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2021
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Masemula, Floyd. (2021). Impact of safety leading indicators on workplace safety conditions at a selected mine and the influence of this on workplace safety [Master's dissertation, University of the Witwatersrand, Johannesburg]. WireDSpace.

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Impact of safety leading indicators on workplace safety conditions at a selected mine and the influence of this on workplace safety outcomes

Floyd Masemula

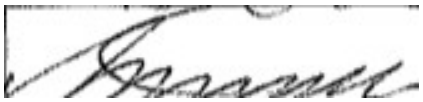
WITS Business School

Thesis presented in partial fulfilment for the degree of Master of Business Administration to the Faculty of Commerce, Law, and Management, University of the Witwatersrand

April 2021

DECLARATION

I Floyd Masemula declare that this research report entitled 'Impact of safety leading indicators on workplace safety conditions at a selected mine and the influence of this on workplace safety outcomes' is my own unaided work. I have acknowledged, attributed, and referenced all ideas sourced elsewhere. I am hereby submitting it in partial fulfilment of the requirements of the degree of Master of Business Administration at the University of the Witwatersrand, Johannesburg. I have not submitted this report before for any other degree or examination to any other institution.



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Signed at Johannesburg on 30th April 2021

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ABSTRACT

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Thesis title: Impact of safety leading indicators on workplace safety conditions at a selected mine and the influence of this on workplace safety outcomes

Safety leading indicators are precursors and can give warning on potential failures or harm. As such, they enable organisations to proactively identify safety problems, and facilitate implementation of measures to prevent occurrence of accidents or incidents. Recent developments in occupational health and safety management emphasises the use of safety leading indicators, and the SA mining industry has adopted to these developments. This study aims to determine the impact of safety leading indicators on workplace safety conditions in the context of an underground mine, and determine the influence of leading indicators on workplace safety outcomes.

Two hypothesis are developed to achieve these objectives,: (1) there is a statistically significant relationship between the safety leading indicators and safety conditions, (2) there is a statistically significant relationship between safety leading indicators and workplace safety outcomes. To test these hypotheses, the Organisational Performance Metric-Monash University (OPM-MU) survey tool was used to measure leading indicators, while data for workplace safety conditions and safety outcomes was collected from the reports at the selected mine. Data was analysed using one-way ANOVA to test for statistical significance between the chosen variables. The results showed that there is no statistically significant relationship between safety leading indicators and workplace safety conditions, and that there is a statistically significant relationship between safety leading indicators and safety outcomes.

The findings concerning Hypothesis 1 reveal that risk ratings of workplace safety conditions may not be the best representation of the variable of workplace safety conditions, and that other factors highlighted in the chosen interpretive framework for this study affect safety conditions. While the results of this study found there is a statistically significant relationship between safety leading indicators and safety outcomes, it is however a weak one. The implications of this is that safety leading indicators are more concerned with the circumstances preceding and giving rise to the safety outcomes rather than the safety outcomes themselves.

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ACKNOWLEDGEMENTS

I wish to thank my supervisor, Dr Roselyne Koech, for all her guidance, encouragement and dedication in helping me complete this study.

A special thanks to the mine for allowing me to collect the data that enabled this study, my friend Paul Eseme for help with the statistics.

I would like to thank my wife and children for their continued support and encouragement throughout this journey.

DEFINITION OF KEY TERMS AND CONCEPTS

For the purpose of this study, the key terms and concepts are defined below:

Leading indicators:	proactive measures that measure prevention efforts and can be observed and can be observed and recorded prior to an accidents or incident.
Lagging indicators:	reactive measures that track negative outcomes such as injury, once it has occurred.
Safety conditions:	represent the state of safety in a workplace as informed by the amount of hazards or level of risk to life, limb or health of persons
Safety outcomes:	measurement of safety outcomes include accidents, incidents, injuries to people, lost workdays etc.

1 INTRODUCTION TO THE RESEARCH

1.1 Background and context

More generally, this research seeks to establish the impact of safety leading indicators on workplace safety conditions and, ultimately, safety outcomes. However, before getting to the research conceptualisation (Section 1.2), we briefly introduce the terms and concepts that we have used in conceptualising this research in Section 1.1 generally and broadly—while Chapter 2 has a more specific and detailed discussion on the research context. The research conceptualisation section provides for the research problem statement (Section 1.2.1) and consequently the purpose of this research (Section 1.2.2) as well as the research questions (Section 1.2.3). The delimitations and assumptions of the research study are in Section 1.3 while we discuss the significance of the research study in Section 1.4 and provide a preface to the research report in Section 1.5.

1.1.1 Introduction to safety leading indicators

Safety leading indicators, similar to economic leading indicators, allow organisations to watch the level of safety and safety activity ((Shea, Cieri, Donohue and others, 2016), and therefore enable management to proactively identify safety problems and facilitate the development and/or implementation of remedial measures to prevent occurrence of unwanted events. The nature of leading indicators is not historical and this gives them the ability to predict future safety performance (Hinze, Thurman, & Wehle, 2013). Leading indicators are related to events, conditions, practices and measures that take place prior to an unwanted outcome such as an accidents and near misses. Sinelnikov, Inouye, & Kerper, (2015), stated the purpose of leading indicators for occupational health and safety (OHS) in three significant points: 1) anticipate, prevent, eliminate risks and loses, 2) monitor and evaluate safety performance, 3) motivate safe behaviour, commitment and continuous improvement. Measurements for leading indicators vary and predominantly make use of safety constructs. However, there are validated measures for safety leading indicators that available and address a large proportion of leading indicators constructs.

1.1.2 Workplace Safety Conditions

Safety conditions represent the state of safety in a workplace as informed by the presence of hazards. Safety conditions are continuously changing over time and are affected by positive safety practices and negative pressures, for example, production pressures as experienced in the workplace (Guo, Yiu, & Asce, 2009). Various accident causation theories and models list safety conditions as one of the direct factors causing accidents or incidents. Reiman & Pietikainen, (2011), stated that the changing nature of workplace safety conditions could alter the possibility of workplace accidents.

As a high level construct, safety conditions cannot be measured and therefore necessitates the identification of lower-mid level constructs to measure and explain state of safety (Guo et al., 2009).

1.1.3 Safety outcomes

Safety outcomes are related to unwanted occurrences such as accidents or incidents that can result in injuries to persons and can provide important information on the areas of the safety system in which failures are occurring. Safety outcomes can inform organizations on the effectiveness and failures of safety barriers (Lingard, Wakefield, & Blismas, 2014). Safety outcomes always follow and can be a result of different contextual and situational factors (Reiman & Pietikainen, 2011). Safety outcomes are not a direct measure of the level of safety in the system or in an organisation as they do not provide a detailed picture on safety events and activities but outcomes of events and activities that have already occurred (Lingard et al., 2014). Measurements of safety outcomes include accidents, incidents, injuries to people, lost workdays etc.

1.2 Research conceptualization

1.2.1 The research problem statement

The mining industry historically employed safety lagging indicators, such as injury rates, to measure, monitor and report on occupational health and safety performance. Lagging indicators measure occupational health and safety injury and illness that have occurred (KevinNG, 2010). Job injuries is an example of lagging indicators (Coleman & Kerkering, 2002). Lagging indicators are failure orientated as they measure events and or outcomes that have already materialized (Sheehan and others, 2016).

Recent developments in occupational health and safety have placed more emphasis on the use of safety leading indicators to measure occupational health and safety

performance. Safety leading indicators are thought of as precursors to potential failure or harm (Paul, 2009), and as such give organizations the opportunity to detect and proactively implement action to mitigate risks prior to the occurrence of an incident or accident (Shea and others, 2016). Kevin (2010) states that "safety leading indicators provide foresight for proactive safety management and also useful information to direct safety actions".

In order to continuously improve, the mining industry has adopted the use of leading indicators to proactively detect and respond to risks. However, despite adopting these proactive measures to occupational health and safety management, mines continue to record fatalities and accidents. Investigations into mine accidents consistently find that unsafe workplace conditions are, amongst others, one of the leading contributing factors to mine accidents and fatalities. In addition, various accident causation models detail conditions as one of the contributors to accidents. For example, the accident causation theory/model originally developed by Heinrich (1959), the "Swiss Cheese Model" developed by James Reason (1970-1997) and the updated domino management model by Bird and Loftus (1974). The aim of this study is to assess the impact of safety leading indicators on workplace safety conditions at a selected underground mine and the influence of this on workplace safety outcomes. It intends to test the hypothesis that there is a relationship between safety leading indicators and workplace safety conditions, and also that there is a relationship between safety leading indicators and workplace safety outcomes.

Literature show that previous studies on the use of leading indicators to measure safety performance mostly focused on the international construction industry, and no literature could be sourced specifically for studies conducted in South Africa and/or the mining industry. For example, Pandit (2018), conducted a study on empirical evaluation of leading indicators in construction. In addition, Nadhim and others, 2018, Kevin (2010) and Akroush (2010) also conducted studies on leading indicators for safety in the construction sector all of which were in the international context. In addition, this research will also contribute to the growing body of knowledge on the use of leading indicators in occupational safety and health management from a South African mining context.

1.2.2 The research purpose (aim and objectives) statement

The purpose of this research is to interrogate the theory of occupational health and safety management to determine the impact of safety leading indicators on workplace safety conditions in the context of an underground mine, and also determine the influence of leading indicators on workplace safety outcomes. Firstly, we review literature to derive the conceptual framework for undertaking this study. Second, we collect data on workplace safety risk ratings (safety conditions) and lost day injuries (safety outcomes). Third, we conduct an employee survey to determine through employee response the level of safety leading indicators, and statistically model this against workplace safety risk ratings and safety outcomes. Lastly, based on the outcomes, we determine the impact of safety leading indicators on workplace safety conditions and the influence of this on workplace safety outcomes.

1.2.3 The research questions and the accompanying research hypotheses

Hypothesis 1:

Question: Is there a statistically significant relationship between safety leading indicators and workplace safety conditions?

Null hypothesis: There is no statistically significant relationship between safety leading indicators and workplace safety conditions

Research hypothesis: There is a statistically significant relationship between the safety leading indicators and workplace safety conditions

Hypothesis 2:

Question: Is there is a statistically significant relationship between safety leading indicators and workplace safety outcomes?

Null hypothesis: There is no statistically significant relationship between safety leading indicators and workplace safety outcomes

Research hypothesis: There is a statistically significant relationship between safety leading indicators and workplace safety outcomes

1.3 Delimitations and assumptions of the research study

- The research will focus on a selected large, underground platinum mine, therefore, the results cannot be used to generalise to other South African mines
- The study will focus at workplace level of the organisation
- The study will use a quantitative method of research
- The study will not assess the application of safety leading indicators but rather their impact on workplace safety conditions and safety outcomes

1.4 Significance of the research study

Even though there has been research in many countries on the use of leading indicators and their impact on various aspects of safety performance, these studies have been done predominantly in the construction industry (Pandit, 2018). There has also been minimal research on safety leading indicators in South Africa and specifically the South African mining industry. Some aspects that contribute to the significance of this study are as follows:

- It will help contribute to the body of knowledge on the implementation and influence of leading indicators (Sheehan, Donohue, Shea and others, 2016) particularly from a South African mining industry perspective
- This study will emphasize from an empirical point of view the important role of safety leading indicators in accidents and incidents prevention and their impact on safety conditions
- The study will help influence safety management measurements and practices to shift towards leading indicators, particularly in the mining sector
- Government agencies such as the Department of Minerals Resources and Energy (DMRE), might benefit from this study as they aim to help mines improve the level of safety performance
- South African mining industry, although showing significant safety improvements over time in terms of fatalities and injuries, still lags behind international benchmarks. This study will help contribute knowledge to

continuous safety improvement efforts on the prevention of accidents and incidents.

1.5 Preface to the research report

The purpose of this research report is to present the findings regarding the impact of safety leading indicators on workplace safety conditions and influence of this on safety outcomes at an underground mine.

To this end, the report has six chapters. Following this introductory chapter, Chapter 2 provides a literature review covering the problem, the past studies, the explanatory framework and the conceptual framework. In section 2.1 of this report details the symptoms, root-causes and consequences of unsafe working conditions at an underground mine as it relates to this study. Section 2.2 of this report details literature review undertaken on studies that have attempted similar study or research. The aim of this undertaking was to identify the knowledge gap. Section 2.3 details the attributes that are key to this research. This section relies on literature to provide the description of these attributes including their purpose, established facts, key issues and their measurements. Section 2.4 details framework for interpreting research findings. This framework is based on extensive literature review that looked at its development, usefulness, advantages, as well as its limitations and disadvantages.

Chapter 3 discusses the research strategy, design, procedures, reliability and validity measures as well as limitations. A quantitative research strategy was adopted for this research using cross-sectional research design to address the problem. The research is undertaken at a selected mine which consists of over 200 separate underground production working places. Surveys and reports are used as techniques for data collection. Ethical considerations and limitations about this research are also highlighted in this chapter.

Chapter 4 and Chapter 5 presents and discusses the findings, respectively, to interrogating our research questions while Chapter 6 summarises and concludes the research.

2 LITERATURE REVIEW

This chapter has three broad objectives; namely to understand the research problem, to identify the knowledge gap, and to develop a framework for interpreting the research findings. Specifically, in Section 2.1, we detail the research problem. In Section 2.2, we review literature on studies that have attempted a similar study or research. With information arising from Section 2.2, we identify and detail quantitative variables that are key to this research in Section 2.3 as well as a framework that we will use to interpret our research findings in Section 2.4.

