2.631
7	1.109	3.962	70.827	1.109	3.962	70.827	2.140

There were five factors with factor loadings greater than 2. These factors were teste for reliability, by calculating Cronbach's Alpha coefficient. The findings are dipicted in the tabel below:

Table 3.3: Reliability: Factors extracted

Factor	Alpha Value
Factor 1 – Colleagues	0.915
Factor 2 – Incidents	0.785
Factor 3 - Supervisor	0.899
Factor 4 - Availability	0.806
Factor 5 - Contribution	0.826
Factor 6 - Logistics	0.770
Factor 7 - Health and Safety	0.583

These items, grouped into the seven factors, roughly correspond with the seven factors used for compiling the questionnaire.

The components matrix for the seven factors above are parented in Table 3.4 below:

Table 3.4: The Principle Component Matrix: Exploratory factors

Component Matrix[a]

	Component							
	1	2	3	4	5	6	7	
B25	0.757				-0.317			My colleagues are always ready to help me with my duties. (B25)
B24	0.748				-0.348			My colleagues support me in executing my duties. (B24)
B23	0.704		0.368					My colleagues provide the necessary resources to help me perform my duties. (B23)
B26	0.689			0.308	-0.341			If necessary, I can count on the expertise of my colleagues to execute my duties. (B26)
B21	0.686		-0.455					If necessary, I can count on the expertise of my supervisor to execute my duties. (B21)
B20	0.678		-0.447					My supervisor is always ready to help me with my duties. (B20)
B27	0.641		0.305		-0.450			If I encounter a problem in the execution of my duties, I can always count on my colleagues. (B27)
B22	0.616		-0.340					If I encounter a problem in the execution of my duties, I can always count on my supervisor. (B22)
B19	0.593	0.314	-0.407					My supervisor supports me in executing my duties. (B19)
B18	0.528	0.305	-0.432		0.313			My supervisor provides the necessary resources to help me perform my duties. (B18)
B15		0.608		-0.413			-0.352	Engineering breakdowns in workplaces, impact negatively on production. (B15)
B7		0.606				-0.310		Ventilation constraints impact negatively on production. (B7)
B17		0.577		-0.357				Low morale of employees in the working place impacts negatively on production. (B17)
B6	-0.336	0.557		0.518				The availability of services, such as air, water and electricity impacts negatively on production. (6)
B9	-0.337	0.541	-0.418	0.497				Availability of labour impacts negatively on production. (B9)
B16		0.539					-0.444	Ineffective services departments impact negatively on production. (B16)
B12		0.539		-0.404				Major loss incidents, e.g. an underground fire, have a negative impact on production. (B12)
B10	-0.300	0.531		-0.431				Accidents and injuries impact negatively on production. (B10)
B11		0.442		-0.423			0.322	Fatal Accidents have a negative impact on production. (B11)

B14		0.391	-0.348					The influence of Unions in the workplace impacts negatively on production. (B14)
B3		0.334	0.549		0.492			I think I am effective in completing my tasks. (B3)
B8	-0.316	0.525	-0.345	0.567				Availability of equipment impacts negatively on production. (B8)
B1			0.335		0.728			In my opinion, I contribute to the success of my section. (B1)
B2		0.339	0.430		0.640			I think I am performing well in executing my responsibilities. (B2)
B4		0.539				-0.628		Mining further away from the shaft impacts negatively on production. (B4)
B5		0.525				-0.607		Further travelling to workplaces impacts negatively on available face time to complete daily work. (B5)
B28				0.314		0.388		I believe underground conditions can lead to heat related illness. (B28)
B13		0.422					0.608	When older employees retire, the loss of skills and experience impacts negatively on production. (B13)

Extraction Method: Principal Component Analysis.

A total of 7 components were extracted

The pattern matrix for the seven factors above are presented in Table 3.5 below:

Table 3.5: The principle Pattern Matrix: Exploratory factors

Pattern Matrix[a]							
	Component						
	1	2	3	4	5	6	7
If I encounter a problem in the execution of my duties, I can always count on my colleagues. (B27)	0.909						
If necessary, I can count on the expertise of my colleagues to execute my duties. (B26)	0.878						
My colleagues support me in executing my duties. (B24)	0.867						
My colleagues are always ready to help me with my duties. (B25)	0.845						
My colleagues provide the necessary resources to help me perform my duties. (B23)	0.716						
Engineering breakdowns in workplaces impact negatively on production. (B15)		0.836					
Ineffective services departments impact negatively on production. (B16)		0.779					
Low morale of employees in the working place impacts negatively on production. (B17)		0.696					
Accidents and injuries impact negatively on production. (B10)		0.596					0.413
My supervisor is always ready to help me with my duties. (B20)			-0.885				

If necessary, I can count on the expertise of my supervisor to execute my duties. (B21)			-0.855				
My supervisor supports me in executing my duties. (B19)			-0.848				
My supervisor provides the necessary resources to help me perform my duties. (B18)			-0.766				
If I encounter a problem in the execution of my duties, I can always count on my supervisor. (B22)			-0.750				
Availability of equipment impacts negatively on production. (B8)				0.912			
Availability of labour impacts negatively on production. (B9)				0.887			
The availability of services, such as air, water and electricity impacts negatively on production. (6)				0.815			
The influence of Unions in the workplace impacts negatively on production. (B14)				0.460			
I think I am performing well in executing my responsibilities. (B2)					0.871		
In my opinion, I contribute to the success of my section. (B1)					0.817		
I think I am effective in completing my tasks. (B3)					0.803		
I believe underground conditions can lead to heat related illness. (B28)				0.390	0.405		
Mining further away from the shaft impacts negatively on production. (B4)						-0.859	
Further travelling to workplaces impact negatively on available face time to complete daily work. (B5)						-0.842	
Ventilation constraints impact negatively on production. (B7)				0.394		-0.541	
When older employees retire, the loss of skills and experience impact negatively on production. (B13)							0.707
Fatal accidents have a negative impact on production. (B11)		0.352					0.578
Major loss incidents, e.g. an underground fire, have a negative impact on production.(B12)		0.420					0.523

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

a. Rotation converged in 12 iterations.

3.3.2 Confirmatory Factor Analysis: Factors linked with research constructs

The questionnaire was designed with seven constructs, these seven pre-defined constructs were independently tested for reliability and validity.

In the confirmatory study, the data was divided into groups. The seven constructs represented by seven groupings of questions. These are from the Pattern Matrix, B1 to B3; B4, B5 and B7; B10, B15-B17; B11-B13; B18-B22; B6, B8, B9, B14 and B28;

B23-27. To determine the correlation between the questions of each group, a correlation matrix of each of the datasets was drawn.

Table 3.6: Keyser-Meyer-Olkin Measure and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.757
Bartlett's Test of Sphericity	Approx. Chi-Square	2235.081
	df	378
	Sig.	0.000

A Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated for each of the constructs, in order to test whether the sample was sufficient in terms of its size. The KMO value that was calculated, was 0.757, which means that the sample was large enough to draw meaningful conclusions, as this value is larger than 0.6. The Bartlett's Test of Sphericity sigma was smaller than 0.05.

3.3.2.1 Factor 1: Colleagues

When the factor analysis was conducted, the first factor that was extracted, was Colleagues. Below follows a discussion on the total variance explained for this factor, and shows the factor loading for this particular factor. This is followed by all the items that make up the factor.

Table 3.7: The Total Reliability explained: Colleagues

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.915	0.915	5

The Cronbach Alpha coefficient for the Colleagues factor was calculated, which provided the value of 0.915. This Cronbach Alpha coefficient means this factor is reliable, and can be used for further analysis.

Table 3.8: The Total Items: Colleagues

Colleagues Items	Factors
1	My colleagues are always ready to help me with my duties. (B25)
2	My colleagues support me in executing my duties. (B24)
3	My colleagues provide the necessary resources to help me perform my duties. (B23)
4	If necessary, I can count on the expertise of my colleagues to execute my duties. (B26)
5	If I encounter a problem in the execution of my duties, I can always count on my colleagues. (B27)

Extraction Method: Principal Component Analysis.

In Table 3.9, the Principle Pattern Matrix of the Colleagues component is presented. Since the loaded items display positive values, this factor should be included.

Table 3.9: The Principle Pattern Matrix: Colleagues

Pattern Matrix[a]		
	Component	
	1	2
If I encounter a problem in the execution of my duties, I can always count on my colleagues. (B27)	0.909	
If necessary, I can count on the expertise of my colleagues to execute my duties. (B26)	0.878	
My colleagues support me in executing my duties. (B24)	0.867	
My colleagues are always ready to help me with my duties. (B25)	0.845	
My colleagues provide the necessary resources to help me perform my duties. (B23)	0.716	

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

3.3.2.2 Factor 2: Incidents

When the factor analysis was conducted, the second factor that was extracted, was Incidents. Below follows a discussion on the total variance explained for this factor, and shows the factor loading for this factor. This is followed by all the items that make up the factor.

Table 3.10: The Total Reliability explained: Incidents

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.785	0.790	4

The Cronbach Alpha coefficient for the Incidents factor was calculated, which provided the value of 0.785. This Cronbach Alpha coefficient means this factor is reliable and can be used for further analysis.

Table 3.11: The Total Items: Incidents

Incidents Items	Factors
1	Engineering breakdowns in workplaces impact negatively on production. (B15)
2	Low morale of employees in the working place impacts negatively on production. (B17)
3	Ineffective services departments impact negatively on production. (B16)
4	Accidents and injuries impact negatively on production. (B10)

Extraction Method: Principal Component Analysis.

In Table 3.12, the Principle Pattern Matrix of the Incidents component is presented. The second column (labelled 2), shows the value, should this specific item be excluded from the factor. Since the loaded items display positive value, this factor should be included.

Table 3.12: The Principle Patter Matrix: Incidents

Pattern Matrix[a]		
	Component	
	1	2
Engineering breakdowns in workplaces impact negatively on production. (B15)	0.836	
Ineffective services departments impact negatively on production. (B16)	0.779	
Low morale of employees in the working place impacts negatively on production. (B17)	0.696	
Accidents and injuries impact negatively on production. (B10)	0.596	0.413

Extraction Method: Principal Component Analysis.

3.3.2.3 Factor 3: Supervisor

When the factor analysis was conducted, the third factor that was extracted, was Supervisor. Below follows a discussion on the total variance explained for this factor, and shows the factor loading for this factor. This is followed by all the items that make up the factor.

Table 3.13: The Total Reliability explained: Supervisor

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.899	0.898	5

The Cronbach Alpha coefficient for the Supervisor factor was calculated, which presented the value of 0.899. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.14: The Total Items: Supervisor

Supervisor Items	Factors
1	If necessary, I can count on the expertise of my supervisor to execute my duties. (B21)
2	My supervisor is always ready to help me with my duties. (B20)
3	If I encounter a problem in the execution of my duties, I can always count on my supervisor. (B22)
4	My supervisor supports me in executing my duties. (B19)
5	My supervisor provides the necessary resources to help me perform my duties. (B18)

Extraction Method: Principal Component Analysis.