2.1 Research problem analysis [Symptoms, root causes, and consequences of unsafe working conditions at an underground mine]

Introduction

Mining, particularly underground, is an inherently hazardous task. Accidents statistics show that fatalities and injuries continue to pose a challenge for the South African Mining Industry(DepartmentofMineralResourcesandEnergy, 2018). Occurrence of a mine accident can be a violation of South African laws, can cost the organisation a lot of money, and can result in a loss of productivity, time and reputational damage (van den Honert & Vlok, 2015).

The Mine Health and Safety Act (MHSA) of 1996 is the legislation that regulates mining in South Africa, and the Mine Health and Safety Inspectorate of the Department of Mineral Resources and Energy (DMRE) its mandated administrator. Section 54 of the MHSA give the DMRE inspector of mines discretionary powers to issue instructions to the mines if he/she has reason to believe that any occurrence, practice or condition at a mine endangers, or may endanger, the health and safety of any person at a mine (DepartmentofMineralResourcesandEnergy, 2018). Section 54 instructions may result in the stoppage of mining operations at the mine or part of a mine (Gloy, 2014).

Mines rely on health and safety indicators to predict the likelihood of an event, advance initiatives to control risks, and track progress (E. J. Haas et al., 2018). Haas and Yorio (2016:2) state that“ the purpose of leading indicators is to understand and manage organizational circumstances thought to precede undesired occupational health and safety outcomes” (E. Haas & Yorio, 2016).

Symptoms

Mines continue to report a high number of occupational injuries. The number of mine injuries reported in 2017 showed a slight improvement of 6% from 2846 in 2016 to 2664 in 2017 (DepartmentofMineralResourcesandEnergy, 2018). In addition, the number of injuries reported in the mining industry for 2019 was 2406 compared to 2447 in 2018 (DepartmentofMineralResourcesandEnergy, 2018). Although the number of fatalities has improved over time, 51 fatalities were reported in 2019 (MineralsCouncilSouthAfrica, 2019). In 2017, 88 fatalities were reported in the mining industry compared to 73 reported in 2016 (DepartmentofMineralResourcesandEnergy, 2018).

The mine inspectors of the DMRE issue section 54 stoppage notices to mines that report serious injuries or fatalities. In 2017, 99% of section 54 instructions issued to mines were for partial mine closure and 1% for total mine closure (DepartmentofMineralResourcesandEnergy, 2018). The impact of section 54 mine stoppages, partial or otherwise, is a direct loss of production days and the subsequent slow process to have these instructions uplifted or set aside further exacerbates this (ChamberofMinesofSouthAfrica, 2016). Impala Platinum, in 2016, lost 5000 ounces of output due to the implementation of section 54 mine stoppages (Ryan, 2017).

The loss of production days because of the implementation of section 54 mine stoppages results in huge revenue losses for the mining industry. In 2016, the mining industry lost R4.84 billion revenue due to the application of mine stoppages in terms of section 54 (Mckay, 2016). A mid-size South African gold mining company loses, on average, R15m/day in revenue when the mine is not operating due to a safety related stoppage (ChamberofMinesofSouthAfrica, 2016). In 2015, Impala platinum recorded 58 safety related stoppages in the six months leading to December, which cost the group R570 million in-lost revenue (Ryan, 2017).

Root causes

<u>Workplace risk scores (risk ratings) insufficiently quantified</u>

Quantified work place risk ratings or risk scores provide a measure of risk for the safety violations that present significant risk by creating unsafe conditions (Megan, Kecojevic, Grayson, & Nieto, 2010). Risk assessment methods are effective and useful when quantifying risk scores for safety violations and leading indicators (Megan et al., 2010).

Inadequate risk ratings quantification for safety violations, unsafe conditions and leading indicators non-compliance result in workplace risk being under-reported. Pre-established tables on likelihood and consequence are utilised to create a quantified risk value or score for each unwanted event in a workplace (Joy, 2004). This information is provided through safety inspection reports or leading indicator reports to inform management response on control measures to be implemented (E. Haas & Yorio, 2016). The analysis on safety leading indicators compliance level and on workplace risk scores is utilised to reduce the frequency of occurrence of violations that lead to the creation of unsafe conditions (Kevin, Laulund, Howell, & Lancos, 2010).

Lack of escalation protocol on leading indicators

Lack of escalation for the attention of management of workplaces shown by leading indicators not comply with safety control measures leads to inadequate and ineffective management response to unsafe workplaces and unsafe working conditions. Communication of leading indicators and safety inspection reports to management is important in order to facilitate strategic health and safety decisions, and the implementation of actions to respond to workplaces with high risk or low levels of compliance to leading indicators (E. Haas & Yorio, 2016). Efficient tools and data display formats that are direct and easy to read and comprehend are essential to communicate leading indicators and safety audit results and reports (Kevin et al., 2010).

Inadequate process for closing out actioned leading indicator reports

The measurement of leading indicators is a proactive measure of safety performance (Kevin et al., 2010). Megan, Kecojevic, Grayson, and others (2010), argued that the management of leading indicators require a systematic approach that seek to implement permanent solutions to problems in order to prevent a reoccurrence (Megan et al., 2010). This implies the implementation of measures to correct unsafe workplace conditions and leading indicator deviations (Megan et al., 2010). Critical success factor of using leading indicators to monitor safety performance is the execution of work to implement control measures that address leading indicator deviations (Nikulin & Nikulina, 2017).

Safety risk perception and lack of communication

Lack of communication with the crew on leading indicators combined with risk taking culture results in lack of compliance on safety control measure therefore increasing the

level of workplace risk. Gunningham and Sinclair (2016:14) found that "the most distinctive feature of mines with success in safety was their high level of communication". It is important that leading indicator outcomes are communicated directly to the people responsible for physically executing work (Nikulin & Nikulina, 2017). Better outcomes on leading indicators were achieved when tools and reporting were developed for ensuring participation from the workplace target audience (Kevin et al., 2010). Provision of proper occupational health and safety training and communication to employees to enables them to execute work on leading indicators must be developed to ensure their participation (Nikulin & Nikulina, 2017).

Inadequate workplace inspections

Inadequate number or quality of workplace inspections or audits affects the reporting on leading indicators. Workplace safety inspections and audits collect, categorize and report data on workplace safety violations or non-compliances, workplace conditions and also provide details of hazards in the workplace (Kevin et al., 2010). Effective monitoring and auditing measures the extent to which risk control measures are implemented and maintained, and should focus on priority controls (Joy, 2004). Inspections and audit reports must detail non-compliances and the required and/or implemented corrective measures to address them (Nikulin & Nikulina, 2017).

Consequences

High number of workplace injuries results in increased labour costs and skills shortages. One of the causes to severe workforce shortage is high levels of industrial injuries (Nikulin & Nikulina, 2017). While mines are idle due to the safety related mine stoppage, the cost of mine labour and other infrastructure including the costs of restarting of shafts one the stoppage is uplifted still have to be paid (Mckay, 2016).

Increased number of mine fatalities will tarnish the image of South African mining industry and result in loss of investments. Increased safety related stoppages is driving marginal mines to closure quicker because of loss of production days and consequently revenue (Mckay, 2016). Most mines arrive at breakeven only after at least twenty operating days in a month, and a loss of five production shifts due to safety related stoppages renders them economically unsustainable (Ryan, 2017). Safety related mine closures have similar, if not the same effect as strikes on losses suffered and investor sentiment (Gloy, 2014).

Reporting on leading indicators informs management response on the implementation of control measures to prevent occurrence of an unwanted event. Leading indicators help management to understand and respond to "workplace circumstances that precede undesired occupational health and safety outcomes" (Haas & Yorio, 2016:2). Incorrect reporting on leading indicators result in inadequate risk mitigation measures, including training and work procedures, therefore increasing workplace risk (Kevin et al., 2010).

Loss of revenue due to safety stoppages threatens viability of mines and results in job losses. Between 2012 and 2015 the mining industry lost R13.63 billion in revenue as a consequence of safety related mine closures (Mckay, 2016). Mine stoppages due to poor safety outcomes pose a significant risks for mines and has led to production and financial loses (Gloy, 2014).

2.2 Research knowledge gap analysis [Methods, data, findings, and conclusions of studies and evaluations of the use of safety leading indicators]

Introduction

This section interrogates literature to understand the knowledge gap between the research problem and what other researchers have already pursued on this research problem. In addition, this section also interrogates the research methods employed by various studies as well as their findings and conclusions. Establishing the gap between this research study and what has already been done helps to provide justification and reasons for undertaking this study. In order to help assess the knowledge gap, the literature reviewed focused on empirical studies only.

Previous research on the use of safety leading indicators

Liu, Huang, Wang, and others, (2015), conducted a study to examine whether the associations between safety climate, safety behaviour, and occupational injuries found in Western countries also exists in Chinese manufacturing enterprises. From 3375 front line workers sampled across 42 enterprises, the study found key empirical evidence of inter-correlations between workplace safety climate, behaviour and occupational injuries. In addition, the results of the study showed that occupational safety climate and behaviour in the workplace are related to the occurrence of occupational injury in Chinese manufacturing factories. The authors of this study further added that to decrease the number of occupational injuries in a workplace might require improving

workplace safety climate and employee safety behaviour (Liu, Huang, Wang and others, 2015).

Sheehan, Donohue, Shea and others (2016), conducted a study that examined the empirical association between leading and lagging indicators of occupational health and safety and the moderating effect of safety leadership between leading and lagging indicators. From a sample size of 3568 respondents, the results showed that higher levels of leading indicators are associated with fewer lagging indicators of unreported occupational health and safety incidents. In addition, the study showed that leading indicators are negatively related to near misses but not significantly related to reported occupational health and safety incidents. It is from these results that the authors suggest that the association between leading and lagging indicators of both unreported incidents and near misses will help support efforts by organizations towards a preventative approach of leading indicators rather than the traditional focus on lagging indicators.

Givehchi, Hemmativaghef, & Hoveidi, 2017, conducted a study to evaluate the association of leading indicators for health and safety, particularly safety inspections and non-compliances, with safety climate levels. From a sample size of 89 respondents, the results showed that the number of safety inspections and resultant non-compliances influence safety climate levels. The authors state that these finding imply that non-compliances detected during safety inspections can be used as an indicator of safety climate.

(Pandit, 2018) conducted a study to evaluate whether safety climate as a measure of leading indicators does influence hazard recognition performance and safety risk perception. Data collection for safety climate and hazard recognition respectively leveraged on survey instruments by making use of questionnaire, and observations that made use of pre-selected images for hazard recognition performance. The data used for collection for this study was from 287 construction workers spanning 57 construction projects. The results of this study showed that safety climate could positively influence both hazard recognition and safety risk perception. The implication of this is that organizations that are willing to invest efforts in creating a positive safety climate can benefit from improved hazard recognition and higher levels of perceived safety risk. In addition, the study showed that hazard recognition strongly correlates with safety risk

perception even when safety climate remains unchanged. This implies that employees with low risk perception are unlikely to recognize hazards and therefore risk perception can be used as a valid indicator for workplace risk. The study suggests that differences in safety climate in workplaces can partly explain variation in hazard recognition and safety risk perception. Finally, the study suggested modifications to a widely adopted workplace safety model to include hazard recognition and safety risk perception.

Nadhim, Hon, Xia, and others (2018), conducted a study to investigate the relationship between safety climate as a leading indicator and safety performance in retrofitting works. From a sample size of 310 employees spread across 41 retrofitting projects, results showed that safety climate positively affects safety performance. Safety compliance, occupational injuries and safety participation were used to measure safety performance. These results are consistent with another study conducted by Almost, VanDenKerkhof, Strahlendorf, and others (2018). These authors evaluated effectiveness of having implemented six pre-identified leading indicators, one of them being workplace safety climate, on improving selected health and safety indicators which included occupational injuries and safety compliance. From a sample of 180 healthcare workers across two hospitals, their study showed the positive influence of leading indicators on improving lagging indicators of workplace health and safety.

Although various studies have been conducted on the use of leading indicators as a proactive measure to monitor health and safety performance in various industries, there are some gaps in literature that require further exploration. These gaps in literature form the knowledge gap which partly guided this research. Although the mining industry in South Africa has adopted the use of safety leading indicators, however there are limited studies on their use and effectiveness including factors that influence their effectiveness within the South African mining context. International studies conducted on the use of safety leading indicators were mostly done in the construction sector and this limits the results to be generalized across other sectors. With the exception of India and Iran, most of the studies were conducted in the developed countries like Australia and the United States of America; in this case, the results might have limited applicability to South Africa as a developing nation. This research therefore aims to close these knowledge gaps.

There are methodologies and theoretical frameworks used in the international studies that will be adopted to guide to this research. For instance, (Pandit, 2018), provided the empirical evaluation of the use of safety leading indicators in the construction industry in India. To achieve this, he evaluated whether safety climate does influence hazard recognition performance and safety risk perception. In addition, Sheehan, Donohue, Shea, and others (2016), studied the association of leading and lagging indicators of occupational health and safety by pre-selecting leading indicators to be measured and focusing on occupational health and safety incidents for lagging indicators. A combination of these approaches will be looked at in relation to the South African mining context to better understand the effectiveness of the use of leading indicators and the factors influencing that influence their effectiveness.