In Table 3.15, the principle pattern matrix of the Supervisor component is presented. Since the loaded items display negative values, this factor should be included.

Table 3.15: The Principle Pattern Matrix: Supervisor

Pattern Matrix[a]		
	Component	
	1	2
My supervisor is always ready to help me with my duties.(B20)	-0.885	
If necessary, I can count on the expertise of my supervisor to execute my duties.(B21)	-0.855	
My supervisor supports me in executing my duties.(B19)	-0.848	
My supervisor provides the necessary resources to help me perform my Duties.(B18)	-0.766	
If I encounter a problem in the execution of my duties, I can always count on my supervisor.(B22)	-0.750	

Extraction Method: Principal Component Analysis.

3.3.2.4 Factor 4: Availability

When the factor analysis was conducted, the fourth factor that was extracted, was availability. Below follows a discussion on the total variance explained for this factor, and shows the factor loading for this factor. This is followed by all the items that make up the factor.

Table 3.16: The Total Reliability explained: Availability

Reliability Statistics		
Cronbach Alpha	**Cronbach Alpha Based on Standardised Items**	**N of Items**
0.806	0.782	5

The Cronbach Alpha coefficient for the Availability factor was calculated, which provided the value of 0.806. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.17: The Total Items: Availability

Availability Items	Factors
1	The availability of services such as air, water and electricity impacts negatively on production. (6)
2	Availability of labour impacts negatively on production. (B9)
3	The influence of Unions in the workplace impacts negatively on production. (B14)
4	Availability of equipment impacts negatively on production. (B8)
5	I believe underground conditions can lead to heat related illness. (B28)

Extraction Method: Principal Component Analysis.

In Table 3.18, the Principle Pattern Matrix of the Availability component is presented. The second column (labelled ‘2’), shows the value, should this specific item be excluded from the factor. Since the loaded items display positive values, this factor should be included.

Table 3.18: The Principle Pattern matrix: Availability

Pattern Matrix[a]		
	Component	
	1	2
Availability of equipment impact negatively on production.(B8)	0.912	
Availability of labour impact negatively on production.(B9)	0.887	
The availability of services such as air, water and electricity impact negatively on production.(6)	0.815	
The influence of Unions in the workplace impact negatively on production.(B14)	0.460	
I believe underground conditions can lead to heat related illness.(B28)	0.390	0.405

Extraction Method: Principal Component Analysis.

3.3.2.5 Factor 5: Contribution

When the factor analysis was conducted, the fifth factor the was extracted, was Contribution. Below follows a discussion on the total variance explained for the factor, and shows the factor loading for the factor. This is followed by all the items that make up the factor.

Table 3.19: The Total Reliability explained: Contribution

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.826	0.826	3

The Cronbach Alpha coefficient for the Contribution factor was calculated, which provided the value of 0.826. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.20: The Total Items: Contribution

Contribution Items	Factors
1	I think I am effective in completing my tasks. (B3)
2	In my opinion, I contribute to the success of my section. (B1)
3	I think I am performing well in executing my responsibilities. (B2)

Extraction Method: Principal Component Analysis.

In Table 3.21, the Principle Pattern Matrix of the Contribution component shows the value of the factor. Since the loaded items display positive values, this factor should be included.

Table 3.21: The Principle Pattern matrix: Contribution

Pattern Matrix[a]		
	Component	
	1	2
I think I am performing well in executing my responsibilities. (B2)	0.871	
In my opinion, I contribute to the success of my section. (B1)	0.817	
I think I am effective in completing my tasks. (B3)	0.803	

Extraction Method: Principal Component Analysis.

3.3.2.6 Factor 6: Production Impact

When the factor analysis was conducted, the sixth factor that was extracted, was Production Impact. Below follows a discussion on the total variance explained for this factor, and shows the factor loading for this factor. This is followed by all the items that make up the factor.

Table 3.22: The Total Reliability explained: Production Impact

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.770	0.777	3

The Cronbach Alpha coefficient for the Production Impact factor was calculated, which provided the value of 0.770. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.23: The Total Items: Production Impact

Production Impact Items	Factors
1	Ventilation constraints impact negatively on production. (B7)
2	Mining further away from the shaft impacts negatively on production. (B4)
3	Further travelling to workplaces impacts negatively on available face time to complete daily work. (B5)

In Table 3.24, the Principle Pattern Matrix of the Production Impact component shows the value for the factor. Since the loaded items display both positive and negative values, this factor should be discarded.

Table 3.24: The Principle Pattern matrix: Production Impact

Pattern Matrix[a]		
	Component	
	1	2
Mining further away from the shaft impacts negatively on production.(B4)	-0.859	
Further travelling to workplaces impact negatively on available face time to complete daily work. (B5)	-0.842	
Ventilation constraints impact negatively on production. (B7)	-0.541	0.394

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

3.3.2.7 Factor 7: Health and Safety

When the factor analysis was conducted, the seventh factor that was extracted, was Health and Safety. Below follows a discussion on the total variance explained for this factor, and shows the factor loading for this factor. This is followed by all the items that make up the factor.

Table 3.25: The Total Reliability explained: Health and Safety

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.583	0.600	3

The Cronbach Alpha coefficient for the Health and Safety factor was calculated, which provided the value of 0.583. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.26: The Total Items: Health and Safety

Health and Safety Items	Factors
1	Major loss incidents, e.g. an underground fire, have a negative impact on production. (B12)
2	Fatal Accidents have a negative impact on production. (B11)
3	When older employees retire, the loss of skills and experience impacts negatively on production. (B13)

In Table 3.27, the Principle Pattern Matrix of the Health and Safety component is presented. The second column (labelled '2'), shows the value, should this specific item be excluded from the factor. Since the loaded items display positive values, this factor should be included.

Table 3.27: The Principle Pattern matrix: Health and Safety

Pattern Matrix[a]		
	Component	
	1	2
When older employees retire, the loss of skills and experience impact negatively on production. (B13)	0.707	
Fatal Accidents have a negative impact on production. (B11)	0.578	0.352
Major loss incidents, e.g. an underground fire, have a negative impact on production. (B12)	0.523	0.420

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

3.2.2 Relationships Between Constructs

The questionnaire was divided into the two constructs – the physical underground conditions and production output – to determine whether or not the factors identified in the original factor analysis correspond to these constructs.

3.2.2.1 Construct 1: Physical Underground Conditions

For the physical underground conditions construct, two factors with an Eigenvalue greater than two were extracted. This would explain the variance of 68.065%. In Table 3.29, which presents the total variance explained for physical underground conditions, and shows the factor loading for physical underground conditions. Then Table 3.30 presents the total items for physical underground conditions, shows all the items that make up the factor.

Table 3.28: The Total Reliability explained: Physical Underground Conditions

Reliability Statistics		
Cronbach Alpha	Cronbach Alpha Based on Standardised Items	N of Items
0.735	0.747	7

The Cronbach Alpha coefficient for the physical underground conditions construct factor was calculated, which presented a value of 0.747. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.29: The Total Variance explained: Physical Underground Conditions

Total Variance Explained							
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.718	33.701	33.701	4.718	33.701	33.701	3.384
2	2.309	16.496	50.197	2.309	16.496	50.197	3.351
3	1.440	10.283	60.480	1.440	10.283	60.480	2.560
4	1.062	7.586	68.065	1.062	7.586	68.065	2.068
5	0.870	6.217	74.282				
6	0.764	5.454	79.736				
7	0.619	4.422	84.158				
8	0.527	3.761	87.919				
9	0.468	3.341	91.260				
10	0.397	2.835	94.096				
11	0.291	2.078	96.174				
12	0.236	1.688	97.862				
13	0.213	1.521	99.383				
14	0.086	0.617	100.000				

Extraction Method: Principal Component Analysis.

Table 3.30: The Total Items: Physical Underground Conditions

Incident Items	Factors
1	Mining further away from the shaft impacts negatively on production. (B4)
2	Further travelling to workplaces impacts negatively on available face time to complete daily work. (B5)
3	The availability of services, such as air, water and electricity impacts negatively on production. (6)
4	Ventilation constraints impact negatively on production. (B7)
5	Availability of equipment impacts negatively on production. (B8)
6	Availability of labour impacts negatively on production. (B9)
7	Accidents and injuries impact negatively on production. (B10)
8	Fatal accidents have a negative impact on production. (B11)
9	Major loss incidents, e.g. an underground fire, have a negative impact on production. (B12)
10	When older employees retire, the loss of skills and experience impacts negatively on production. (B13)
11	The influence of Unions in the workplace impacts negatively on production. (B14)
12	Engineering breakdowns in workplaces impact negatively on production. (B15)

13	Ineffective services departments impact negatively on production. (B16)
14	Low morale of employees in the working place impacts negatively on production. (B17)

Table 3.31 shows the Principle Pattern Matrix of the construct. This question showed twice, but is better suited to factor 4. Thus, this value was ignored, as to ensure each item only features once. The same was done for all the values that are highlighted in the grey cells of the Table 3.31, where all the items that featured more than once, were only used once, in order to ensure convergent validity.