The study conducted by (Pandit, 2018) applied some useful model and frameworks and these will be utilized for this research. These models and theoretical frameworks are as follow:

- **Conceptual Injury Prevention Model:** This theoretical model focuses on injury prevention process highlighting the working together of leading indicators, response to leading indicators including the element of behaviour and risk management in the prevention of injuries (Pandit, 2018). According to this model, proper hazard identification, evaluation of safety risk and the implementation of effective safety measures are fundamental in the prevention of injuries.
- **Organizational Performance Metric – Monash University (OPM-MU):** This framework is 8-items scale that and has been empirically validated as a measure of leading indicators (Sheehan, Donohue, Shea, and others, 2016). It was found that the OPM-MU framework incorporated 8-items of the 10-leading indicators construct, easy to administer and was generic enough to be applied across industries and at any level of the analysis i.e. employee or workplace level (Sheehan, Donohue, Shea, and others, 2016).

2.3 Quantitative variables key to the research

Introduction

With information derived from Section 2.2, this section identifies and details the quantitative variables that are key to this research. This section relies on literature to provide the description of these quantitative variables as well as information on their purpose, established facts, keys issues and debates. Most importantly, this section also includes their respective information and data sources in order to enable collection of this information towards fulfilling the objectives of this research.

Leading indicators

Leading indicators are related to events, conditions or measures that take place prior to an unwanted outcome such as an accident, and can be used to predict future occupational health and safety performance. Leading indicators do not rely on what has already occurred and as such can be used as an early warning of unwanted occupational health and safety events, conditions and occurrences, for example, accidents and near misses. Leading indicators precede undesirable events and their value lies in predicting the undesirable event which can be an accident, near miss or overall undesirable safety state (Guo, Yiu, and Asce, 2009). In addition, Hinze, Thurman and Wehle (2012) stated that the nature of leading indicators is not historical and this gives them the ability to be used to predict future safety performance.

Leading indicators allow organisations to watch the level of safety and safety activity and therefore proactively identify safety problems and implement remedial measures to prevent the occurrence of unwanted events. Guo, Yiu and Asce, (2009), state that leading indicators are used to monitor the overall safety activity in the system, highlight problems and push those with authority to develop and implement measures to remedy the problems. In addition, Sinelnikov, Inouye, & Kerper, (2015, 3) stated that "the purpose of leading indicators of occupational health and safety was to (1) anticipate, prevent, eliminate risks and loses (2) monitor and evaluate performance, (3) motivate safe behavior, commitment and continuous improvement". Leading indicators do not make use of individual safety measures but a set of pre-selected safety measures that are able to describe the effectiveness of the safety systems and processes (Hinze et al., 2013).

Several authors, for example Guo, Yiu and Asce (2009) have discussed measurements for leading indicators. Almost all of them agree that measurements of safety leading indicators vary and predominantly rely on the use of safety constructs. For example, Shea and others, (2015), and Sheehan and others, (2016) suggested that the

> "construct of leading indicators of OHS performance must cover 10 areas: OHS system (policies, procedures, practices); management commitment and leadership; OHS training, interventions, information, tools and resources; Workplace OHS inspections and audits; consultation and communication about OHS; prioritization of OHS; OHS empowerment and employee involvement in decision making; OHS accountability; positive feedback and recognition for OHS; and risk management".

Information collection on leading indicators measures can be both qualitative or quantitative (Hinze et al., 2013) and (Guo et al., 2009). After reviewing and validating several measures for leading indicators, (Shea et al., 2016) and (Sheehan et al., 2016) suggested an 8-item scale measure of organizational safety performance (OPM) developed by the institute for work and health in Canada, (IWH, 2011, 2013) to measure leading indicators. The OPM covers 80 percent of the 10 leading indicator constructs, and while easy to use it can be administered across industries and multiple levels in an organization (Shea et al., 2016) and it is shown in Appendix 1.1.

Safety conditions

Safety conditions represent the state of safety as informed by the presence of hazards in the work place. Reiman & Pietikainen, (2011, 3) argued that "safety conditions is the state of safety as determined by the presence or absence of physical and procedural barriers that reduce the workers exposure to hazards". Guo, Yiu and Asce, (2009) stated that safety conditions are dynamic and are subject to change over time as they are affected by positive safety practices and negative pressures, for example production pressures. In addition, the changing nature of safety conditions can alter the possibility of accidents (Reiman & Pietikainen, 2011).

Several authors have discussed measurements for safety conditions and Guo, Yiu and Asce (2009:6) suggested that "safety conditions are not directly measurable as a high level construct". Both Guo, Yiu and Asce (2009) and Reiman & Pietikainen, (2011) suggest that measurable medium level construct must be identified to measure and explain the existing state of safety conditions. Guo, Yiu and Asce (2009) presented a set

of constructs to describe and reflect safety conditions and these included, amongst others, physical hazard identification and management, worker safety motivation, supervisor safety leadership, worker safety perceptions.

Safety outcomes

Safety outcomes relate to unwanted occurrences such accidents or incidents and can be a result of multiple factors, and provide information of the areas of the safety system in which failure is occurring. Reiman & Pietikainen, (2011) stated that outcome indicators always follow something and are a result of different contextual and situational factors. Both Khan, Abunada, & John, (2010) and Reiman & Pietikainen, (2011) are of the view that safety outcomes signify the performance of the safety system. Similarly, Lingard, Wakefield, & Blismas, (2014) and Reiman & Pietikainen, (2011) stated that measurement of safety outcomes enables organisations to detect problems and provide information on the effectiveness and/or failure of safety barriers. Management can use safety outcomes to set goals for safety improvement (Reiman & Pietikainen, 2011) and also determine optimal deployment of resources to meet those safety goals based areas that report the highest accidents or incidents (Khan, Abunada and John, 2010).

Lingard, Wakefield, & Blismas, (2014:4) argue that "safety outcomes are not a direct measure of the level of safety in the organisation" because they capture the absence of safety rather than the presence thereof. In addition, Khan, Abunada and John, (2010) supported this view and stated that safety outcomes on their own do not provide a detailed picture of the state of occupational health and safety in the organisation. Other factors affecting the limitation of safety outcomes is their use related to reward systems, performance appraisals and bonus payments which encourages under-reporting (Lingard, Wakefield and Blismas, 2014). Reiman & Pietikainen, (2011) argue that the value of safety outcomes for organisations is in their detailed analysis which can provide meaningful information about their driving factors and contexts under which they occurred.

Lingard, Wakefield and Blismas, (2014) and Reiman & Pietikainen, (2011) argued that safety outcomes are essentially lagging indicators and as such it is easy to collect data and information on them because they measure outcomes of events or activities that have already materialised. Reiman & Pietikainen, (2011), Khan, Abunada and John, (2010) and Lingard, Wakefield and Blismas, (2014), all of them agree that measurement for safety outcomes include accidents, incidents, injuries to people or lost work days

such as accidents or fatal accident rates, near misses and number of safety events like loss of primary containment, amongst others.

2.4 Framework(s) for interpreting research findings [Established frameworks that interpret the accident causation factors]

Introduction

This section introduces interpretive theoretical framework which was developed and applied to explain causes of accidents in the industry in order to prevent or eliminate their occurrence. In addition, by relying on the perspectives of various proponents and critics of this theory over time, this section explains the development of this framework including its usefulness, advantages as well as its limitations and disadvantages.

Accident causation theory

Heinrich developed the accident causation theory (model) in 1959 (Hosseinian & Torghabeh, 2012) and (Abdelhamid & Everett, 2015). Heinrich sought to explain the occurrence of workplace injuries and the factors that influence this, including how they interact with one another. To achieve this, Heinrich established the Domino Theory (Model) of accident causation. He chose to name it as such in order to emphasize the serial nature of events prior to and after the occurrence of an accident, and the behaviour of factors involved, which he found to be similar to toppling dominos. This theory proposes that the occurrence of accidents is an outcome of five sequential factors or dominos that fall one after the other if the first factor or domino falls. The dominos in the theory represent Ancestry and Social environment, fault of person (carelessness), Unsafe Act and/or conditions (hazards), accidents and injury. The domino accident causation theory or model proposes that the inherited or acquired negative aspects of people will lead to unsafe acts and/or existence of unsafe conditions (physical or mechanical hazards), which in turn cause an accident that leads to an injury. According to this domino theory (model), accidents can be prevented if the sequence of falling dominos is disturbed. For example, elimination of unsafe condition or unsafe acts will stop the sequence to an accident therefore preventing an injury. Two principles capture the essence of Heinrich's accident causation theory (model): the fundamental

reason behind accidents is people, and management has the power, authority and responsibility to prevent accidents(Abdelhamid & Everett, 2015).

The domino theory of accident causation became the foundation for many other studies on accident causation models(Hosseinian & Torghabeh, 2012). The domino theory (model) received various updates over the years which emphasised that management is the fundamental cause of accidents and these revisions became known as management models or updated domino models. Management models hold that management is the primary cause of accidents and therefore attempt to identify failures in the management system.

Heinrich received criticism directed towards his accident causation model for oversimplifying human behaviour and control in his theory. Further criticism was for his narrow interpretation of accident causation factors

Weaver (1971) developed his accident causation theory on Heinrich's dominos theory (Idris, Rafe, Hisham and others, 2018). He however added and emphasized the role of management and management system. He explained the role of operational errors as the reasons for the persistence of unsafe acts. Weaver developed a set of questions aimed at identifying underlying causes of operational errors that caused an accident, and establish reasons for a worker conducting work under unsafe conditions if management has the requisite knowledge of safety including standards of work and safety rules. The answer to these questions provided clarity on underlying operational errors that contributed to an accident.

Petersen (1971) introduced a non-domino based accident causation model and his theory is premised on management systems (Idris, Rafe, Hisham and others, 2018). He contended that, contrary to Heinrich's accident causation theory (model), there is more than one factor that leads to the creation of unsafe acts and/or unsafe conditions that lead to the occurrence of an accident. He argued that an accident is caused by many factors, causes and sub-causes which combine together in random fashion to cause an accident. This is the reason he named his accident causation theory Multi-causation theory.

Petersen argued that his theory advocates for a wider interpretation of accident causation factors as opposed to the narrow interpretation of the Domino theory (model). He further suggests that these factors combine and interact in random fashion

rather than a linear sequence as suggested by the Domino theory (model). The factors identified by Petersen in his theory included training, workplace inspections, role clarity, pre-work planning, supervision and leadership, amongst others. Petersen stated that in order to achieve permanent improvement in accident prevention, root causes to accident must be identified and contended that that these relate to management systems such as policies, procedures, supervision and training, amongst others. In this regard, he viewed the Domino causation theory (model) as operating at the symptomatic level therefore unable to identify the root cause of accidents. He further contended that unsafe acts and/or unsafe conditions represent "proximate causes" and not the root causes to an accident.

Bird and Loftus 1974, also based their updated domino management model on Heinrich's domino theory and provided an updated version of the domino model to reflect the role of management systems (Hosseinian & Torghabeh, 2012) and (Idris, Rafe, Hisham and others, 2018). In their model, the dominos represent Lack of control/management (inadequate program, standards, compliance to standards), Basic causes/origins (personal factors and job factors), Immediate causes/symptoms (sub-standard acts/conditions), Incident (contact with energy and substance) and Loss (property, people, process). The basic causes are factors such as motivation to work safe or correction of hazards, all of which management has control over. This model emphasized that while all the dominos provided an opportunity to intervene prior to an incident, the first domino has the greatest potential to achieve this. In this manner of presenting the model, emphasis is made that management control is most significant factor in accident prevention.

James Reason (1970-1997) developed the "Swiss Cheese" accident causation model. It is a linear accident causation model that suggests that accidents are prevented by the introduction of various layered organizational defences that work to mitigate risks and hazards from become losses (Reason, 1997). The "Swiss Cheese" model groups organizational defences into two distinct two groups: Hard defences that include early warning systems, physical obstacles, and engineered safety solutions and protection of weak points with systems such as fuses. Soft defences that are people depended and include procedure; regulations of required performance, inspections, education and training, supervision and operators. The factors that line up in the "Swiss Chesse" model to cause and accident which the defences must work against are latent failures (management and supervisory), unsafe conditions and unsafe acts. The consequence of

failure of these defences is the realization of the hazard or threat that will result in a loss to people, assets or equipment. Reason further argued that there must be a state of equilibrium between the level of safety and protection in an organization and the risk associated with the work. This theory is widely accepted and used.

The Accident Root Cause Tracing Model (ARCTM) further progresses Heinrich causation theory and the subsequent accident causation models that supported and built on his work (Hosseinian & Torghabeh, 2012) and (Idris, Rafe, Hisham and others, 2018). This model was developed to provide an easy model for the identification of root causes of accident in the construction industry. The ARCTM proposes that one or more of the following factors cause accidents: failure to identify pre-existing unsafe conditions or the advancement thereof after an activity has started; reaction of worker to unsafe condition (performing a task under known unsafe conditions); unsafe act of worker by failing identify the environmental conditions associated with the task. This model suggest that unsafe conditions are a result of a number of factors which include management acts or omissions, worker or co-worker unsafe acts, and events not related to human act such as inherent unsafe conditions and natural occurrences. In addition, reaction of worker to unsafe conditions is depended the worker identifying the unsafe condition and his/her reaction thereto.