Table 3.31: The Principle Pattern Matrix: Physical Underground Conditions

Pattern Matrix[a]				
	Component			
	1	2	3	4
Engineering breakdowns in workplaces impact negatively on production. (B15)	0.858			
Ineffective services departments impact negatively on production. (B16)	0.814			
Low morale of employees in the working place impacts negatively on production. (B17)	0.653			
Accidents and injuries impact negatively on production. (B10)	0.619			0.378
Availability of equipment impacts negatively on production. (B8)		-0.924		
Availability of labour impacts negatively on production. (B9)		-0.919		
The availability of services, such as air, water and electricity, impact negatively on production. (6)		-0.828		
The influence of Unions in the workplace impacts negatively on production. (B14)		-0.498		
Further travelling to workplaces impacts negatively on available face time to complete daily work. (B5)			-0.886	
Mining further away from the shaft impacts negatively on production. (B4)			-0.875	
Ventilation constraints impact negatively on production. (B7)		-0.440	-0.457	
When older employees retire, the loss of skills and experience impacts negatively on production. (B13)				0.766
Fatal accidents have a negative impact on production. (B11)	0.365			0.569
Major loss incidents, e.g. an underground fire, have a negative impact on production. (B12)	0.434		-0.307	0.478

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

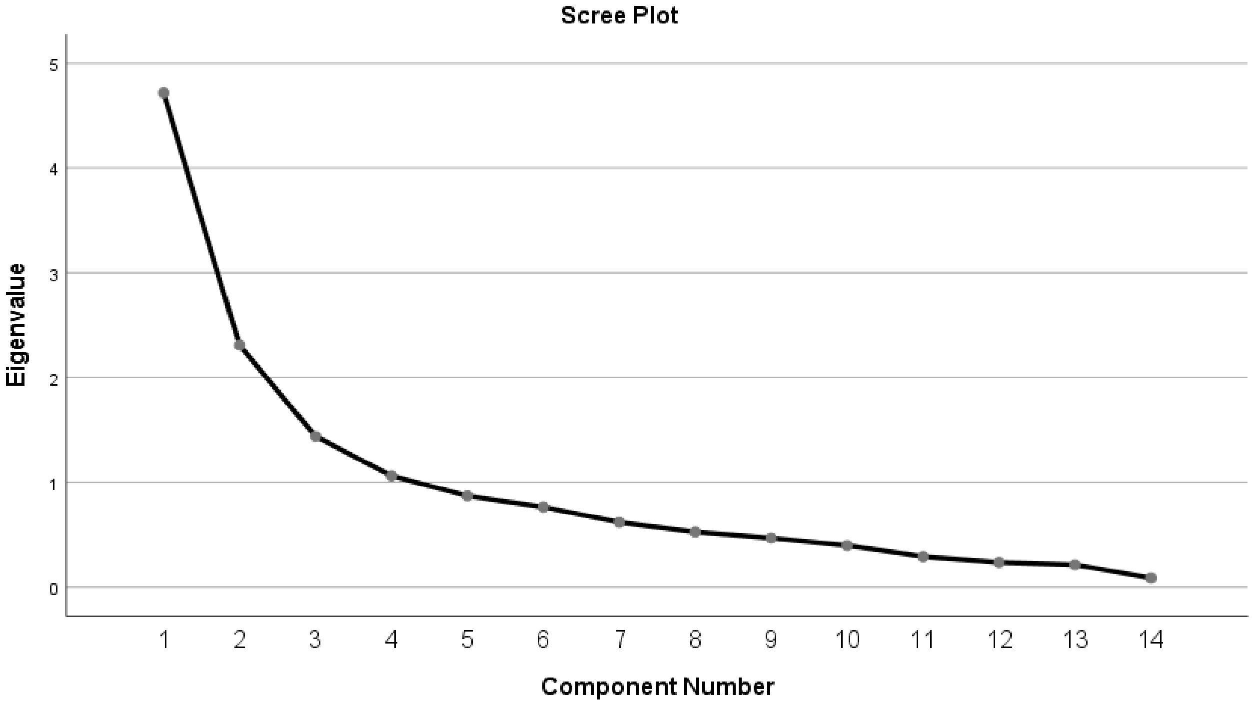

Figure 3.2: The Scree plot of the underground conditions factor analysis

3.2.2.2 Construct 2: Production Output

For the Production Output construct, three factors with an Eigenvalue greater than two were extracted. This would explain the variance of 71.360%. In Table 3.33, the total variance explained for Production Output is presented, and shows the factor loading for Production Output. Followed by Table 3.34, which shows all the items that make up the construct.

Table 3.32: The Total Reliability explained: Production Output

Reliability Statistics		
Cronbach Alpha	**Cronbach Alpha Based on Standardised Items**	**N of Items**
0.847	0.844	14

The Cronbach Alpha coefficient for the Production Output construct factor was calculated, which provided a value of 0.844. This Cronbach Alpha coefficient means that this factor is reliable, and can be used for further analysis.

Table 3.33: The Total Variance explained: Production Output

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.213	37.235	37.235	5.213	37.235	37.235	4.068
2	2.478	17.699	54.934	2.478	17.699	54.934	2.616
3	2.300	16.426	71.360	2.300	16.426	71.360	4.269
4	0.939	6.708	78.069				
5	0.616	4.399	82.468				
6	0.434	3.102	85.570				
7	0.399	2.846	88.416				
8	0.394	2.817	91.234				
9	0.339	2.423	93.657				
10	0.249	1.782	95.439				
11	0.214	1.527	96.965				
12	0.169	1.207	98.172				
13	0.137	0.981	99.154				
14	0.119	0.846	100.000				

Extraction Method: Principal Component Analysis.

Table 3.34: The Total Items: Production Output

Incident Items	Factors
1	In my opinion, I contribute to the success of my section. (B1)
2	I think I am performing well in executing my responsibilities. (B2)
3	I think I am effective in completing my tasks. (B3)
4	My supervisor provides the necessary resources to help me perform my duties. (B18)
5	My supervisor supports me in executing my duties. (B19)
6	My supervisor is always ready to help me with my duties. (B20)
7	If necessary, I can count on the expertise of my supervisor to execute my duties. (B21)
8	If I encounter a problem in the execution of my duties, I can always count on my supervisor. (B22)
9	My colleagues provide the necessary resources to help me perform my duties. (B23)
10	My colleagues support me in executing my duties. (B24)
11	My colleagues are always ready to help me with my duties. (B25)
12	If necessary, I can count on the expertise of my colleagues to execute my duties. (B26)
13	If I encounter a problem in the execution of my duties, I can always count on my colleagues. (B27)
14	I believe underground conditions can lead to heat related illness. (B28)

In Table 3.35, the Principle Pattern Matrix of the Production Output is presented. The Pattern Matrix divides the three factors that make up production very clearly.

Table 3.35: The Principle Pattern matrix: Production Output

Pattern Matrix[a]			
	Component		
	1	2	3
My supervisor is always ready to help me with my duties. (B20)	0.898		
If necessary, I can count on the expertise of my supervisor to execute my duties. (B21)	0.860		
My supervisor supports me in executing my duties. (B19)	0.850		
My supervisor provides the necessary resources to help me perform my Duties. (B18)	0.778		
If I encounter a problem in the execution of my duties, I can always count on my supervisor. (B22)	0.752		
I think I am performing well in executing my responsibilities. (B2)		0.904	
In my opinion, I contribute to the success of my section. (B1)		0.894	
I think I am effective in completing my tasks. (B3)		0.837	
I believe underground conditions can lead to heat related illness. (B28)		0.373	
If I encounter a problem in the execution of my duties, I can always count on my colleagues. (B27)			-0.913
If necessary, I can count on the expertise of my colleagues to execute my duties. (B26)			-0.882
My colleagues support me in executing my duties. (B24)			-0.877
My colleagues are always ready to help me with my duties. (B25)			-0.849
My colleagues provide the necessary resources to help me perform my duties. (B23)			-0.737

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

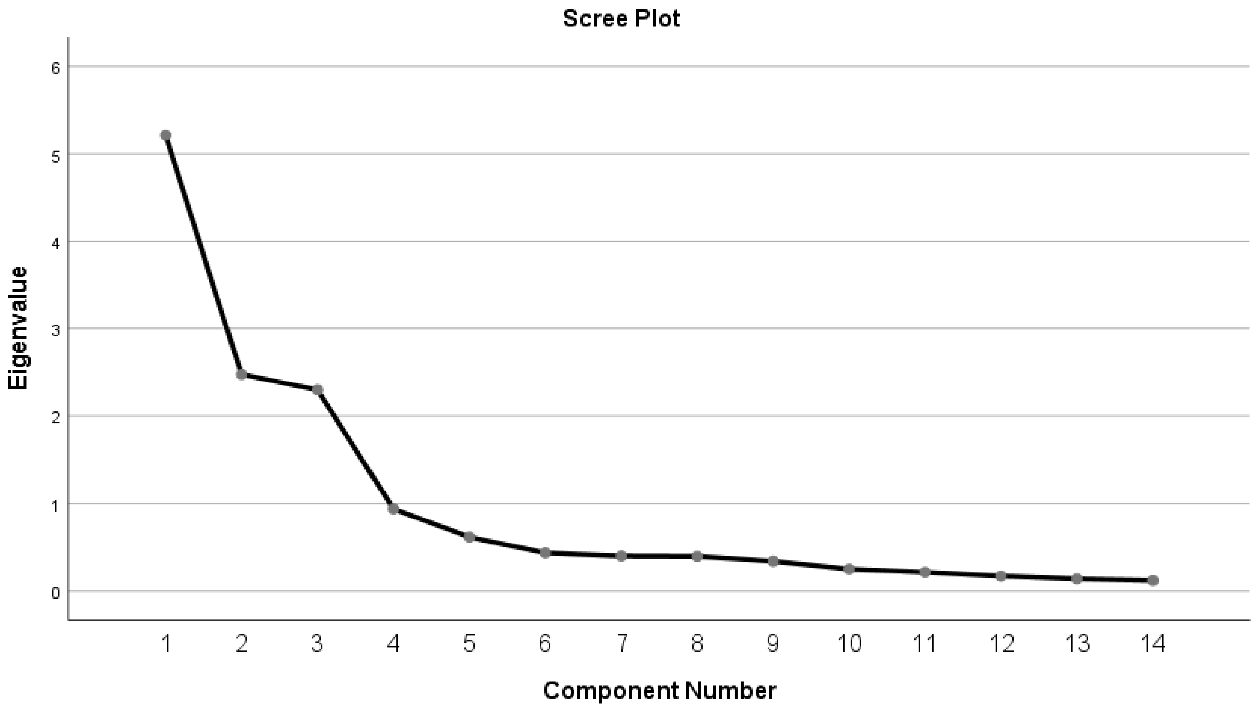

Figure 3.3: The Scree plot of the production output factor analysis

Looking in detail at the factor analysis it became clear that the factors colleagues, supervisors and contribution describe production output and the other four factors (logistics, health & safety, incidents and availability describe underground conditions

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3.4 Descriptive Statistics of different factors

Table 3.36 below, shows the descriptive statistics for the variables of production impact, colleagues, supervisor, availability, contribution, health and safety and incidents. For each of the factors the number, mean and standard deviation is provided.

Table 3.36: Descriptive Statistics

Descriptive Statistics			
Factor	**N**	**Mean**	**Std. Deviation**
Production impact	136	5.0349	0.79825
Colleagues	136	4.4809	0.93027
Supervisor	136	4.5941	0.95311

Availability	136	4.4691	1.15120
Contribution	136	5.2598	0.59448
Health and Safety	136	4.8088	1.11896
Incidents	136	5.5294	0.87298

3.5 Regression Analysis

3.5.1 Correlations

All of the factors were tested for reliability, by calculating Pearson's correlation coefficients. Correlations were found between the various factors. The results of the underground conditions against production outputs are reported in Table 3.37. As indicated in the table, the dimensions are normally distributed. It was, therefore, decided to use the Pearson correlations for the two scales.

Table 3.37: Correlation co-efficient between the dimensions

Correlations								
		Production impact	**Colleagues**	**Supervisor**	**Availability**	**Contribution**	**Health and Safety**	**Incidents**
Pearson Correlation	**Production impact**	1.000	-0.044	0.050	0.298	0.095	0.305	0.566
	Colleagues	-0.044	1.000	0.385	-0.102	0.164	-0.013	-0.049
	Supervisor	0.050	0.385	1.000	-0.027	0.126	-0.072	-0.074
	Availability	0.298	-0.102	-0.027	1.000	0.039	0.289	0.138
	Contribution	0.095	0.164	0.126	0.039	1.000	0.198	0.073
	Health and Safety	0.305	-0.013	-0.072	0.289	0.198	1.000	0.355
	Incidents	0.566	-0.049	-0.074	0.138	0.073	0.355	1.000
Sig. (1-tailed)	**Production impact**		0.305	0.282	0.000	0.135	0.000	0.000
	Colleagues	0.305		0.000	0.120	0.028	0.441	0.284
	Supervisor	0.282	0.000		0.376	0.073	0.203	0.197
	Availability	0.000	0.120	0.376		0.328	0.000	0.055
	Contribution	0.135	0.028	0.073	0.328		0.011	0.199
	Health and Safety	0.000	0.441	0.203	0.000	0.011		0.000
	Incidents	0.000	0.284	0.197	0.055	0.199	0.000	
N	**Production impact**	136	136	136	136	136	136	136
	Colleagues	136	136	136	136	136	136	136

	Supervisor	136	136	136	136	136	136	136
	Availability	136	136	136	136	136	136	136
	Contribution	136	136	136	136	136	136	136
	Health and Safety	136	136	136	136	136	136	136
	Incidents	136	136	136	136	136	136	136

3.5.2 Discussion of correlations analysis

From Table 3.37 it can be seen that all the significant correlations were positive. As can be seen, 'Supervisor' is positively correlated to 'Colleagues' (practically significant, medium effect).

'Availability' is positively correlated to 'Production impact' (practically significant, medium effect).

'Health and Safety' is positively correlated to 'Production impact', as well as 'availability' (practically significant, medium effect). 'Health and Safety' is positively correlated to 'contribution' (practically significant, low effect).

'Incidents' is positively correlated to 'Production impact' (practically significant, high effect), as well as to 'Health and Safety' (practically significant, medium effect). 'Incidents' is positively correlated to 'Availability' (practically significant, low effect).

'Contribution' is positively correlated to 'Colleagues' and 'Supervisor' (practically significant, low effect).

3.5.3 Specific correlations between Production Output and different Underground Conditions

Table 3.38 was obtained when correlations between the construct, production output and the other underground conditions' factors were measured.

The results showed that the correlation between all these factors is relatively high, and the significance levels is good enough between the different factors (these are shown in the blue cells of Table 3.38).

Correlation results of 0.2 and above are regarded as medium strong, and correlation results of 0.5 and above are regarded as high and strong, as can be seen in the top blue cells in Table 3.38. The top green cells show a low correlation, with no statistical significance (p>0.5).

Table 3.38: Correlation - Production Output and different Underground conditions

Correlations						
		Mine Production	Incidents	Availability	Contribution	Health & Safety
Pearson Correlation	Mine Production	1.000	0.071	-0.038	-0.002	0.037
	Incidents	0.071	1.000	0.292	0.361	0.529
	Availability	-0.038	0.292	1.000	0.421	0.215
	Contribution	-0.002	0.361	0.421	1.000	0.388
	Health and Safety	0.037	0.529	0.215	0.388	1.000
Sig. (1-tailed)	Mine Production		0.207	0.329	0.489	0.336
	Incidents	0.207		0.000	0.000	0.000
	Availability	0.329	0.000		0.000	0.006
	Contribution	0.489	0.000	0.000		0.000
	Health and Safety	0.336	0.000	0.006	0.000	
N	Mine Production	136	136	136	136	136
	Incidents	136	136	136	136	136
	Availability	136	136	136	136	136
	Contribution	136	136	136	170	136
	Health and Safety	136	136	136	136	136

3.5.4 Multiple linear regression

Pearson's correlation coefficients give the relationship between constructs and factors, but does not give any causal relationship between these constructs. Therefore, multiple linear regressions were carried out to look for causal relationship. All assumptions for multiple regression were tested for and satisfied. Since four factors describe the independent variable (Underground Conditions), the first regression analysis was to look for a relationship between the different factors making up the dependent variable (Production Output) to look for causal relationships. The results in Table 3.39 below, were obtained when the underground conditions were set as the dependant variable, and the other underground factors were set as the independent variables.

This exercise did not yield any significant results.

Table 3.39: Regression - Production Output and different Underground conditions

Correlations Coefficients[a]						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
Production Output	(Constant) Production Output	4.545	0.406		11.206	0.000
	Breakdown	0.060	0.072	0.089	0.839	0.403
	Availability	-0.027	0.044	-0.061	-0.626	0.532
	Logistics	-0.006	0.052	-0.012	-0.112	0.911
	Health and Safety	0.006	0.088	0.007	0.068	0.946

The results presented in Table 3.40 below, were obtained when the supervisor was set as the dependant variable, and the other underground factors were set as the independent variables.

This exercise also did not yield any significant results.

Table 3.40: Regression - Supervisor and different Underground conditions

Correlation Coefficients[a]						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
Supervisor	(Constant)	4.533	0.640		7.081	0.000
	Breakdown	0.161	0.114	0.149	1.414	0.160
	Availability	-0.004	0.069	-0.005	-0.053	0.958
	Logistics	-0.071	0.082	-0.088	-0.863	0.390
	Health and Safety	-0.073	0.139	-0.055	-0.524	0.601

It can be concluded that none of the independent factors contribute to the total production output as described in the questionnaire. It was then decided to look which of the factors making up the dependent variable would in fact be influenced by the different factors making up the underground conditions. The most logical one to start with was the factor Contribution, which gauges the respondent's individual contribution towards production output. The results in Table 3.41 below, were obtained when contribution was set as the dependant variable, and the other underground factors were set as the independent variables.

This exercise yielded the most significant results. Where the significance was lower than 0.05, the results show that the issues related to logistics – these are ventilation, travel distances etc. – have a significant influence on how employees perceive their own output. With this, availability has a medium influence on production, but this influence is negative.

Table 3.41: Regression - Contribution and different Underground conditions

Correlation Coefficients[a]						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
Contribution	(Constant)	4.190	0.441		9.501	0.000
	Breakdown	-0.051	0.078	-0.061	-0.652	0.516
	Availability	-0.124	0.048	-0.223	-2.607	0.010
	Logistics	0.344	0.057	0.548	6.066	0.000
	Health and Safety	-0.004	0.096	-0.003	-0.037	0.970

In the above table it can be seen that logistics has a statistically significant influence on contribution, with a large beta coefficient. The beta coefficient of availability is negligibly small and can therefore be ignored. **This result is important, because it answers the main research question posed in paragraph 1.2 and: There are certain underground conditions, specifically logistical issues such as travel time to the work site that have a significant impact on production output** The results in Table 3.42 below, were obtained when colleagues were set as the dependant variable, and the other underground factors were set as the independent variables.

This exercise yielded significant results. Where the significance was lower than 0.05, the results show that the issues related to logistics – these are ventilation, travel distances etc. – have a significant influence on how employees perceive their own output.

Table 3.42: Regression - Colleagues and different Underground conditions

Correlation Coefficients[a]						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
Colleagues	(Constant)	4.631	0.626		7.396	0.000
	Breakdown	0.002	0.111	0.002	0.022	0.982
	Availability	-0.087	0.067	-0.126	-1.296	0.197
	Logistics	0.003	0.081	0.003	0.031	0.975
	Health and Safety	0.039	0.136	0.030	0.286	0.775

The results in Table 3.43 below, were obtained when contribution was set as the dependant variable, and supervisor and colleagues were set as the independent variables.

This exercise yielded results. Where the significance was lower than 0.05, the results show that the assistance from supervisors and colleagues do not contribute significantly to employees' contribution and output. Although there is a correlation, and a link between these factors, it is not the cause of the problem.

Table 3.43: Regression - Contribution and Supervisor + Colleagues

Correlation Coefficients[a]						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
Contribution	(Constant)	4.237	0.372		11.376	0.000
	Supervisor	0.057	0.072	0.073	0.791	0.430
	Colleagues	0.109	0.074	0.136	1.474	0.143

The regression results showed a few relationships that are causal in nature. The discussion will follow in the next chapter.

3.6 Comparing Demographical Data

Following the establishment of causal relationships between the different constructs, the information and responses of the different demographical groups were compared using independent T-tests. This was followed by running ANOVA tests on the different variables.

T-tests were conducted to measure whether there is a difference in responses from two different groups, as well as whether these differences have a statistical significance.

ANOVA tests were conducted to measure whether there is a difference in responses from more than two groups. In this case the significance was measures and compared.

3.6.1 Gender

A T-test was conducted to determine whether females and males responded differently to the different questions. Table 3.44 shows the results for the t-test, and the p-value (Sig. 2 tailed) is of significance. The research questionnaire was completed by 123 males and 13 female employees.

Table 3.44: Results of the T-test for gender

Independent Samples Test										
		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed) p-value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Underground Conditions	Equal variances assumed	0.097	0.756	-1.647	134	0.102	-0.34669	0.21055	-0.76312	0.06974
	Equal variances not assumed			-1.578	14.380	0.136	-0.34669	0.21973	-0.81681	0.12343
Mine Production	Equal variances assumed	3.666	0.058	-0.709	134	0.479	-0.12454	0.17554	-0.47173	0.22265
	Equal variances not assumed			-1.025	19.136	0.318	-0.12454	0.12152	-0.37877	0.12968
Supervisor	Equal variances assumed	0.247	0.620	0.587	134	0.558	0.16360	0.27864	-0.38750	0.71470
	Equal variances not assumed			0.552	14.265	0.590	0.16360	0.29649	-0.47119	0.79840

Contribution	**Equal variances assumed**	0.179	0.673	-2.212	199	0.028	-0.30753	0.13905	-0.58174	-0.03332
	Equal variances not assumed			-2.670	22.657	0.014	-0.30753	0.11518	-0.54599	-0.06906
Colleagues	**Equal variances assumed**	1.671	0.198	-0.924	134	0.357	-0.25078	0.27145	-0.78766	0.28610
	Equal variances not assumed			-1.238	17.762	0.232	-0.25078	0.20257	-0.67678	0.17521
Breakdown	**Equal variances assumed**	1.083	0.300	-1.569	134	0.119	-0.40129	0.25582	-0.90726	0.10467
	Equal variances not assumed			-1.928	16.551	0.071	-0.40129	0.20810	-0.84126	0.03867
Availability	**Equal variances assumed**	1.657	0.200	-1.473	134	0.143	-0.57176	0.38815	-1.33947	0.19594
	Equal variances not assumed			-1.820	16.613	0.087	-0.57176	0.31419	-1.23582	0.09229
Logistics	**Equal variances assumed**	0.085	0.771	-1.206	147	0.230	-0.40290	0.33400	-1.06296	0.25716
	Equal variances not assumed			-1.437	15.730	0.170	-0.40290	0.28038	-0.99810	0.19230
Health and Safety	**Equal variances assumed**	0.276	0.600	-0.639	134	0.524	-0.13462	0.21071	-0.55137	0.28214
	Equal variances not assumed			-0.814	17.014	0.427	-0.13462	0.16539	-0.48353	0.21429

The results in Table 3.44 above, show that the p-value for contribution is smaller than 0.05 (red cells). This indicates that the male and female participants statistically answered the questions in a significantly different manner. For the rest of the dimensions, the p-value was greater than 0.05, which indicates that the participants statistically answered the questions in a significantly similar manner.