Proposed interpretive framework

In order to understand the impact of leading indicators on workplace safety conditions and the influence thereof on safety outcomes, it is proposed that the updated domino causation model by Bird and Loftus (1974) is best suited for this purpose. In this updated domino causation theory, the dominos are represented by Lack of control/management (inadequate programs, standards, compliance to standards); Basic causes/origins (personal factors and job factors); Immediate causes/symptoms (sub-standard acts/conditions); Incident (contact with energy and substance) and Loss (property, people, process) and shown in figure 1below. This theory further proposes that the occurrence of an incident is the outcome of five sequential factors or dominos that fall one after the other if the first factor or domino falls.

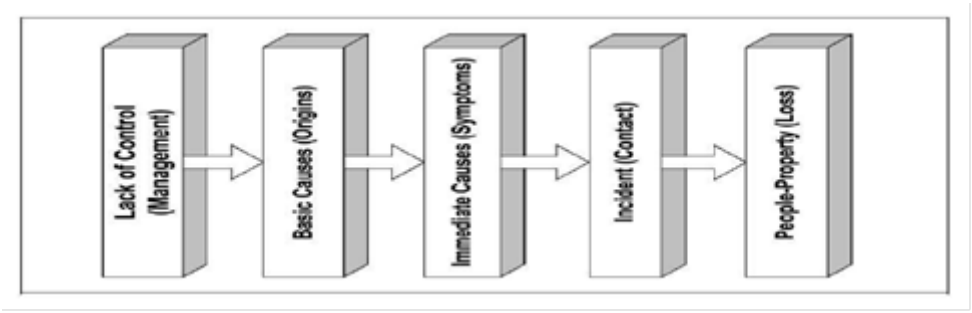


Figure 2.1: Updated domino accident causation model (Bird and Loftus, 1974) adopted from *Idris, Rafe, Hisham and others, (2018).*

This model has a well-established link with our variables in that leading indicators are represented by lack of control/management and basic causes and origins in the model. Immediate causes in the model directly links to the variable of safety conditions. Safety outcomes link directly to loss in the model, specifically as it relates to people.

The updated domino causation model will help to answer the questions of this research study because it demonstrates well-established links and linear interaction of the attributes of this research.

2.5 Summary and conclusion

2.5.1 Summary of literature reviewed

The literature review covered four areas and these were research problem analysis, research knowledge gap analysis, establishing variables applicable to the research and establishing theoretical framework for assessing the research results.

The problem analysis part of the literature review highlighted the symptoms of mines continuing to report high number of serious injuries. Although mine fatal accidents have reduced over time, mines still report a considerable number of fatal injuries annually. The root causes established with the literature review include insufficient quantification of workplace risk, lack of escalation on leading indicators non-compliances, inadequate process for monitoring close-out of hazards and leading indicator reports, inadequate workplace inspections as well as employee safety risk perceptions and lack of communication. The consequences of mine that continue to report serious accidents or fatal accident is loss of revenue and production due to safety related mine stoppages, increased operational cost and poor labour availability.

The research knowledge gap component interrogated literature to understand the knowledge gap between the research problem and what other researchers have already

pursued on this research problem. In addition, this section also interrogates the research methods employed by various studies as well as their findings and conclusions. Although various studies have been conducted on the use of leading indicators, these focused predominantly in the international construction industry. This gap in literature partly informed this research.

The variables key to this research are safety leading indicators, safety conditions and safety outcomes. The literature review interrogated these variables, their measurements, data sources and their limitations and advantages.

Lastly, the literature review interrogated various frameworks in order to establish a theoretical framework for interpreting research findings. The accident causation theory (model), introduced by Heinrich (1959) provided the basis upon which subsequent theories and frameworks were based. For this research, the updated accident causation model by Bird and Loftus (1974) is proposed to be the best suited for this research.

2.5.2 Proposed research strategy, design, procedure and methods arising from the literature reviewed

The proposed research method from for this study from the literature reviewed is quantitative strategy. All the empirical studies reviewed in this literature review followed this research strategy. We also propose a cross-sectional research design which will allow collection of data on more than one case at a point in time for at least two variables. The research procedure proposed for this study, specifically information collection is to employ structured observation schedules in the form of surveys/questionnaire which will be administered by pen and paper or online.

3 RESEARCH STRATEGY, DESIGN, PROCEDURE AND METHODS

In the prior sections, we have posed two questions that this research report intends to answer—that is, 'is there a statistically significant relationship between safety leading indicators and workplace safety conditions?', 'is there a statistically significant relationship between safety leading indicators and workplace safety outcomes?'. We have since reviewed literature and developed an interpretative as well as conceptual framework that will guide the choices of techniques we will use. This chapter identifies and describes the research approach and design, as well as the procedure and methods that we employ in this research to collect, process, and analyze empirical evidence. Broadly, it has three objectives; namely, to identify and describe the research strategy (Section 3.1), the research design (Section 3.2), as well as the procedure and methods (Section 3.3). The chapter also describes the reliability and validity measures (Section 3.4) that this research applies to make it credible as well as the technical and administrative limitations of the choices we make (Section 3.5).

3.1 Research strategy

Research strategy, broadly, means the overall direction or orientation of the research undertaking (Bryman, 2014). The choice of a research strategy is influenced by numerous factors, including but not limited to the research question and/or hypothesis and the theoretical framework (Marczyk, DeMatteo, & Festinger, 2005). There are three types of research strategies: qualitative, quantitative and mixed strategies (Bhattacherjee, 2012; Bryman, 2014).

A quantitative research strategy is utilised in this study. Quantitative research strategy focuses on numbers or quantification (Bryman, 2014), and measurement of quantity or amount rather than words (Bhattacherjee, 2012; Kothari, 2004). The collection and analysis of data in quantitative research strategy is in the form of numbers (Bryman, 2014) and makes use of statistical analysis to arrive at findings (Marczyk et al., 2005). Quantitative approach uses research data to establish relationship between variables (Kothari, 2004), and specifically to provide causal explanation between them (Bryman, 2014). Quantitative research strategy relies on deductive methods to explain the relationship between research and theory (Bryman, 2014). The epistemological orientation of quantitative research strategy is that of positivism or theory testing

(Bhattacherjee, 2012; Bryman, 2014) which places emphasis on the application of natural science models and methods (Kothari, 2004). Ontological orientation of quantitative research approach is objectivism (Bryman, 2014). Quantitative research is suitable for testing theories or hypothesis (Marczyk et al., 2005). The abovementioned characteristics of a quantitative research strategy (such as testing of theories and establishment of relationships between variables) will benefit my research study and hence my choice to employ the quantitative approach. In addition, this research strategy is effectively used in prior studies that have investigated similar phenomenon to my research, as outlined below.

Sheehan, Donohue, Shea and others, (2015), conducted research with the objective of providing empirical evidence of a link or association between leading and lagging safety indicators of occupational health and safety (OHS). The main rationale for selecting this approach was to establish causal relationship between variables and also the fact that all the variables being investigated could be measured quantitatively – Safety leading indicators (8-item questionnaire measured on a 5-point Linkert scale), lagging indicators (reported number of Occupational Health and Safety Incidents). The benefit using quantitative strategy for the chosen study was that they could perform Statistical Multi-level modelling to test their hypothesis. In a similar matter, this study seeks to establish the nature of relationships between quantifiable variables. It will therefore derive similar benefit as previous studies.

3.2 Research design

A research design details the structure or framework that is used for data collection and analysis (Bryman, 2014). The choice of a specific research design is dependent on the research question, hypothesis and the chosen variables (Marczyk et al., 2005). Research design enables the researcher to provide answers to the research question or hypothesis (Bryman, 2014). As a framework, research design helps generate the detail supporting the criteria against which the research is measured in terms of reliability, trustworthiness, validity, replication and authenticity (Bryman, 2014 and Kothari, 2004). Bryman (2012) identified five generic research designs: cross-sectional (survey), longitudinal design, case study, comparative design, and experimental design.

This study will utilise cross-sectional research design. Cross-sectional research necessitates the collection of data on at least one case (usually large number of cases) at a particular time (Bryman, 2014; Kothari, 2004). This design requires observations of

sample population or subjects of interest which is referred to as "cross-section" (Marczyk et al., 2005). Data collection in cross sectional research is applied to quantifiable data involving two or more variables to determine patterns of associations between them (Bryman, 2014). Kothari, (2004:p120) states that "survey-type studies is concerned with recording, analysing and interpreting conditions that either exist or existed, the researcher does not manipulate the variable or arrange for events to happen". This implies that cross-sectional design is concerned with observing variables that exist or have already occurred. This research aims to establish relationships between leading indicators as independent variables, and safety conditions and outcomes as dependent variables. The proposed study will involve collection of data from more than one case at a time, and as such, it is suitable to a cross-sectional research design.

Sinelnikov, Inouye and Kerper, (2015), undertook a study to investigate the use leading indicators to measure occupational health and safety performance. One of the main objectives of the study was to explore organisational practices pertaining tracking, analysing and applying information provided by leading indicators to improve OHS performance. This study employed the cross-sectional design. The main rationale for selecting this approach is that it enabled the understanding of the use leading indicators in OHS performance measurement across surveyed organizations, which required the collection of data from a larger number of cases at a time. Secondly, this study is concerned with observing variables that already exist without manipulation from the researcher. My research study requires the collection of data from a number of cases at a time; therefore, it will derive similar benefit by utilising the cross-sectional design.

3.3 Research procedure and methods

This section documents the actual procedure and the methods employed in this research to collect, collate, process, and analyze empirical evidence. In broadly terms, this section provides details on the data and information collection instruments (Section 3.3.1), the target population and sampling of respondents (Section 3.3.2), the ethical considerations during the research process (Section 3.3.3), data and information collection process and storage (Section 3.3.4), data and information processing and analysis (Section 3.3.5) as well as the background description of the respondents who provided empirical evidence for this research study (Section 3.3.6).

3.3.1 Research data and information collection instrument(s)

Research data collection instruments are devices or tools used to collect data for analysis (Kothari, 2004). The choice of data collection instrument is influenced by the type of data to be collected – quantitative data or qualitative data (Kothari, 2004). Interviews and observations are two types of data collection instruments used in qualitative research (Bryman, 2014; Kothari, 2004). For quantitative research, observations, interviews and self-completion questionnaires are the three main categories of data collection instruments applicable (Bryman, 2014; Kothari, 2004). Content analysis and secondary data analysis are also mentioned by Bryman, (2014) as other instruments applicable to quantitative data collection.

Leading indicators measurement

For the purposes of data collection concerning leading indicators (independent variable), this study made use of a self-completion questionnaire. The use of questionnaires for data collection is effective for big enquiries or surveys involving asking many respondents the same questions (Bryman, 2014; Kothari, 2004). Kothari (2004:96), states that "survey refers to the method of collecting information concerning the phenomenon under study from all or selected respondents of the concerned universe" The questionnaire is made up of a number of questions that are printed or typed on a document or form (Kothari, 2004). Self-completion questionnaires require respondents to answer questions without assistance from the interviewer (Bryman, 2014), and respondents must read and understand the questionnaire and record their own answers (Kothari, 2004). Self-completion questionnaires can be administered in several ways including email, internet, groups and via post mail (Bryman, 2014; Kothari, 2004; Marczyk et al., 2005). The key advantages of using self-administered questionnaires are that it is free from the bias of the interviewer, cheaper and quicker to administer, applicable to large samples and affords respondents adequate time think through their answers (Bryman, 2014; Kothari, 2004).

Research data collection instrument structure

The general form of research data collection instruments can be structured or unstructured (Kothari, 2004). Structured instruments are definite, concrete with pre-determined questions (Kothari, 2004) that evaluate specific concepts and topics that are key to the study, and are generally applicable in quantitative research (Bryman, 2014). In

structured instruments, questions are presented in exactly the same wording and order to all respondents (Kothari, 2004). Qualitative is normally less structured (Bryman, 2014; Kothari, 2004) and the question formulation is largely left to the interviewer who must also record the replies in the respondent's own words to the extent possible (Kothari, 2004). Bryman, (2014), identified three structures of data collection instruments – unstructured, semi-structured, and fully structured.

This study made use of a fully structured data collection instrument, which is also referred to as 'structured interviews' or 'structured questionnaire' by authors in the reviewed textbooks (Bryman, 2014; Kothari, 2004; Marczyk et al., 2005). A structured interview is normally conducted in a survey format and all respondents are asked exactly the same questions in the same order (Bryman, 2014; Kothari, 2004). In addition, all questions are pre-determined and put to the respondents in exactly the same order (Kothari, 2004). A fully structured questionnaire allows for rapid coding and processing of data (Bryman, 2014). This study derived benefit from the above-mentioned characteristics and advantages by applying a fully structured-self completion questionnaire.

In a prior study, Sheehan, Donohue, Shea and others, (2015), made use of the Organisational Performance Metric (OPM-MU) to measure leading indicators in their study. The OPM-MU was developed as a specific a measure for leading indicators, and can be self-completed. The aim of their study was to provide empirical evidence of a link or association between leading and lagging safety indicators of occupational health and safety (OHS). This allowed the study to collect standardized quantitative data from a large number of respondents spread across a number of organisations. In addition, this technique allowed faster or speedy collection of data at low costs. My study will also derive similar benefit from a fully structured self-completion questionnaire.