From the results in Table 3.45, it can be concluded that the female participants rated this factor the highest (shown in the orange cells). It must be reiterated that there were far more male participants than female participants.

Table 3.45: Results of the Group statistics for Gender

Group Statistics					
Gender? (A1)		N	Mean	Std. Deviation	Std. Error Mean
Underground Conditions	Male	123	4.7962	0.71841	0.06478
	Female	13	5.1429	0.75705	0.20997
Mine Production	Male	123	4.7161	0.61890	0.05580
	Female	13	4.8407	0.38922	0.10795
Supervisor	Male	123	4.6098	0.94846	0.08552
	Female	13	4.4462	1.02357	0.28389
Contribution	Male	123	5.1184	0.57199	0.04228
	Female	13	5.4259	0.45454	0.10714
Colleagues	Male	123	4.4569	0.95317	0.08594
	Female	13	4.7077	0.66139	0.18344
Breakdown	Male	123	4.8808	0.89334	0.08055
	Female	13	5.2821	0.69183	0.19188
Availability	Male	123	4.2744	1.35593	0.12226
	Female	13	4.8462	1.04352	0.28942
Logistics	Male	123	4.6740	1.16708	0.10008
	Female	13	5.0769	0.94432	0.26191
Health and Safety	Male	123	5.2500	0.73760	0.06651
	Female	13	5.3846	0.54596	0.15142

3.6.2 Age Group

To do this T-test, the five age groups were divided into two groups: under 40 years of age and over forty years of age. A T-test was conducted to test whether or not the age group of under forty years old and the age group of over forty years old responded differently to the various questions. Table 3.46 shows the results for the T-test, and the p-value (Sig. 2 tailed) is of significance. The research questionnaire was completed by 85 employees under the age of forty, and 51 employees over the age of forty.

Table 3.46: Results of the T-test for Age Group

Independent Samples Test										
		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed) P Value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Underground Conditions	Equal variances assumed	3.047	0.083	0.280	134	0.780	0.03613	0.12912	-0.21925	0.29152
	Equal variances not assumed			0.264	87.037	0.793	0.03613	0.13696	-0.23608	0.30835
Mine Production	Equal variances assumed	0.472	0.493	0.215	134	0.830	0.02301	0.10679	-0.18821	0.23423
	Equal variances not assumed			0.209	95.482	0.835	0.02301	0.11012	-0.19558	0.24161
Supervisor	Equal variances assumed	1.623	0.205	1.550	134	0.123	0.26039	0.16795	-0.07178	0.59256
	Equal variances not assumed			1.504	95.474	0.136	0.26039	0.17318	-0.08338	0.60417
Contribution	Equal variances assumed	2.297	0.131	-3.292	263	0.001	-0.34709	0.10543	-0.55469	-0.13950
	Equal variances not assumed			-4.145	237.320	0.000	-0.34709	0.08375	-0.51208	-0.18211
Colleagues	Equal variances assumed	0.070	0.791	-0.204	134	0.839	-0.03373	0.16536	-0.36078	0.29333
	Equal variances not assumed			-0.199	96.914	0.843	-0.03373	0.16973	-0.37060	0.30315
Breakdown	Equal variances assumed	4.414	0.038	-1.437	134	0.153	-0.22353	0.15560	-0.53127	0.08421
	Equal variances not assumed			-1.346	85.299	0.182	-0.22353	0.16606	-0.55368	0.10662
Availability	Equal variances assumed	3.152	0.078	0.698	134	0.486	0.16569	0.23721	-0.30347	0.63485
	Equal variances not assumed			0.676	94.828	0.501	0.16569	0.24510	-0.32092	0.65229
Logistics	Equal variances assumed	0.013	0.908	-0.489	168	0.626	-0.09451	0.19331	-0.47614	0.28713

	Equal variances not assumed			-0.501	116.755	0.617	-0.09451	0.18863	-0.46809	0.27908
Health and Safety	Equal variances assumed	2.422	0.122	1.021	134	0.309	0.13039	0.12767	-0.12212	0.38291
	Equal variances not assumed			0.919	75.060	0.361	0.13039	0.14185	-0.15218	0.41297

The results in Table 3.46 above show that the p-value for contribution is smaller than 0.05 (red cells). This indicates that the under 40's and over 40's participants statistically answered the questions in a statistically significantly different manner. For the rest of the dimensions, the p-value was greater than 0.05, which indicates that the participants statistically answered the questions in a significantly similar manner.

From the results in Table 3.47, it can be concluded that the participants over the age of 40 rated this factor the highest (shown in the orange cells). It must be noted that there were more participants under 40 years of age, than those of over 40 years old.

Table 3.47: Results of the Group statistics for Gender

Group Statistics						
Age group? (A2)		N	Mean	Std. Deviation	Std. Error Mean
Underground Conditions	>= 3 (under 40 years)	85	4.8429	0.65806	0.07138
	< 3 (over 40 years)	51	4.8067	0.83474	0.11689
Mine Production	>= 3 (under 40 years)	85	4.7367	0.57402	0.06226
	< 3 (over 40 years)	51	4.7136	0.64862	0.09083
Supervisor	>= 3 (under 40 years)	85	4.6918	0.90267	0.09791
	< 3 (over 40 years)	51	4.4314	1.02010	0.14284
Contribution	>= 3 (under 40 years)	85	4.8854	0.86642	0.06302
	< 3 (over 40 years)	51	5.2325	0.48080	0.05515
Colleagues	>= 3 (under 40 years)	85	4.4682	0.89579	0.09716
	< 3 (over 40 years)	51	4.5020	0.99388	0.13917
Breakdown	>= 3 (under 40 years)	85	4.8353	0.78279	0.08491
	< 3 (over 40 years)	51	5.0588	1.01916	0.14271
Availability	>= 3 (under 40 years)	85	4.3912	1.27034	0.13779
	< 3 (over 40 years)	51	4.2255	1.44763	0.20271
Logistics	>= 3 (under 40 years)	85	4.6257	1.21134	0.11345

	< 3 (over 40 years)	51	4.7202	1.12775	0.15070
Health and Safety	>= 3 (under 40 years)	85	5.3118	0.58236	0.06317
	< 3 (over 40 years)	51	5.1814	0.90703	0.12701

3.6.3 Managerial Level

Table 3.48 below, shows the results of the ANOVA tests calculations done on the managerial level. The ANOVA tests calculation measure the difference between more than two groups. From the ANOVA tests calculation in Table 3.48, the significance column (cells marked in red) is important. When a value is smaller than 0.05 ($p<0.05$), it is statistically significant. The underground conditions (yellow cell) is the independent variable and mine production (also yellow cell) is the dependant variable. The remaining factors describe the individual factors.

Table 3.48: The ANOVA tests calculation for the Managerial Levels

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Underground Conditions	Between Groups	2.220	2	1.110	2.139	0.122
	Within Groups	69.036	133	0.519		
	Total	71.257	135			
Mine Production	Between Groups	2.380	2	1.190	3.414	0.036
	Within Groups	46.350	133	0.348		
	Total	48.730	135			
Supervisor	Between Groups	0.597	2	0.298	0.325	0.723
	Within Groups	122.038	133	0.918		
	Total	122.635	135			
Contribution	Between Groups	15.601	4	3.900	6.579	0.000
	Within Groups	149.393	252	0.593		
	Total	164.993	256			
Colleagues	Between Groups	7.805	2	3.903	4.761	0.010
	Within Groups	109.025	133	0.820		
	Total	116.830	135			
Breakdown	Between Groups	3.173	2	1.587	2.072	0.130
	Within Groups	101.826	133	0.766		
	Total	104.999	135			
Availability	Between Groups	5.305	2	2.652	1.495	0.228
	Within Groups	235.908	133	1.774		
	Total	241.213	135			

Logistics	Between Groups	7.489	3	2.496	1.813	0.147
	Within Groups	228.606	166	1.377		
	Total	236.095	169			
Health and Safety	Between Groups	0.976	2	0.488	0.938	0.394
	Within Groups	69.189	133	0.520		
	Total	70.165	135			

From Table 3.48, it can be concluded that the groups statistically differ about the production output (dependent variable), but not about the underground conditions (independent variable). This is indicated by the first red cell in Table 3.48.

From Table 3.48, the contribution and colleagues (cells indicated in orange) are indicators why the mine production displayed in a red cell. These two factors show a significant difference between the commented groups. The aforementioned would describe the managerial level, as seen in the blue cells in Table 3.49 below. This is an indication that there is a significant difference in the way the different managerial levels see their level of contribution, as well as the contribution from their colleagues.