Source of questions

This research study made use of the already-existing Organisational Performance Metric – Monash University (OPM-MU) instrument or questionnaire to collect research data related to leading indicators. The administration of the questionnaire was through survey in order to obtain responses from a number of respondents. The OPM-MU was developed by Monash University to measure leading indicators and is based on an eight-item scale that has been reported to be a reliable and valid measure of leading indicators for occupational health and safety, and has been validated in the study by Shea et al.,

(2016). The OPM-MU instrument makes use of a five-point Linkert scale therefore making quantification of information possible for the purposes of this study. Appendix 1 shows the OMP-MU instrument.

Safety conditions and safety outcomes measurements

For safety conditions and Safety outcomes (dependent variables), this study utilized secondary data sourced from occupational health and safety reports at the selected mine. In this study, safety risk scores (workplace risk ratings) and occupational injuries (lost day injuries) respectively measure safety conditions and safety outcomes at workplace level.

Similarly, in their study, Sheehan, Donohue, Shea and others, (2015) also made use of secondary data sourced from occupational health and safety incidents reports for the surveyed organisations to measure lagging indicators, specifically safety incidents. This study adopted this approach similar to Sheehan, Donohue, Shea and others, (2015) on the measurements of safety conditions and safety outcomes.

3.3.2 Research target population and selection of respondents

Research target population

A target population is the total group of individuals or items from which a sample is drawn (Kothari, 2004). According to Bryman, (2014:48), "a target population is a universe of units, people, cities, nations, firms etc., from which a sample is to be drawn". Considerations of time and money in field studies invariably requires a selection of respondents or a sample population (Kothari, 2004), that is aligned to and based on the focus of the research (Bryman, 2014).

The target population for my study consists of adults who are over 18 years old, that work specifically underground at the selected mine and are part of a production crew that has a designated workplace. This research specifically aims at this target population because of its interaction with and exposure to the variables of this research study at a workplace level. The link of the target population to a crew and workplace enabled data collation and subsequent analysis for this study.

In a prior study, Sheehan, Donohue, Shea and others, (2015) effectively utilized a target population similar to my study. Their target population consisted of employees at

multiple sites across six different industries who were part of sixty-six participating crews. Each participating crew had its own designated workplace and individuals within a crew participated in the study. The authors state that employees sample was suitable for their research given their levels of interaction and exposure to the variables of the study. In addition, the data collected from these employees nested within workplaces and therefore necessitating multi-level or hierarchical modelling. My research also derives the benefit of mine employees' enhanced understanding due to exposure and interaction with the selected variables.

Sampling or selecting respondents from the target population

According to Bryman, (2014), a sample is the segment or subset of the population selected for investigation. Sampling means the process of selecting the group from which research data will be collected(Bryman, 2014; Mitchell & Jolley, 2010). The factors that influence the choice of sampling technique to select participants or sample design are representation and the selection technique (Kothari, 2004). Two basic types of sampling techniques are probability sampling which is based on the random selection concept and non-probability sampling which is non-random sampling (Kothari, 2004; Mitchell & Jolley, 2010).

This study made use of non-probability sampling technique. The non-probability sampling technique is not concerned about the probability of each item in the population being included in the sample (Kothari, 2004) and some items have a higher chance of being chosen than others (Bryman, 2014). In this technique, the selection of items for the sample are chosen deliberately by the researcher (Kothari, 2004), who takes into account the required characteristics of the population in order to meet the aim of the research (Mitchell & Jolley, 2010). This means that items are actively chosen or excluded based on their appropriateness for the study as determined by the researcher (Kothari, 2004). Although non-probability sampling is less accurate in terms of representative sample, it is an acceptable alternative to the more time consuming, costly and sometimes impractical and impossible probability sampling technique (Kothari, 2004; Mitchell & Jolley, 2010). Quantitative research makes use of three types of non-probability sampling techniques – convenience sampling (also referred to as accidental, purposive, and nonprobability sampling); quota sampling; and snowball sampling (Bryman, 2014; Kothari, 2004; Mitchell & Jolley, 2010). My research study will utilize the convenience non-probability technique.

The convenience sampling technique targets people that are easy to survey who meet the particular criteria (Mitchell & Jolley, 2010). In this technique, the researcher selects anyone who meets the criteria (Kothari, 2004) and hence it is the fastest type of sampling comparatively (Mitchell & Jolley, 2010). In this study, the researcher had convenient access to employee population at the selected mine, hence the reason for selecting convenience sampling.

Prior studies investigating the phenomenon similar to this study made use of non-probability sampling techniques. For instance, Pandit, (2018), conducted a study to empirically evaluate the impact of leading indicators in construction. One of the key objectives of his study was to explore the effect of safety climate on the leading indicators of safety performance – namely hazard recognition and safety risk perception levels. Non-probability sampling, specifically convenience sampling was used in this study. Construction employees across 57 construction projects, structured into their work crews, participated in the study. In total 287 employees' participated making up 57 crews performing varying tasks. The convenience sample technique allowed the study to gather data from a large sample size in a simple, fast and cost effective manner. My research study derived similar benefit in utilizing the non-probability sampling technique.

Sample size

Sample size refer to the number of respondents or individuals in the sample (Bryman, 2014). A more representative sample is important in quantitative research and is likely to be achieved through bigger samples (Kothari, 2004). However, factors that must be considered when determining sample size are time, costs and the need to accuracy (Bryman, 2014).

For this proposed study, data is collected from a sample of 171 respondents at the selected mine. All the respondents work underground and are spread across twenty-four production crews and linked to a designated workplace. Table 3.1 below gives a breakdown of the respondents by function within their respective crew:

Table: 3.1 Breakdown of respondents by function

Function of research respondents		Frequency	Percent
1	Supervisor	29	17.0
2	Team leader	32	18.7
3	Safety representative	36	21.1
4	Operator	45	26.3
5	Crew member	29	17.0
Total		171	100

Source: SPSS 27 (IBM, 2021)

3.3.3 Ethical considerations when collecting research data

Data collection and analysis in research require participation of people and must be done in an ethical manner (Mitchell & Jolley, 2010). Individuals who participate in research studies must be protected (Marczyk et al., 2005). Bryman (2014), states that ethical principles in business research fall into four main categories: whether there is harm to people participating in the research, granting of informed consent, whether invasion of privacy of participants and that there is no deception of participants.

My interest in this research is purely of academic nature. Therefore, there are no sponsors for this study and I do not stand to gain commercially from this research. The researcher addressed the ethical issues detailed by Bryman (2014) above in the manner described below:

Deception

- Deception refers to issues around self-declaration. It includes situations when the researcher does not fully disclose their work or what it entails, often with the result that limits the participants' understanding of what the study is about and deceiving them to responding naturally to the study (Bryman, 2014).
- Disclosure – in order to counter deception, respondents were provided with information about the researcher, the study including its aims prior to the start of the survey (as per the consent form on the questionnaire – refer to

Appendix). The explanation of the purpose of the research given to respondents and all the information that affect their participation disclosed to them.

Harm

- The researcher has the responsibility to minimise harm and risk to participants (Marczyk et al., 2005). Harm can refer to physical harm; developmental harm; and loss of self-esteem (Bryman, 2014) and in other instances can include legal and economic harm (Marczyk et al., 2005).

- Ethical committee clearance – the Wits Business School Ethics Committee performs the gate keeping role of reviewing research proposals and including data collection instrument in order ensure that the proposed study conforms to ethical requirements and that no harm will befall participants. The researcher receiver ethical clearance for this research from ethics committee of the school.

Informed consent

- The participant has the right to agree or refuse to participate in a research study (Bryman, 2014). According to the Nuremberg Code, the voluntary consent of the human subject in research is absolutely essential (Marczyk et al., 2005). In this regard, the researcher has the responsibility to honestly disclose all the information that that affect the respondents' decision to participate or not (Marczyk et al., 2005; Mitchell & Jolley, 2010).

- Voluntary participation – the researcher provided all the information that affects respondents' participation in the study, including that participation is voluntary, in line with mitigation of deception above.

Privacy

- Anonymity and confidentiality – respondents were not required provide personal information (ID numbers or employee numbers) for demographical information in this study. However, anonymity and confidentiality was ensured in this study (as per the consent form on the questionnaire – refer to Appendix1).

- Data protection – hard copies of responses are be locked away in a lockable filing cabinet. Scanned copies are stored in a password-protected computer.

3.3.4 Research data and information collection process

Data collection in research is the process of gathering data from the sample on variables or attributes of interest (Bryman, 2014). Kothari, (2004), identified two types of data – primary and secondary, and further stated that the type selected is depended on the research problem and research design. According to Bryman, (2014), primary data modes consist of participant observation or ethnography, interviews (face-to-face, telephone, or internet), and focus group discussions; and secondary data mode consists of documents.

This study made use of self-completion questionnaire distributed during safety meetings to collect data. Respondents completed this survey using paper and pencil during workplace safety meetings. Workplace safety meetings take place underground at designated meeting areas for underground crews, prior to start of shift. This mode of data collection proved effective for the target population due to their nature of work, varying levels of computer literacy and lack of access to computers at work.

In an earlier study, Sheehan, Donohue, Shea and others, (2015), conducted research with the objective of providing empirical evidence of a link or association between leading and lagging safety indicators of occupational health and safety (OHS). Their distribution of the survey was workplace dependent and included both paper and pencil and online. The self-administered questionnaire to be completed by paper and pencil was distributed at staff meetings and via internal mail. While time was spent on data collation and processing, this approach was convenient and suitable for certain workplaces and allowed them to easily reach the required number of respondents.

3.3.5 Research data and information processing and analysis

Research data and information processing

Generally, research data processing is the capturing and manipulation of data items to produce meaningful information (Kothari, 2004), and for quantitative research it involves preparation of variables for quantification (Bryman, 2014). For quantitative research, data processing technically implies three steps - coding, entering onto computer and data cleaning as described below:

Data coding

Coding involves expressing answers in numerals or other symbols such that responses can be arranged into a limited number of categories (Kothari, 2004). Coding transforms data into meaningful numerical format (TerreBlanche, Durrheim, & Painter, 2006). Coding data means interpreting and re-presenting data such that it is not presented in its original form (Bryman, 2014).

For this study, data coding required manually capturing and coding responses from the pen and paper questionnaire. Responses captured in line with the 5-point Linkert scale.

Data entry

Data entry onto computer means an act of capturing data recorded on a questionnaire into the computer software format that can be used for statistical analysis (TerreBlanche et al., 2006).

In order to create a database, manual data entries done manually form the paper and pencil questionnaires.

Data cleaning

Data cleaning is the act of detecting and correcting inaccurate or corrupt data and errors from the database or dataset (TerreBlanche et al., 2006). Example of corrupt/inaccurate data includes incorrectly captured data, irrelevant part and incomplete part of data.

TerreBlanche et al., (2006), recommends random selection of 10%-15% dataset to check errors. Frequency tables for all the captured answers completed on SPSS.

Research data and information analysis

Research data analysis involves the use of analytical tools and logical reasoning to interpret data in order to determine trends, patterns or relationships (TerreBlanche et al., 2006). Data analysis is the most crucial part of research (Kothari, 2004). Bhattacherjee, (2012), identifies two ways in which numeric data can be analyzed quantitatively by means of statistical tools – descriptive analysis (statistically describing, aggregating, and presenting the constructs of interests or associations between them) and inferential analysis (refers to statistical testing of hypothesis, known as theory testing). Univariate analysis (analysis of a single variable) is statistical technique used in descriptive analysis and included frequency distribution, central tendency and dispersion (Bhattacherjee, 2012; TerreBlanche et al., 2006). Statistical techniques used in inferential

analysis for bivariate and multivariate scenarios include linear regression, cluster analysis, ANOVA (T-test), multivariate regression, factor analysis, path analysis, time series analysis and others (Bhattacherjee, 2012; TerreBlanche et al., 2006)

This study made use of inferential analysis, specifically multivariate linear regression and ANOVA. Multivariate regression analysis involves multiple outcome variables modeled as being predicted by the same set of predictor variables. This statistical technique is suitable for my study as it seeks to establish the impact of safety leading indicators (independent variable) on safety conditions and safety outcomes (the two dependent variables).

In a prior study that investigated a phenomenon similar to my research, Pandit, (2018), effectively used multivariate regression to establish associations between one predictor variable and two outcome variables. The objective of the study was to investigate the effect of leading indicators of safety climate on hazard recognition performance and safety risk perception levels. In their statistical analysis, leading indicator of safety climate was predictor variable, while both hazard recognition and safety risk perception levels were outcome variables. The benefit derived by this study from utilizing the multivariate regression analysis was to establish and describe associations between variables. This study derived the same benefit by employing this statistical technique.

3.3.6 Description of the research respondents

Respondents for the purpose of this study are 18 years and over, employed underground at the selected mine and allocated to a production crew and workplace.

3.4 Research strengthens—reliability and validity measures applied

The quality of research is determined by the measures of reliability and validity (Bryman, 2014). Reliability relates to the degree of consistency or dependability (Bhattacherjee, 2012), and the extent to which findings are repeatable (Bryman, 2014). Validity is concerned with the accuracy of the research study (Bryman, 2014), and the extent to which a measure truly represents the construct of interest it is supposed measure (Bhattacherjee, 2012) .