Table 3.49: The Multiple Comparisons for the Managerial Levels

Multiple Comparisons								
Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Contribution	Tukey HSD	1	2	0.22885	0.11370	0.263	-0.0836	0.5413
			3	.73478*	0.16426	0.000	0.2835	1.1861
			5	.45532*	0.15162	0.024	0.0387	0.8719
			6	0.69774	0.39145	0.386	-0.3778	1.7733
		2	1	-0.22885	0.11370	0.263	-0.5413	0.0836
			3	.50593*	0.17280	0.030	0.0311	0.9807
			5	0.22646	0.16084	0.623	-0.2155	0.6684
			6	0.46889	0.39511	0.759	-0.6167	1.5545
		3	1	-.73478*	0.16426	0.000	-1.1861	-0.2835
			2	-.50593*	0.17280	0.030	-0.9807	-0.0311
			5	-0.27946	0.19980	0.629	-0.8284	0.2695
			6	-0.03704	0.41251	1.000	-1.1705	1.0964

		5	1	-.45532*	0.15162	0.024	-0.8719	-0.0387
			2	-0.22646	0.16084	0.623	-0.6684	0.2155
			3	0.27946	0.19980	0.629	-0.2695	0.8284
			6	0.24242	0.40764	0.976	-0.8776	1.3625
		6	1	-0.69774	0.39145	0.386	-1.7733	0.3778
			2	-0.46889	0.39511	0.759	-1.5545	0.6167
			3	0.03704	0.41251	1.000	-1.0964	1.1705
			5	-0.24242	0.40764	0.976	-1.3625	0.8776
	Bonferroni	1	2	0.22885	0.11370	0.452	-0.0932	0.5509
			3	.73478*	0.16426	0.000	0.2696	1.1999
			5	.45532*	0.15162	0.029	0.0259	0.8847
			6	0.69774	0.39145	0.759	-0.4108	1.8063
		2	1	-0.22885	0.11370	0.452	-0.5509	0.0932
			3	.50593*	0.17280	0.037	0.0166	0.9953
			5	0.22646	0.16084	1.000	-0.2290	0.6820
			6	0.46889	0.39511	1.000	-0.6500	1.5878
		3	1	-.73478*	0.16426	0.000	-1.1999	-0.2696
			2	-.50593*	0.17280	0.037	-0.9953	-0.0166
			5	-0.27946	0.19980	1.000	-0.8453	0.2864
			6	-0.03704	0.41251	1.000	-1.2052	1.1312
		5	1	-.45532*	0.15162	0.029	-0.8847	-0.0259
			2	-0.22646	0.16084	1.000	-0.6820	0.2290
			3	0.27946	0.19980	1.000	-0.2864	0.8453
			6	0.24242	0.40764	1.000	-0.9120	1.3968
		6	1	-0.69774	0.39145	0.759	-1.8063	0.4108
			2	-0.46889	0.39511	1.000	-1.5878	0.6500
			3	0.03704	0.41251	1.000	-1.1312	1.2052
			5	-0.24242	0.40764	1.000	-1.3968	0.9120

* The mean difference is significant at the 0.05 level.

From Table 3.49 above, the mean difference (indicated in blue) showed that the junior management level feels that their contribution is the most of all the managerial levels. The significance levels (emphasised in green) indicate that there is no major significant difference between level 1 and level 2; however, there is a significant difference with the other levels.

From the results in Table 3.50, it can be concluded that the junior management level rated the contribution factor the highest (shown in the orange cells). It must be noted that junior management was the biggest participant group.

Table 3.50: The Descriptive Statistics for Managerial Levels

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Underground Conditions	Junior Management	77	4.8590	0.73009	0.08320	4.6933	5.0247	2.00	5.93
	Middle Management	47	4.6960	0.71327	0.10404	4.4866	4.9055	2.43	5.93
	Senior Management	12	5.1607	0.68249	0.19702	4.7271	5.5943	3.86	5.93
	Total	136	4.8293	0.72652	0.06230	4.7061	4.9525	2.00	5.93
Mine Production	Junior Management	77	4.8438	0.60448	0.06889	4.7066	4.9810	3.00	5.93
	Middle Management	47	4.5783	0.60018	0.08755	4.4021	4.7545	3.14	5.57
	Senior Management	12	4.5714	0.42749	0.12341	4.2998	4.8430	3.93	5.21
	Total	136	4.7280	0.60080	0.05152	4.6261	4.8299	3.00	5.93
Supervisor	Junior Management	77	4.6519	1.05402	0.12012	4.4127	4.8912	1.40	6.00
	Middle Management	47	4.5149	0.87749	0.12800	4.2573	4.7725	2.40	6.00
	Senior Management	12	4.5333	0.44586	0.12871	4.2500	4.8166	4.00	5.40
	Total	136	4.5941	0.95311	0.08173	4.4325	4.7558	1.40	6.00
Contribution	Junior Management	77	5.1977	0.54822	0.05047	5.0978	5.2977	3.00	6.00
	Middle Management	47	4.9689	0.71905	0.08303	4.8034	5.1343	2.33	6.00
	Senior Management	12	4.4630	1.49238	0.28721	3.8726	5.0533	1.00	6.00
	Total	136	4.9844	0.80281	0.05008	4.8858	5.0831	1.00	6.00
Colleagues	Junior Management	77	4.6805	0.89281	0.10175	4.4779	4.8832	2.00	6.00
	Middle Management	47	4.2766	0.92365	0.13473	4.0054	4.5478	2.00	5.60
	Senior Management	12	4.0000	0.91453	0.26400	3.4189	4.5811	2.20	5.20
	Total	136	4.4809	0.93027	0.07977	4.3231	4.6386	2.00	6.00
Breakdown	Junior Management	77	5.0260	0.91888	0.10472	4.8174	5.2345	2.00	6.00
	Middle Management	47	4.7092	0.83295	0.12150	4.4647	4.9538	2.33	6.00
	Senior Management	12	5.0556	0.72242	0.20854	4.5966	5.5146	3.67	6.00
	Total	136	4.9191	0.88191	0.07562	4.7696	5.0687	2.00	6.00
Availability	Junior Management	77	4.2468	1.39754	0.15926	3.9296	4.5640	1.00	6.00
	Middle Management	47	4.3032	1.29583	0.18902	3.9227	4.6837	1.00	6.00
	Senior Management	12	4.9583	0.96433	0.27838	4.3456	5.5710	3.25	5.75
	Total	136	4.3290	1.33670	0.11462	4.1024	4.5557	1.00	6.00
Logistics	Junior Management	77	4.8431	1.06233	0.11523	4.6140	5.0723	1.00	6.00
	Middle Management	47	4.3697	1.35882	0.18322	4.0024	4.7370	1.00	6.00
	Senior Management	12	4.6667	1.23528	0.30882	4.0084	5.3249	2.00	6.00
	Total	136	4.6569	1.18195	0.09065	4.4779	4.8358	1.00	6.00
Health and Safety	Junior Management	77	5.2922	0.73270	0.08350	5.1259	5.4585	2.00	6.00
	Middle Management	47	5.1649	0.72845	0.10626	4.9510	5.3788	2.25	6.00
	Senior Management	12	5.4583	0.60145	0.17362	5.0762	5.8405	4.25	6.00
	Total	136	5.2629	0.72093	0.06182	5.1406	5.3851	2.00	6.00

3.6.4 Department

Table 3.51 below, shows the results of the ANOVA tests calculations performed on the departments. The ANOVA tests calculation measure the difference between more than two groups. From the ANOVA tests calculation in Table 3.51, the statistical significance column (marked with red cells) is important. When a p-value is smaller than 0.05, it is significant. The underground conditions (marked in yellow) is the independent variable and mine production (also marked in yellow) is the dependant variable, and the others describe the individual factors.

Table 3.51: The ANOVA test calculation for the Departments

ANOVA Department						
		Sum of Squares	df	Mean Square	F	Sig.
Underground Conditions	Between Groups	5.463	2	2.732	5.522	0.005
	Within Groups	65.794	133	0.495		
	Total	71.257	135			
Mine Production	Between Groups	0.048	2	0.024	0.065	0.937
	Within Groups	48.682	133	0.366		
	Total	48.730	135			
Supervisor	Between Groups	2.351	2	1.176	1.300	0.276
	Within Groups	120.284	133	0.904		
	Total	122.635	135			
Contribution	Between Groups	10.242	4	2.560	4.732	0.001
	Within Groups	154.759	286	0.541		
	Total	165.001	290			
Colleagues	Between Groups	1.539	2	0.769	0.888	0.414
	Within Groups	115.292	133	0.867		
	Total	116.830	135			
Breakdown	Between Groups	5.634	2	2.817	3.770	0.026
	Within Groups	99.365	133	0.747		
	Total	104.999	135			
Availability	Between Groups	14.888	2	7.444	4.374	0.014
	Within Groups	226.325	133	1.702		
	Total	241.213	135			
Logistics	Between Groups	8.353	4	2.088	1.513	0.201
	Within Groups	227.742	165	1.380		
	Total	236.095	169			
Health Safety	Between Groups	2.502	2	1.251	2.459	0.089
	Within Groups	67.663	133	0.509		
	Total	70.165	135			

From Table 3.51 it can be concluded that the groups statistically differ about the production output (dependant variable), but not about the underground conditions (independent variable). This is indicated by the first red cell in Table 3-51.

From Table 3.51, the contribution, breakdown and availability (cells indicated in orange) are indicators why the mine production displayed in a red cell. These three factors show a significant difference between the groups. This would describe the department, as seen in the blue cells of Table 3.52 below. This is an indication that there is a significant difference the different managerial levels see as their level of contribution, as well as the contribution from their colleagues.

Table 3.52: The Multiple Comparisons between the Departments

Multiple Comparisons								
Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Contribution	Tukey HSD	1	2	.46008*	0.16518	0.045	0.0066	0.9135
			3	0.15747	0.10629	0.575	-0.1343	0.4493
			5	.58508*	0.16518	0.004	0.1316	1.0385
			6	0.68627	0.34085	0.262	-0.2495	1.6220
		2	1	-.46008*	0.16518	0.045	-0.9135	-0.0066
			3	-0.30262	0.15055	0.264	-0.7159	0.1107
			5	0.12500	0.19660	0.969	-0.4147	0.6647
			6	0.22619	0.35714	0.970	-0.7543	1.2066
		3	1	-0.15747	0.10629	0.575	-0.4493	0.1343
			2	0.30262	0.15055	0.264	-0.1107	0.7159
			5	.42762*	0.15055	0.039	0.0143	0.8409
			6	0.52881	0.33401	0.509	-0.3881	1.4458
		5	1	-.58508*	0.16518	0.004	-1.0385	-0.1316
			2	-0.12500	0.19660	0.969	-0.6647	0.4147
			3	-.42762*	0.15055	0.039	-0.8409	-0.0143
			6	0.10119	0.35714	0.999	-0.8793	1.0816
		6	1	-0.68627	0.34085	0.262	-1.6220	0.2495
			2	-0.22619	0.35714	0.970	-1.2066	0.7543
			3	-0.52881	0.33401	0.509	-1.4458	0.3881
			5	-0.10119	0.35714	0.999	-1.0816	0.8793

		1	2	0.46008	0.16518	0.057	-0.0072	0.9274
			3	0.15747	0.10629	1.000	-0.1432	0.4582
			5	.58508*	0.16518	0.005	0.1178	1.0524
			6	0.68627	0.34085	0.450	-0.2780	1.6505
		2	1	-0.46008	0.16518	0.057	-0.9274	0.0072
			3	-0.30262	0.15055	0.454	-0.7285	0.1233
			5	0.12500	0.19660	1.000	-0.4312	0.6812
			6	0.22619	0.35714	1.000	-0.7841	1.2365
	Bonferroni	3	1	-0.15747	0.10629	1.000	-0.4582	0.1432
			2	0.30262	0.15055	0.454	-0.1233	0.7285
			5	.42762*	0.15055	0.048	0.0017	0.8535
			6	0.52881	0.33401	1.000	-0.4161	1.4737
		5	1	-.58508*	0.16518	0.005	-1.0524	-0.1178
			2	-0.12500	0.19660	1.000	-0.6812	0.4312
			3	-.42762*	0.15055	0.048	-0.8535	-0.0017
			6	0.10119	0.35714	1.000	-0.9091	1.1115
		6	1	-0.68627	0.34085	0.450	-1.6505	0.2780
			2	-0.22619	0.35714	1.000	-1.2365	0.7841
			3	-0.52881	0.33401	1.000	-1.4737	0.4161
			5	-0.10119	0.35714	1.000	-1.1115	0.9091

* The mean difference is significant at the 0.05 level.