In this study, the predictor variable – measurement for leading indicators utilizes the already existing OPM-MU data collection tool as detailed earlier in this report. The reliability and validity of this tool is well established as it is successfully applied in prior

research studies. This study rely on secondary data from occupational health and safety reports of the selected mine for safety conditions and safety outcomes (outcome variables). Therefore, outcome variables do not require establishment of reliability and validity measures.

Reliability

Reliability assesses the ability of a measurement to produce consistent results in which values are equal all the time (Mahajan, 2017). Bhattacherjee, (2012), mentioned that measurement instruments must be tested for reliability using one of the four methods he identified – inter-observer reliability, test-retest reliability, split-half reliability and internal consistency reliability. The reliability of the proposed OMP-MU scale for our predictor variable has been well-established. This measurement has been validated in a study conducted by Shea et al., (2016) in which its Cronbach's alpha coefficient was 0.88 meaning that the OMP-MU has excellent reliability . This tool was also reliably used in other subsequent studies, for instance in a study by Sheehan et al., (2016) in which the Cronbach Alpha coefficient was also high at 0.89 with a different data set.

Validity

Validity relates to the research instrument and its ability to measure that which it is designed to measure (Bhattacherjee, 2012). There are four main types of validating quantitative research— measurement validity, internal validity, external validity, and ecological validity (Bhattacherjee, 2012; Bryman, 2014).

Measurement validity

Measurement validity (also called content validity) refers to an extent that an indicator and its theoretical or conceptual construct fit together. Bhattacherjee, (2012:59) mentioned that "content validity is an assessment of how well a set of scale items matches with relevant content domain of the construct that it is trying to measure".

In the validation study by Shea et al., (2016), OPM-MU revealed good results of measurement validity when tested for leading indicators for both construct and indicator validity at employee and workplace level.

Internal validity

In quantitative research, internal validity is concerned with findings that involve causal relationship between variables (Bryman, 2014). Bhattacherjee, (2012:36) states that "internal validity examines whether the observed change in a dependent variable is indeed caused by a corresponding change in hypothesized independent variable, and not by variables extraneous to the research" As per prior study by Pandit, (2018), my study will utilise a survey. Given this method, the researcher cannot control the independent variable (unlike in experimental design) and therefore, causality between variables cannot be established but only inferred. As such, one of the limitations of this this study is being unable to achieve internal validity.

External validity

External validity determines whether the findings of the research study can be generalized beyond the particular research context (Bryman, 2014), or to a broader context, from sample to population or other groups of people (Bhattacherjee, 2012). Cross-sectional convenience sampling is utilized in this study and all the respondents are employees at the selected mine. Given this scenario, external validity is reasonable for population validity (from sample to population), as mentioned in Bhattacherjee, (2012) for this specific research design and in a similar research by Nadhim et al., (2018).

Ecological validity

Ecological validity establishes whether research findings can be appropriately generalized to other people, contexts, organizations or time (Bhattacherjee, 2012). Example of this is whether social scientific results can be applied to natural, daily social settings of people (Bryman, 2014). This study will add to the growing body of knowledge on the use of safety leading indicators to improve workplace safety. In addition to this, as per the study by Sheehan et al., (2016), this study will further provide relevant insights to Occupational Health and Safety practitioners and other professionals in the mining industry.

3.5 Research weaknesses—technical and administrative limitations

Technical limitations

- Research design and data collection instrument – the proposed study is utilising a survey to collect data and the researcher cannot control the independent variable (cause). This technicality has a bearing on the internal validity of the study and therefore requires exercise of caution when interpreting the results of the study.

- Sample and sampling constraints – this study employed non-probability sampling techniques (convenience sampling), and mainly surveyed employees of the selected mine. Therefore, the limitation to generalize results of this study to other contexts, people or organizations.

- Respondent error – the use of self-completed questionnaire in this study increases the likelihood for respondents to misunderstand questions, and there was no opportunity to receive clarification from the interviewer.

- With the utilisation secondary data for outcome variables, the researcher cannot control other extraneous variables than can affect these variables.

4 PRESENTATION OF RESEARCH RESULTS

The objective of this study is to determine the impact of leading indicators of safety on workplace safety conditions and safety outcomes. This chapter is set out to present and discuss findings to the two research questions as well as their accompanying hypothesis. Section 4.1 presents descriptive statistics. Section 4.2 presents and discusses findings to the first research questions – is there a relationship between safety leading indicators and workplace safety conditions? This discussion is accompanied by its hypothesis; there is a relationship between safety leading indicators and workplace safety conditions. Section 4.3 seeks to present and discuss findings to the second research question – is there a relationship between safety leading indicators and workplace safety outcomes? In addition, this section discussed the hypothesis that states that there is a negative relationship between safety leading indicators and workplace safety outcomes.

4.1 Descriptive statistics

Descriptive statistics were carried out on safety leading indicators data collected by utilizing an eight-item questionnaire measured on a 5-point Linkert type scale that provided respondents with the following response choices; 1 (Strongly disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), 5 (Strongly Agree).

Table 4.1below shows the means and standard deviations of the responses from each respondent.

Table 4.1 Mean and standard deviations of the responses on Safety Leading Indicators

	Variable	Mean	Standard Deviation
1	Formal Occupational Health and Safety (OHS) audits at regular intervals are a normal part of our work.	3.94	0.449
2	Everyone at this workplace values ongoing OHS improvement in this workplace.	4.15	0.460
3	This workplace considers health and safety at least as important as production and quality in the way work is done.	4.09	0.587

4	Workers and supervisors have the information they need to work safely.	3.90	0.962
5	Employees are always involved in decisions involving their safety.	4.04	0.903
6	Those in charge of OHS have the authority to make changes they have identified as necessary.	3.98	0.976
7	Those who act safely receive positive recognition.	4.19	0.920
8	Everyone has the resources and/or equipment they need to complete their work safely.	4.18	0.990

Source: SPSS 27 (IBM, 2021)

As shown in Table 4.1, the means of the variables range from 3.90 to 4.19 which shows that the respondents mostly agreed to the questions asked suggesting a relatively high level of compliance to leading indicators among the participating crews and workplaces. The standard deviations are all below 1 which shows that most of the respondents may be close to the mean.

To better understand the variable leading indicators of workplace safety, the sub-variables in Table 4.1 were grouped using SPSS mean function to generate the group variable of leading indicators of workplace safety. Table 4.2 below shows the group variable of safety leading indicators.

Table 4.2: Group variable – workplace safety leading indicators

Group Variable	Minimum	Maximum	Mean	Standard Deviation
Leading indicators of workplace safety	1.88	5.00	4.06	0.582

Source: SPSS 27 (IBM, 2021)

As shown on Table 4.2, the mean of the group variable of leading indicators of workplace safety is 4.06, and this shows that research respondents' answers mostly agreed in terms of the Linkert scale used. The standard deviation in table 4.2 is below 1 which shows that most of the respondents answers may be close to the mean.

Figure 4.1 below shows the distribution of the group variable of workplace safety leading indicator based on the responses to questions based on the 5-point Linkert-type scale. The mean scores of the respondents are mostly at the scale 4 with the graph skewed to the right. The scale mean stands at M=4.06 with SD=0.582. This shows that most respondents agree with the questions put to them on leading indicators.

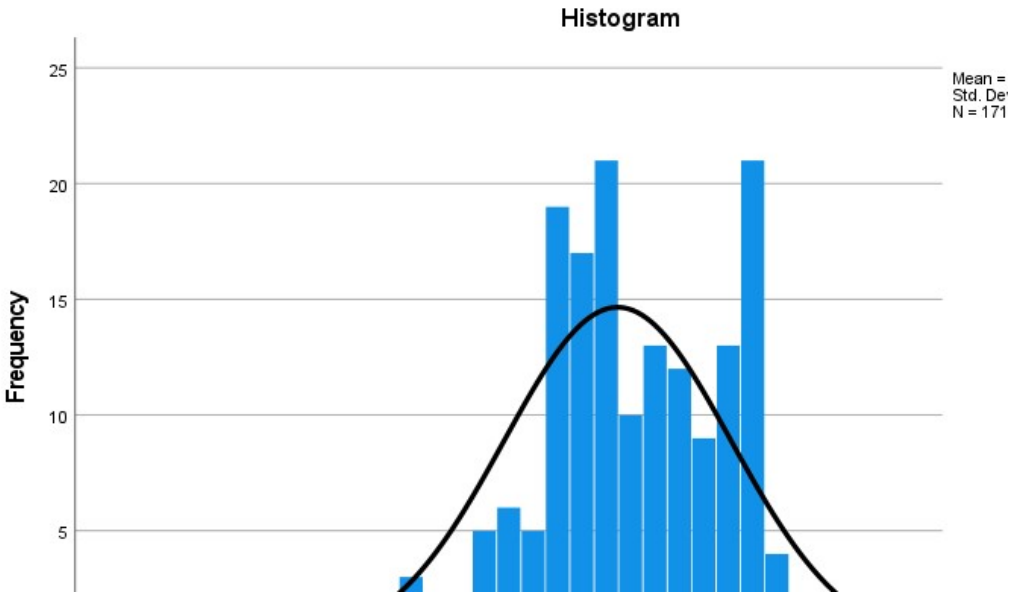


Figure 4.1: Group variable – workplace safety leading indicators

4.2 Relationship between safety leading indicators and workplace safety conditions at a selected mine

The relationship between the group variable of safety leading indicators and workplace safety conditions as represented by risk ratings of workplace conditions was determined using the following linear regression model:

$Y = B_0 + B_1X_1 + e$ (1)

Where:

Y = Risk ratings of workplace conditions

X_1 = Group variable of leading indicators of workplace safety

B_0 = Constant

B_1 = Correlation coefficient, and

e = Error term

Table 4.3: Model Summary 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.013	0.000	-0.006	7.625

Source: SPSS 27 (IBM, 2021)

According to the model summary 1 in Table 4.3 above, there is a positive relationship (R= 0.013) between safety leading indicators (independent variable) and the risk rating of workplace conditions (dependent variable), although indicated as weak by the low R-value. The value of R Square 0.000 indicates that 0% of risk ratings of workplace conditions could be explained by the group variable of leading indicators of workplace safety.

Table 4.4: Analysis of variance (ANOVA)

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.787	1	1.787	0.031	0.861
Residual	9826.892	169	58.147		
Total	9828.678	170			

Source: SPSS 27 (IBM, 2021)

Table 4.4 above shows the analysis of variance (ANOVA) output. According to the ANOVA output, the group variable of safety leading indicators on risk ratings of workplace conditions is not statistically significant as indicated by the high p-value (0.861), that is, greater than 0.05 and low F-value (0.031).

Table 4.5: Coefficients

	Unstandardised Coefficients		Unstandardised Coefficients		
	B	Std. Error	Beta	t	Sig.
Constant	84.764	4.121		20.571	0.000
Group variable of leading indicators of workplace safety	0.176	1.005	0.013	0.175	0.861

Source: SPSS 27 (IBM, 2021)

The coefficients in the above table can be used to re-state the regression Model 1 stated earlier in section 4.4.2 as follows:

$Y = 84.764 + 0.176X_1$

According to this re-stated regression equation above, when the group variable of leading indicators of workplace safety is kept at zero level, the percentage of risk ratings (workplace safety conditions) will be equal to the constant or intercept 84.764. In addition, the findings also reveal that a unit increase in the group variable of leading indicators of workplace safety will results in a 17.6 increase in the percentage of risk ratings of workplace safety conditions. At 5% level of significance, the group variable of leading indicators of workplace safety had a 0.861 level of significance. Therefore, the null hypothesis that there is no statistically significant relationship between safety leading indicators and workplace safety conditions is accepted.

4.3 Relationship between safety leading indicators and workplace safety outcomes at a selected mine

The relationship between the group variable of safety leading indicators and workplace safety outcomes as represented by lost day injuries was determined using the following linear regression model:

$$Y = B_0 + B_1X_1 + e \qquad (2)$$

Where:

Y = Lost day injuries

X_1 = Group variable of leading indicators of workplace safety

B_0 = Constant

B_1 = Correlation coefficient, and

e = Error term

Table 4.6: Model Summary 2

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.222	0.049	0.043	0.835

Source: SPSS 27 (IBM, 2021)

As shown in the model summary in Table 4.6 above, there is a relationship (R= 0.222) between the safety leading indicators (independent variable) and the number of lost day injuries (dependent variable), although weak as indicated by the value of R. The value of R Square 0.049 indicates that only 4.9% of lost day injuries could be explained by the group variable of leading indicators of workplace safety – the independent variable of the regression model.

Table 4.7: Analysis of variance (ANOVA) 2

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.074	1	6.074	8.721	0.004
Residual	117.715	169	0.697		
Total	123.789	170			

Source: SPSS 27 (IBM, 2021)

Table 4.7 above shows the analysis of variance (ANOVA) output. According to the ANOVA output, the group variable of leading indicators of workplace safety on lost day injuries is statistically significant as indicated by the low p-value (0.004), that is, less than 0.05 and high F-value (8.721), and this shows that the overall model is statistically significant.