From Table 3.52 above, the mean difference showed that the mining department feel that their contribution is the most of all of the departments. The significance levels (highlighted in green) indicate that there is no major significant difference between level 1 and level 2; however, there is a significant difference with the other levels.

From the results in Table 3.53, it can be concluded that the service department participants rated this factor the highest (shown in orange blocks). It must be noted that there were more mining department participants than participants from the other departments.

Table 3.53: The Descriptive Statistics for the Departments

Descriptive									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Underground Conditions	Service Departments	42	5.0204	0.64706	0.09984	4.8188	5.2220	3.29	5.93
	Engineering Department	13	4.2802	1.11134	0.30823	3.6086	4.9518	2.00	5.29
	Mining department	81	4.8183	0.65006	0.07223	4.6746	4.9621	2.86	5.93
	Total	136	4.8293	0.72652	0.06230	4.7061	4.9525	2.00	5.93
Mine Production	Service Departments	42	4.7092	0.52735	0.08137	4.5449	4.8735	3.64	5.86
	Engineering Department	13	4.7781	0.50582	0.14029	4.4724	5.0838	3.93	5.64
	Mining department	81	4.7298	0.65393	0.07266	4.5852	4.8743	3.00	5.93
	Total	136	4.7280	0.60080	0.05152	4.6261	4.8299	3.00	5.93
Supervisor	Service Departments	42	4.4190	1.00614	0.15525	4.1055	4.7326	2.00	6.00
	Engineering Department	13	4.4923	1.14780	0.31834	3.7987	5.1859	1.40	6.00
	Mining department	81	4.7012	0.88720	0.09858	4.5051	4.8974	2.00	6.00
	Total	136	4.5941	0.95311	0.08173	4.4325	4.7558	1.40	6.00
Contribution	Service Departments	42	5.1863	0.48658	0.05901	5.0685	5.3041	3.00	6.00
	Engineering Department	13	4.7262	1.08128	0.20434	4.3069	5.1455	1.67	6.00
	Mining department	81	5.0288	0.69841	0.05487	4.9204	5.1372	1.00	6.00
	Total	136	4.9863	0.75430	0.04422	4.8992	5.0733	1.00	6.00
Colleagues	Service Departments	42	4.5238	0.79259	0.12230	4.2768	4.7708	2.60	6.00
	Engineering Department	13	4.7692	0.68725	0.19061	4.3539	5.1845	4.00	6.00
	Mining department	81	4.4123	1.02389	0.11377	4.1859	4.6387	2.00	6.00
	Total	136	4.4809	0.93027	0.07977	4.3231	4.6386	2.00	6.00
Breakdown	Service Departments	42	5.0476	0.78802	0.12159	4.8021	5.2932	3.33	6.00
	Engineering Department	13	4.3077	1.39085	0.38575	3.4672	5.1482	2.00	6.00
	Mining department	81	4.9506	0.79602	0.08845	4.7746	5.1266	2.33	6.00
	Total	136	4.9191	0.88191	0.07562	4.7696	5.0687	2.00	6.00
Availability	Service Departments	42	4.7619	1.03292	0.15938	4.4400	5.0838	1.00	6.00
	Engineering Department	13	3.6538	1.30120	0.36089	2.8675	4.4402	2.00	5.75
	Mining department	81	4.2130	1.42418	0.15824	3.8981	4.5279	1.00	6.00
	Total	136	4.3290	1.33670	0.11462	4.1024	4.5557	1.00	6.00
Logistics	Service Departments	42	4.9259	1.02713	0.15312	4.6173	5.2345	1.00	6.00
	Engineering Department	13	4.2889	1.18768	0.30666	3.6312	4.9466	2.00	6.00
	Mining department	81	4.6007	1.25154	0.12774	4.3471	4.8543	1.00	6.00
	Total	136	4.6569	1.18195	0.09065	4.4779	4.8358	1.00	6.00
Health and Safety	Service Departments	42	5.2976	0.67904	0.10478	5.0860	5.5092	2.50	6.00
	Engineering Department	13	4.8462	1.29316	0.35866	4.0647	5.6276	2.00	5.75
	Mining department	81	5.3117	0.59887	0.06654	5.1793	5.4441	2.75	6.00
	Total	136	5.2629	0.72093	0.06182	5.1406	5.3851	2.00	6.00

3.7 Discussion of Results

The general aim of this research study was to determine whether the physical underground conditions have an influence on the production output at a deep-level gold mine. To be able to achieve this general objective, specific objectives were determined and analysed through statistical properties of the questionnaire, as a measuring instrument. The detail discussion on the meeting of the objectives follows in chapter 4. To be able to meet those objectives, the empirical study was carried out in a number of steps. The first step was to describe the results in general (descriptive statistics), followed by validating the instrument used in the research (exploratory factor analysis) and determining the reliability of the instrument (Cronbach's alpha coefficients). This was followed by an analysis of the relationship between the constructs (correlations and regression analysis) and, finally, by a comparison of the responses of the different demographic segments (t-tests and ANOVA tests).

Step 1 entailed descriptive statistics on the participants and how they answered the different questions in the questionnaire. The sample used in the research is skewed towards male participants (in line with the trend in the mining industry) and participants were from a number of departments and on different managerial levels in the organisation. The mean value and for each question were also calculated.

Step 2 entailed a principal component analysis. This yielded a number of factors that were labelled Supervisor, Colleagues (describing the support obtained from the respondents' supervisor and colleagues respectively), Contribution (describing the contribution that the respondent makes towards output of the mine), Incidents, Availability, Logistics and Health & Safety. It was found that the first three factors describe the overall dependent variable (Mine production) and that the last four factors describe the independent variable (Underground conditions). A Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated for each of the constructs to test if the sample was sufficiently large. The KMO value calculated was 0.757 and this means that the sample was sufficiently large to draw meaningful conclusions as this value is larger than 0.6 and the Bartlett's Test of Sphericity sigma was smaller than 0.05.

Step 3 was to establish whether these factors are reliable. The reliabilities of six of the factors identified in this study ranged from 0.77 to 0.92 indicating strong reliability. The one factor with a value of 0.58 was also retained as it is also deemed acceptable. It can therefore be concluded that the developed questionnaire that was used in this research is a valid and reliable measuring instrument.

Step 4 was to investigate how well the different factors correlated with each other. A number of correlations were noted:

- ‘Supervisor’ is positively correlated to ‘Colleagues’ (practically significant, medium effect).
- ‘Availability’ is positively correlated to ‘Production impact’ (practically significant, medium effect).
- ‘Health and Safety’ is positively correlated to ‘Production impact’ and ‘Availability’ (practically significant, medium effect). ‘Health and Safety’ is positively correlated to ‘Contribution’ (practically significant, low effect).
- ‘Incidents’ is positively correlated to ‘Production impact’ (practically significant, high effect) and ‘Health and Safety’ (practically significant, medium effect). ‘Incidents’ is positively correlated to ‘Availability’ (practically significant, low effect).
- ‘Contribution’ is positively correlated to ‘Colleagues’ and ‘Supervisor’ (practically significant, low effect).

Correlation results of 0.2 and above are regarded as medium strong, and correlation results of 0.5 and above is regarded as high.

Next, multiple linear regressions were computed between the construct, production output and the other underground conditions factors, and the results measured. The results showed that the casual relationships between all these factors are relatively high, and the significance levels between the various factors is sufficient. The results of the multiple regression analyses between the constructs, production output and the other underground conditions are summarised as follows:

- First, the underground conditions were set as the dependant variable and the other underground factors were set as the independent variables. This exercise did not yield any significant results.

- Secondly, supervisor was set as the dependant variable and the other underground factors were set as the independent variables. This exercise did not yield any significant results.
- Thirdly, contribution was set as the dependant variable and the other underground factors was set as the independent variables. This exercise yielded the most significant results. Where the significance was lower than 0.05 the results show that the issues related to logistics, these are ventilation, travel distances etc. has a significant influence on how employees perceive their own output. **This result is important, because it answers the main research question posed in paragraph 1.2 and: There are certain underground conditions, specifically logistical issues such as travel time to the work site that have a significant impact on production output**
- Fourthly, colleagues factor was set as the dependant variable and the other underground factors were set as the independent variables. This exercise yielded significant results. Where the significance was lower than 0.05, the results show that the issues related to logistics – these are ventilation, travel distances etc. – have a significant influence on how employees perceive their own output. With this, health and safety has a medium influence on production, but this influence is negative.
- Fifthly, contribution was set as the dependant variable, and supervisor and colleagues were set as the independent variables. This exercise yielded results. Where the significance was lower than 0.05, the results show that the assistance from supervisors and colleagues does not contribute significantly to employees' contributions and output. Although there is a correlation and a link between these factors, it is not the cause of the problem.

Step 5 was to determine whether significant differences were found between the various demographic groups. T-tests were conducted to measure whether there is a difference in responses from different groups, as well as whether these differences have a statistical significance. ANOVA tests were performed, to measure whether there is a difference in responses from more than two groups. In this case the significance was measures and compared.

The results are summarised as follows:

- **Gender:** Statistically, the male and female participants answered the questions in a significantly different manner. The female participants rated the contribution factor the highest.
- **Age Group:** The participants under the age of 40, and those over the age of 40 statistically answered the questions in a significantly different manner. The participants who are older than 40 rated the contribution factor the highest.
- **Managerial Level:** It can be concluded that the groups statistically differ about the production output (dependant variable), but not about the underground conditions (independent variable). The contribution and colleague's factors are indicators why the mine production displayed negatively. These two factors show a significant difference between the groups. This is an indication that there is a significant difference in the way the different managerial levels see their level of contribution and the contribution from their colleagues.
- **Managerial Level:** The mean difference showed that the participants at the junior management level feel that their contribution is the most of all the managerial levels. The significance levels indicate that there is no major difference between level 1 and level 2; however, there is a significant difference between the other levels.
- **Managerial Level:** It can be concluded that the participants at the junior management level rated the contribution factor the highest. It must be noted that the junior management consisted of the most participants.
- **Departments:** It can be concluded that the groups statistically differ about the production output (dependant variable), but not about the underground conditions (independent variable). The contribution, breakdown and availability factors are indicators why the mine production displayed negatively. These three factors show a significant difference between the groups. This is an indication that there is a significant difference in the way the different managerial levels see their level of contribution and the contribution from their colleagues.