Table 4.8: Coefficients 2

	Unstandardised Coefficients		Unstandardised Coefficients		
	B	Std. Error	Beta	t	Sig.
Constant	-0.617	0.451		-1.367	0.173
Group variable of leading indicators of workplace safety	0.325	0.110	0.222	2.953	0.004

Source: SPSS 27 (IBM, 2021)

The coefficients in above table can be used to re-write the regression Model 2 stated earlier as follows:

$Y= -0.617 + 0.325X_1$

According to this re-written regression equation above, when the group variable of leading indicators of workplace safety is kept at zero level, the number of lost days as a result of injuries will be equal to the constant or intercept -0.617. In addition, the findings also reveal that a unit increase in the group variable of leading indicators of safety will results in a 32.5 percent increase in the number of lost days. At 5% level of significance, the group variable of leading indicators of workplace safety had a 0.004 level of significance. Therefore, the null hypothesis that there is no statistically significant relationship between safety leading indicators and workplace safety outcomes is rejected.

5 DISCUSSION OF RESEARCH FINDINGS

5.1 Introduction

This chapter presents a discussion of the results and findings of this study with respect to the questions and hypotheses outlined at the beginning of the study. The purpose of this study was to interrogate the theory of occupational health and safety management to determine the impact of safety leading indicators on workplace safety conditions in the context of an underground mine, and also determine the influence the same on workplace safety outcomes. The research questions and the applicable accompanying research hypotheses or research propositions were as follows:

> **Question 1:** Is there a statistically significant relationship between safety leading indicators and workplace safety conditions?
>
> Null hypothesis: There is no statistically significant relationship between safety leading indicators and workplace safety conditions
>
> Research hypothesis: There is a statistically significant relationship between the safety leading indicators and workplace safety conditions
>
> **Question 2:** Is there is a statistically significant relationship between safety leading indicators and workplace safety outcomes?
>
> Null hypothesis: There is no statistically significant relationship between safety leading indicators and workplace safety outcomes
>
> Research hypothesis: There is a statistically significant relationship between safety leading indicators and workplace safety outcomes

In addition, this chapter seeks to present connections between the findings of this study existing literature or research. Lastly, this chapter will detail the implications of the results of this study as they relate to current literature, technical applications and professional practice.

5.2 Is there a statistically significant relationship between safety leading indicators and workplace safety conditions?

The results of this study presented in Chapter 4 show a very weak positive contribution of the safety leading indicators as a group on workplace safety conditions represented as risk ratings of workplace conditions in the regression model. According to the regression analysis in Chapter 4, only 17.6% increase in the percentage of risk ratings of workplace safety conditions could be explained by a unit increase in the group variable of safety leading indicators. This shows that there is some relationship between the leading safety indicators as a group and the workplace safety conditions measured as risk ratings of workplace safety conditions. However, the ANOVA output of the regression model shows that the group variable of leading indicators of workplace safety on risk ratings of workplace conditions is not statistically significant as indicated by the high p-value (0.861), that is, greater than 0.05 and low F-value (0.031), and this shows that the overall model was not statistically significant. Therefore, the null hypothesis that there is no relationship between safety leading indicators and workplace safety conditions is accepted.

In addition, the findings of this study further reveal that risk ratings of workplace safety conditions may not be the best representation of the variable of workplace safety conditions due to their dynamic nature. Safety conditions are continuously changing over time and are affected by both positive safety practices and negative pressures (Guo, Yiu, & Asce, 2009). Reiman & Pietikainen, (2011), stated that workplace safety conditions are of a continuously changing nature. The continuously changing nature of workplace safety conditions is even more true in a mining context, whereby workplace are blasted everyday thereby creating new workplace conditions on a daily basis - while the safety risk ratings of workplace conditions at the selected mine are computed monthly during safety inspections. This is consistent with the findings by Givehchi, Hemmativaghef, & Hoveidi, (2017), who found that non-compliances detected during safety inspections are more an indicator of safety climate rather than safety conditions of a workplace.

In section 2.1, the updated domino accident causation model (Bird and Loftus, 1974) was adopted as the interpretive framework for this study. According to this interpretive framework, workplace safety conditions (unsafe conditions) are influenced by a combination of safety leading indicators, basic causes of personal and job factors, as well as substandard acts (Bird and Loftus, 1974). The finding of this study that there is no relationship between safety leading indicators and workplace safety conditions is possibly partly explained by the fact workplaces safety conditions are influenced by more than one factor as explained by the adopted interpretive framework.

The acceptance of the null hypothesis that there is no relationship between safety leading indicators and workplace safety conditions is supported by the fact that the existence of unsafe or safe workplace conditions may be attributed to more factors thank leading indicators. Kevin, Laulund, Howell, & Jones, (2010) found that safety leading indicators, safety climate and proper workplace risk quantification may reduce the violations that lead to the creation of unsafe conditions. E. Haas, Yorio, (2018) stated that communication of safety inspection reports to management in order to facilitate appropriate response to workplace deviations or non-compliances has direct influence on prevailing workplace safety conditions. The implementation of measures to correct deviations at a workplace directly influences the existing workplace safety conditions. Nikulin & Nikulina, (2017), found that execution of work to implement control measures that address leading indicators deviations is one of the critical success factor of using leading indicators to monitor safety performance and safety conditions.

5.3 Is there a statistically significant relationship between safety leading indicators and workplace safety outcomes?

The results of this study show a weak positive contribution of the safety leading indicators as a group on workplace safety outcomes measured as the number of lost day injuries in the regression model. According to the regression analysis in Chapter 4, only 4.9% of lost day injuries could be explained by a unit increase in the group variable of safety leading indicators. This shows there is a relationship between safety leading indicators and workplace safety outcomes, albeit a weak one. In addition, the ANOVA output of the regression model shows that the group variable of safety leading indicators on lost day injuries and consequently safety outcomes is statistically significant as indicated by the low p-value (0.004), that is, less than 0.05 and a high F-value (8.721). This shows that the overall model was statistically significant. Consequently, the null hypothesis that there is no relationship between safety leading indicators and workplace safety outcomes has been rejected, and the research hypothesis is accepted that there is a relationship between the safety leading indicators and workplace safety outcomes.

Over and above the hypothesis which this study sought to test, the results of this study further show that the relationship between safety leading indicators and safety outcomes is a weak one. Haas and Yorio, (2016, p2) state that "the purpose of leading indicators is to understand and manage organizational circumstances thought to precede undesired occupational health and safety outcomes". This implies that safety leading indicators are more concerned with the circumstances preceding and giving rise to the safety outcomes rather than the safety outcomes themselves.

Similar to this study, Sheehan, Donohue, Shea, and others, (2016) found that leading indicators are not significantly related to reported occupational health and safety incidents. Also, research carried out by Liu, Huang, Wang, and others, (2015), found key empirical evidence of inter-correlations between workplace safety climate, behaviour and occupational injuries (safety outcomes). This implies that safety outcomes are more influenced by workplace safety climate and behaviour. A study by Nadhim, Xia, and others, (2018) found that safety climate positively affects safety performance and therefore safety outcomes. Reiman and Pietikainen, (2011), found that outcome indicators like safety outcomes are a result of different contextual and situational factors.

In contrast, Hinze, Thurman and Wehle (2012) concluded that leading indicators have the ability to predict future safety performance. Similarly, Guo, Yiu, and Asce, 2009, mentioned that leading indicators precede undesirable events and their value lies in predicting accidents, near misses or the ovrall safety state. This implies that the relationship between safety leading indicators and safety outcomes needs to be significantly strong to give effect to the ability of leading indicators to predict safety outcomes. In contrast, Lingard, Wakefield and Blismas, 2014, argue that safety outcomes capture the absence of safety rather than the presence thereof and are not a direct measure of the level of safety.

The updated domino accident causation model (Bird and Loftus, 1974) adopted as the interpretive framework for this study shows that safety outcomes, represented as loss in the model, are influenced by leading indicators, basic causes of personal factors and job factors, as well as unsafe acts and unsafe conditions, albeit occurring in a sequence. The finding of this study that there is a weak relationship between safety leading indicators and workplace safety outcomes is possibly partly explained by the fact safety outcomes are influenced by more than one factor as explained by the adopted interpretive framework.

6 SUMMARY, CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

6.1 Summary

The primary purpose of this study was to determine the impact of safety leading indicators on workplace safety conditions and safety outcomes in the context of an underground mine.

In order to achieve the objectives of the research, this study sought to answer two questions; whether there is a statistically significant relationship between safety leading indicators and workplace conditions? and whether there is a statistically significant relationship between safety leading indicators and safety outcomes?

The literature review provided the theoretical basis of the thinking and application of safety leading indicators to anticipate increasing safety risk levels by providing early warning of unwanted occupational health and safety events. Safety leading indicators help those in authority to monitor safety levels and develop and implement proactive measures prevent the occurrence of unwanted occupational health and safety outcomes.

To help this study gain insights into and frame the interaction of safety leading indicators, workplace conditions and safety outcomes, various accident causation models were reviewed during theoretical review. The updated domino accident causation model (Bird and Loftus, 1979) was discussed and chosen as the interpretive framework for this study.

Based on the findings from literature review, research design, research instruments, data analysis, ethical considerations and potential limitations of the study were discussed. In addition, the empirically validated Organizational Performance Metric-Monash University (OPM-MU) was adopted as the measure to collect quantifiable data on leading indicators at workplace level.

With regards to the first question, the data analysis of this research study found that there is no statistically significant relationship between safety leading indicators and workplace safety conditions. In terms of the second question, this research study found that there is a statistically significant relationship between safety indicators and workplace safety outcomes.

The findings of this research study are consistent with those of similar studies, while it is acknowledged that some of the findings were not consistent with some of the studies.

There researcher is therefore of the view that the main objectives and key deliverables of the study were successfully achieved.

6.2 Conclusions

This research study set out to determine the impact of safety leading indicators on workplace safety conditions and safety outcomes in the context of an underground mine. In achieving these objectives, this research study has contributed to the growing body of knowledge on the use of safety leading indicators, particularly in the South African mining industry where literature review revealed that it is still very limited.

This study provided an understanding that safety leading indicators have impact on safety outcomes. Therefore, employers and safety practitioners who aim to reduce work related accidents (safety outcomes) can benefit from superior focus on compliance to safety leading indicators, particularly at workplace level.

The results of this study, together with the chosen interpretive framework, suggest that in addition to leading indicators, workplace safety conditions are also impacted by other factors such as personal factors, job factors, as well substandard acts that were not taken into account in this study. Therefore, the contribution of this study is that in order to improve workplace safety conditions, safety professionals and employers must develop a holistic approach that not only addresses leading indicators, but also the basic causes (personal and job factors) and unsafe acts by employees.

Lastly, the findings of this study read through the interpretive framework reveal that the monthly computation of workplace safety risk ratings as currently employed at the selected mine might not present an accurate representation of workplace conditions as these change on a daily basis. This implies that safety practitioners must relook the frequency of safety inspections and also find a dynamic approach to quantifying workplace risk ratings or other methods of quantifying workplace safety conditions.

6.3 Limitations

The findings of this study must be understood in the context of methodological limitations in that the study pursued non-probability sampling technique (convenience sampling). In this regard, the sample is not completely representative as the researcher deliberately chose the sample according to the required characteristics of the population in order to meet the aim of the research.

Another possible limitation of the study is that it was conducted one mine which employs conventional mining methods. The results of the study therefore cannot be generalized across the mining industry and other mines employing different mining methods, for example mechanize mining and opencast mines.

Lastly, the lack of statistical significance between safety leading indicators and workplace safety conditions is probably a consequence of other factors that impact on workplace safety conditions which were not taken into account in this study such as job factors, personal factors and substandard acts. Therefore, this limits the application of the findings of this study as they pertain to workplace safety conditions.

6.4 Recommendations

This study revealed that, in addition to leading indicators, workplace safety conditions are influenced by a combination of factors such as personal factors, job factors and overall safety climate. It is therefore important that safety improvement programmes for workplace conditions must adopt an integrative approach focusing on all these factors in order to have real impact on workplace safety conditions.

The findings of this study also reveal that there is a weak relationship between safety leading indicators and workplace safety outcomes as explained in the interpretive framework. As such and in order to predict future safety outcomes of a workplace, factors considered must include basic causes (job and personal factors), unsafe acts, workplace conditions, safety climate as well as leading indicators compliance.

Although the study makes important contributions to workplace safety literature and practice, there are opportunities for future research.

First, this study made use of cross-sectional data where safety leading indicators were measured during one visit to the workplace. While this was useful, future longitudinal research is suggested where all the variables of the study are measured over time will be useful.

Second, the results of this study suggest that in addition to leading indicators, workplace safety conditions are also impacted by other factors such as personal factors, job factors, as well substandard acts which were not taken into account in this study. Suggested future research may seek to determine the impact of personal factors, job factors or substandard acts on workplace safety conditions.

Last, future research may seek to replicate this study in more than one mine or at a mine that employs non-conventional mining methods such as mechanized mining or opencast mining.

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APPENDICES

Appendix 1.1: Data collection instrument(s)

Consent Form to participate in the research study

Title of project: **Impact of safety leading indicators on workplace safety conditions at a selected mine and the influence of this on workplace safety outcomes**

Name of researcher: **Floyd Masemula**

I agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. I agree to the following:

(Please circle the relevant options below).

I agree that my participation will remain anonymous and I do not have to give my name or other personal information	YES	NO
I agree that my participation in this survey is voluntary and I may choose to discontinue at any stage of the process	YES	NO
I confirm that I am at least 18 years of age and employed underground at the selected mine	YES	NO

Signature of participant:.....

Date:.....