- **Departments:** The mean difference showed that the mining department feels that their contribution is the most of all the departments. The significance levels indicate that there is no major difference between level 1 and level 2; however, there is a significant difference with the other levels.
- **Departments: I**t can be concluded that the service department participants rated the breakdown factor the highest.

The outcome of this study has shown that the use of the designed questionnaire is acceptable for measuring the influence of the underground conditions on production in a deep-level gold mine, because of its construct validity and high level of reliability

3.8 Chapter Summary

In this chapter the results of the empirical research are reported and discussed in terms of the quantitative results.

A questionnaire was administered to gather demographical data, as well as data regarding the research topic. Two constructs were extracted, accounting for 59% of the total variance. These constructs were labelled underground conditions and production output. Seven factors were extracted from the questionnaire, which account for 71% of the total variance.

Acceptable Cronbach Alpha coefficients were found, which demonstrate that a large portion of the variance is explained by the dimensions. Results indicated that the research hypothesis could be accepted, and that there is an overall positive correlation between the physical underground conditions and the production output.

In Chapter 4, the conclusions pertaining to the research questions, the limitations of the research, and the conclusions specific to the organisation, as well as future research, are given.

CHAPTER 4 – CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

In this chapter, conclusions regarding the main results obtained in this research, as well as the empirical study, will be provided and discussed. Conclusions are drawn in terms of the research objectives that were set. Finally, recommendation will be made towards the organisation and future possible research opportunities, that emanated from this research study, will be presented.

4.2 Research conclusions and meeting of research objectives

4.2.1 Primary objective

The general objective of this research endeavour was to determine the influence of the physical underground conditions on the production achieved, at a deep-level gold mine.

The main conclusion is therefore that logistical issues is the most important factor that influences production output, and the primary research question was therefore answered in paragraph 3.4.1 when a statistically significant causal relationship ($p<0.05$) was found between logistics (describing underground distances, travel times) and contribution (describing the individual's contribution to production output).

4.2.2 Specific objectives

The specific objectives of this research were:

4.2.2.1 To provide an overview of deep-level mining

The mining industry in South Africa, with its challenges and difficulties, was described in chapter 2 as part of the literature study. It can be concluded that the mining industry is under pressure due to aggressive union activity, long logistical distances between the shaft and the rock face.

4.2.2.2 To investigate workers' experience of the physical underground conditions.

This was done in chapter 3 during the empirical study. In general, workers' experience was not very positive, as indicated in the high mean value obtained in the descriptive statistics carried out in paragraph 3.2 for the items making up the independent variable (underground conditions). Logistical issues seem to be the biggest contributor to adverse conditions under in the mine.

4.2.2.3 To determine the reasons for low production at a deep-level mine

This was achieved in paragraph 3.4.1 where multiple linear regression analysis showed that the most important underground condition contributing negatively to production output is logistics, which include time to travel to and from the workplace, logistical distances and adverse climate conditions under in the mine.

4.2.2.4 To quantify the influence of the physical underground workplace conditions on the production at a deep level mine

In the regression analysis carried out in paragraph 3.4.1, the beta coefficient describing the effect of logistical issues on individual contribution is 0.548, which indicates a statistically and practically significant effect size.

4.2.3 Specific Conclusions

The conclusion that can be made from the evidence, is that factors like distances travelled and ventilation are the underground conditions that have the biggest influence on an employee's personal output. In essence, this provides an answers to the research question that was posed in paragraph 1.2. Issues, such as union involvement, availability and health and safety are such an integral part of the current culture, that they have a very small influence on the production output.

The results show that assistance from supervisors and colleagues does not contribute significantly to employees' contributions and output. Although there is a correlation and a link between these factors, it is not the cause of the problem.

4.3 Limitations

The only limitation to this study is that it was carried out on only one of the operations of the organisations. This means the results of this study can, therefore, not necessarily be generalised to the whole organisation and industry.

4.4 Recommendations

4.4.1 Recommendations for the organisation

I would recommend that the mine should address the travelling issues by providing sufficient transport and address the underground ventilation conditions.

Companies should give incentives that promote health and safety compliance and encourage a culture of safety. In the end, both employees and the company will benefit from this.

The company should implement systems for better communication with the underground employees to inform and educate the people. It is important the major unions be included as part of this system.

To be able to address the underground conditions the company should invest in acquiring the services of additional mining engineers to ensure adequate man power and attention is allocated to the problem areas. Specific attention should be given to upgrading the rail system and aging shaft infrastructure to be able to address the underground issues.

The company should ensure good working relations with their employees and together with these good working relations between supervisors and their subordinates.

4.4.2 Recommendations for future research

Regardless of any limitations of the current research, the findings of this research study offer valuable suggestions for future research. The findings obtained in this study need to be replicated with a larger sample groups, in order to draw conclusions about the influence of physical underground conditions on production in the larger South African mining context.

It is then recommended that larger samples with a more powerful sampling method be used, to enable generalisability of the findings to other similar groups in the mining industry.

A third recommendation would be to conduct a qualitative research study, which would include all levels of employees throughout the mining industry, who work in the underground environment to provide for a clearer understanding of their thoughts and perceptions about this topic.

4.5 Chapter Summary

In this chapter, conclusions were made regarding the theoretical and empirical objectives of this research study. Recommendations were made for the organisation in which the research study took place. Recommendations were made for possible future research that can be conducted in this organisation. All the theoretical and empirical objectives formulated for this research, have been attained.

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APPENDIX A

Ethics Informed Consent Form

PARTICIPANT CONSENT

PARTICIPANT INFORMATION SHEET

05 June 2019

Dear Prospective Participant

MBA–STUDY: The Influence of the physical underground workplace conditions on the production at a Deep Level Gold Mine.

My name is Gerhardus Nagel and I am doing research with Dr Johan Jordaan at the North West University Business School, towards a Master of Business Administration degree. We are inviting you to participate in a study.

The sole purpose of this study is to obtain information from experts (such as yourself) employed and/or operating in the mining industry, in an attempt to determine the nature of your everyday experience related to the research topic.

The purpose is to study is to determine whether a relationship exists between the physical underground conditions and poor production achieved at Kusasalethu Gold Mine. By determining how the results would benefit, of not only the organization, but all employees and the community at large. There are some demographic questions in the questionnaire. They are only for scientific purposes, and will not be used for any other purpose other than for data analysis.

You were selected to participate in this study as an employee of Harmony Mine, Kusasalethu Shaft. Band Malunga. The General Manager of the mine granted permission for the study to be conducted. Your name was randomly drawn from a list of all employees. In total 60-90 employees will be approached to participate in the study, which minimizes the possibility that anyone could be identified.

Your role in the study involves completing one questionnaire, which enquires about all the constructs explained earlier. A typical question may read as follows: "My personal values match my organization's values and culture". The questionnaires consist of +- 28 items (questions) in total, and the expected duration of participation is no more than 30 minutes. Some of the items might be viewed as duplications, but the similarity is due to the theoretical and conceptual overlap between constructs, and will be dealt with in a scientific way.

Being in this study is voluntary, and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep for future reference. You are free to withdraw at any time and without giving a reason. As the project involves the submission of non-identifiable material, it will not be possible to withdraw once you have submitted the questionnaire. There is no penalty or loss of benefit for non-participation.

X
____

Gerhardus Nagel
Researcher

X
____

Research Participant

SECTION A: DEMOGRAPHIC INFORMATION

Gender	Male	1	A1
	Female	2	
Age group	20 – 29	1	A2
	30 – 39	2	
	40 – 49	3	
	50 – 59	4	
	60 and older	5	
Number of years of service within the organisation	0 – 10 years	1	A3
	11- 20 years	2	
	21 – 30 years	3	
	31 - 40 years	4	
	41 and more years	5	
Indicate your managerial level	Junior management	1	A4
	Middle Management	2	
	Senior Management	3	
Qualification level	National Certificate (Matric)	1	A5
	Higher Certificate	2	
	Advanced Certificate	3	
	National Diploma	4	
	Diploma	5	
	Post-Graduate Diploma	6	
	Degree	7	
	Honours Degree	8	
	Master's Degree	9	
	PhD	10	
Department	Service Departments	1	A6
	Engineering Department	2	
	Mining Department	3	
Nr of underground shifts per week	0	1	A7
	1 – 2	2	
	3 – 5	3	
	6 - 7	4	

SECTION B: Your choices

No	Question	Not at All	To a small extent	To some extent	To a moderate extent	To a great extent	To a very great extent
B1	In my opinion, I contribute to the success of my section.	1	2	3	4	5	6
B2	I think I am performing well in executing my responsibilities.	1	2	3	4	5	6
B3	I think I am effective in completing my tasks.	1	2	3	4	5	6
B4	Mining further away from the shaft impacts negatively on production.	1	2	3	4	5	6
B5	Further travelling to workplaces impacts negatively on available face time to complete daily work.	1	2	3	4	5	6
B6	The availability of services, such as air, water and	1	2	3	4	5	6

	electricity, impacts negatively on production.						
B7	Ventilation constraints impact negatively on production.	1	2	3	4	5	6
B8	Availability of equipment impacts negatively on production.	1	2	3	4	5	6
B9	Availability of labour impacts negatively on production.	1	2	3	4	5	6
B10	Accidents and injuries impact negatively on production.	1	2	3	4	5	6
B11	Fatal accidents have a negative impact on production.	1	2	3	4	5	6
B12	Major loss incidents, e.g. an underground fire, have a negative impact on production.	1	2	3	4	5	6
B13	When older employees retire, the loss of skills and experience impacts negatively on production.	1	2	3	4	5	6
B14	The influence of Unions in the workplace impacts negatively on production.	1	2	3	4	5	6
B15	Engineering breakdowns in workplaces impact negatively on production.	1	2	3	4	5	6
B16	Ineffective services departments impact negatively on production.	1	2	3	4	5	6
B17	Low morale of employees in the working place impacts negatively on production.	1	2	3	4	5	6
B18	My supervisor provides the necessary resources to help me perform my duties.	1	2	3	4	5	6
B19	My supervisor supports me in executing my duties.	1	2	3	4	5	6
B20	My supervisor is always ready to help me with my duties.	1	2	3	4	5	6
B21	If necessary, I can count on the expertise of my supervisor to execute my duties.	1	2	3	4	5	6
B22	If I encounter a problem in the execution of my duties, I can always count on my supervisor.	1	2	3	4	5	6
B23	My colleagues provide the necessary resources to help me perform my duties.	1	2	3	4	5	6
B24	My colleagues support me in executing my duties.	1	2	3	4	5	6
B25	My colleagues are always ready to help me with my duties.	1	2	3	4	5	6
B26	If necessary, I can count on the expertise of my colleagues to execute my duties.	1	2	3	4	5	6
B27	If I encounter a problem in the execution of my duties, I can always count on my colleagues.	1	2	3	4	5	6
B28	I believe underground conditions can lead to heat related illness.	1	2	3	4	5	6