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Fomal Occupationa Health and Safety (OHS) audits at regular intervals are a normal part of our workplace*	1	2	3	4	5
2. Everyone at this workplace values ongoing OHS improvement in this workplace	1	2	3	4	5
3. This workplace considers health and safety at least as important as production and quality in the way work is done	1	2	3	4	5
4. Workers and supervisors have the information they need to work safely	1	2	3	4	5
5. Employees are always involved in decisions affecting their health and safety	1	2	3	4	5
6. Those in charge of OHS have the authority to make changes they have identified as necessary	1	2	3	4	5
7. Those who act safely receive positive recognition	1	2	3	4	5
8. Everyone has the resources and/or equipment they need to complete their work safely	1	2	3	4	5

*For the purpose of this survey, an audit means a formal process of evaluating on how the workplace manages health and

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Appendix 2.1: One-page bio of the researcher including declaration of interest in the research and funders, if any

The researcher, Floyd Masemula, is an accomplished mining professional. He graduated with B-Eng Mining Engineering degree from the University of Pretoria. He later obtained a postgraduate diploma in Management practice through the University Of Cape Town Graduate School of business.

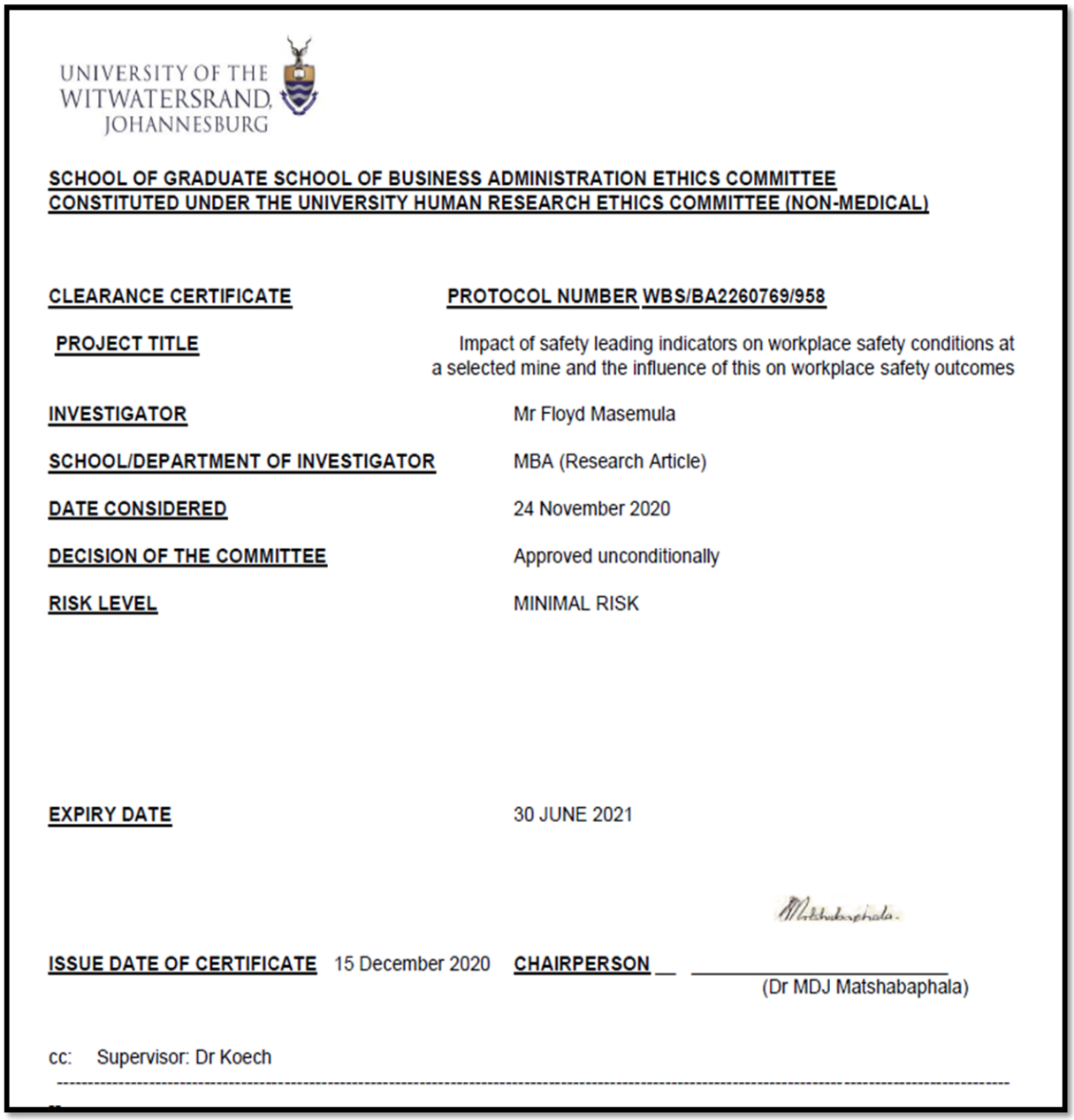
Having come through the ranks, Floyd has held a number of operational and senior management positions at various mines and companies including those of Mine Manager, General Manager and Executive Regional Manager. He currently holds the position of Senior Vice President with a diversified multinational mining company.

Throughout his career and various leadership and management roles, Floyd has acquired competencies in general management, operational and business turn around strategies, business integration, and projects execution. Overall, Floyd is passionate about people and therefore strives to be an authentic and empowering leader.

Floyd is married and together with his wife, they are blessed with three beautiful children. Floyd enjoys outdoor activities including golf and soccer.

Floyd's interest in this research study is purely academic. No person or organization has funded or sponsored this research study.

Appendix 2.2: Ethic documentation



UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF GRADUATE SCHOOL OF BUSINESS ADMINISTRATION ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

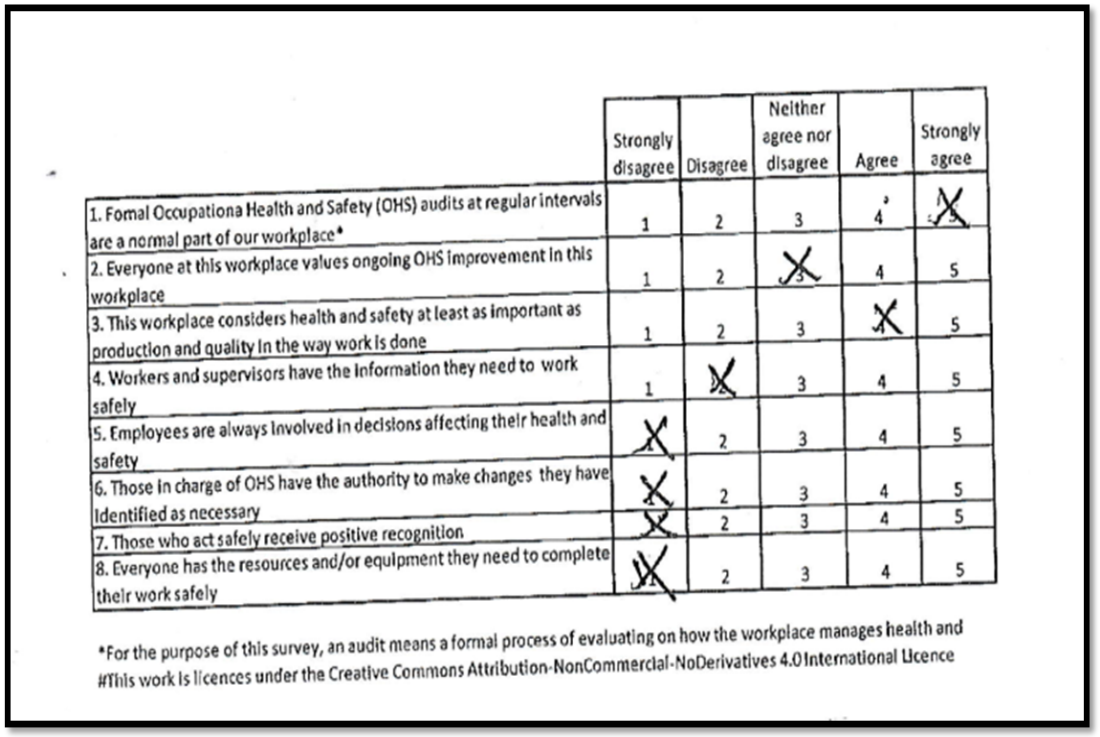
CLEARANCE CERTIFICATE	**PROTOCOL NUMBER WBS/BA2260769/958**
PROJECT TITLE	Impact of safety leading indicators on workplace safety conditions at a selected mine and the influence of this on workplace safety outcomes
INVESTIGATOR	Mr Floyd Masemula
SCHOOL/DEPARTMENT OF INVESTIGATOR	MBA (Research Article)
DATE CONSIDERED	24 November 2020
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	MINIMAL RISK
EXPIRY DATE	30 JUNE 2021

ISSUE DATE OF CERTIFICATE 15 December 2020 **CHAIRPERSON** _____
(Dr MDJ Matshabaphala)

cc: Supervisor: Dr Koech

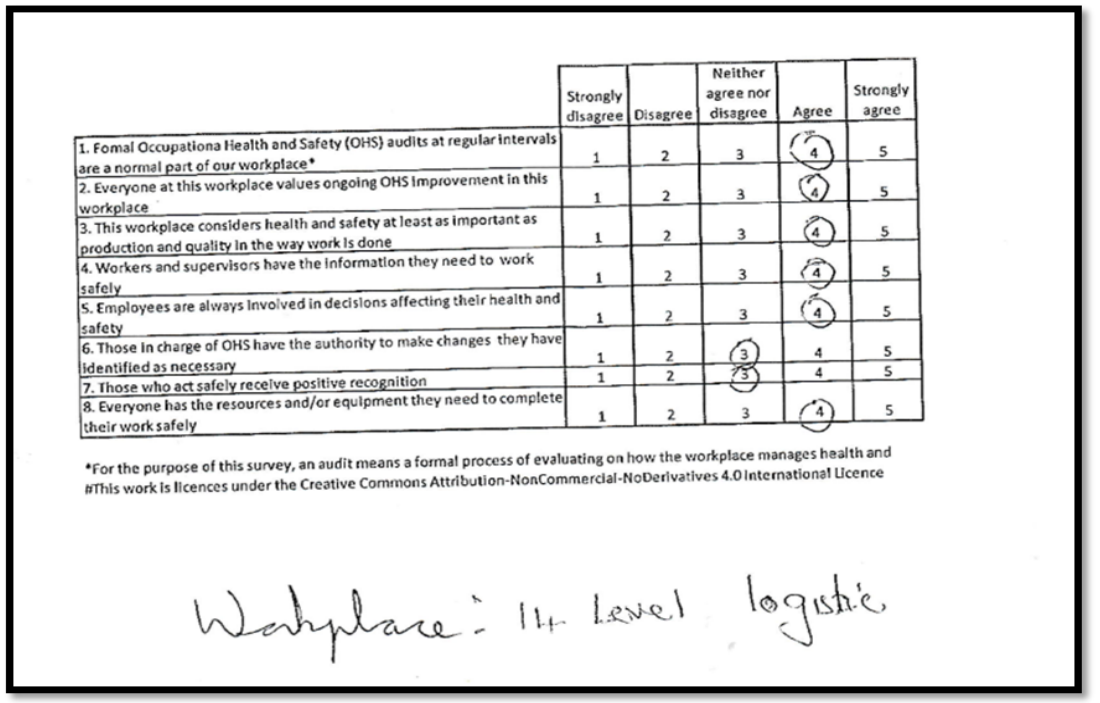
Appendix 2.2: Ethic documentation

Appendix 3.1: Dully filled in data collection instrument(s)



	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Fomal Occupationa Health and Safety (OHS) audits at regular intervals are a normal part of our workplace*	1	2	3	4	X 5
2. Everyone at this workplace values ongoing OHS improvement in this workplace	1	2	X 3	4	5
3. This workplace considers health and safety at least as important as production and quality in the way work is done	1	2	3	X 4	5
4. Workers and supervisors have the information they need to work safely	1	X 2	3	4	5
5. Employees are always involved in decisions affecting their health and safety	X 1	2	3	4	5
6. Those in charge of OHS have the authority to make changes they have identified as necessary	X 1	2	3	4	5
7. Those who act safely receive positive recognition	X 1	2	3	4	5
8. Everyone has the resources and/or equipment they need to complete their work safely	X 1	2	3	4	5

*For the purpose of this survey, an audit means a formal process of evaluating on how the workplace manages health and
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	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Fomal Occupationa Health and Safety (OHS) audits at regular intervals are a normal part of our workplace*	1	2	3	(4)	5
2. Everyone at this workplace values ongoing OHS improvement in this workplace	1	2	3	(4)	5
3. This workplace considers health and safety at least as important as production and quality in the way work is done	1	2	3	(4)	5
4. Workers and supervisors have the information they need to work safely	1	2	3	(4)	5
5. Employees are always involved in decisions affecting their health and safety	1	2	3	(4)	5
6. Those in charge of OHS have the authority to make changes they have identified as necessary	1	2	(3)	4	5
7. Those who act safely receive positive recognition	1	2	(3)	4	5
8. Everyone has the resources and/or equipment they need to complete their work safely	1	2	3	(4)	5

*For the purpose of this survey, an audit means a formal process of evaluating on how the workplace manages health and
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Workplace: 11+ Level logistic