The impact of digital wearables on safety in the South African mining industry

submitted by

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DECLARATION

I, Nthabiseng Bapela, declare that this research article is my own work except as indicated in the references and acknowledgments. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other subject.

NTHABISENG BAPELA

Signed at: Kempton park

Date: 29 February 2024

DEDICATION

I would like to dedicate this research article to the Messiah who never gave up when I was giving up.

To my daughters, Rearabilwe and Kefentse from strength to strength we continued to support each other. Thank you.

To my MBA block cohort, Syndicate 3, thank you for the knowledge and patience throughout the journey.

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- Data analysis
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ABSTRACT

The mining industry is currently at a turning point and is encountering several challenges, including the need to improve efficiency, reduce costs, limit its impact on the natural environment and improve safety. In order for mining organisations to stay globally competitive they need to adjust to the new norms of efficient mining at a low cost. The greater the depth of mining the more dangerous mining activity become (Zulu et al., 2021, pp. 184-200). The research was influenced by the need to improve safety through the use of digital technology to collect active data. The concept of digital wearables allows for the collection of a vast amounts of data in real-time which can be used to reveal unknown reoccurrence's due to certain behaviour or conditions which results in incidents that could have been avoided. Data analytics can be used to design models to easily predict and eliminate a peak in operational scenarios based on the employee groups and mediate prior an incident occurs (Deloitte, 2019). The primary objective of this study is to determine how digital wearables can be utilised to indicate impending hazards by providing data that mines can use to improve safety. There is a need to develop models that are aligned with technological improvements directed at improving safety in mining operations. A quantitative research method was adopted in the research as it describes the investigation and use of numerical data by means of specialised statistical techniques (Oberiri, 2017, pp. 40-47). The method used to conduct the study was a questionnaire in the form of a survey based on a Likert-type scale. Due to a low survey response there were 51 actual respondents and 40 respondents derived from the cleaned data to the survey which included mine management employees, middle management and junior level working on the site. The influence on the dependent variable was populated into the SPSS model to test if the data is a good fit. The data was exported to SPSS and used to run different tests on the sample (Lee, n.d., pp.143-178). Key drivers from the sample data results were identified as the low information efficiency flow currently whereby majority if respondents agree that impeding hazards and injuries can be reduced by way of training to improve human interaction with technology and availability of real time data. The results suggest that technology can play a role in enhancing safety standards in mines. Technology will improve information efficiency but organisations lack "holistic and proactive approaches" in balancing the adoption of technology and industrial social sustainability (Mangaroo-Pillay et al., n.d., pp. 1-12).

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CHAPTER 1

1. INTRODUCTION.

The mining sector has played an important role to the economic development of South Africa. The discovery of minerals laid the foundation of South Africa's political landscape, socio-economic development, and legislation over the last 140 years (Naidoo, 2013, pp. 1-3). Currently, the mining sector accounts for over half a million employees in South Africa. The sector is labour-intensive with labour accounting for around 50% of the overall operational cost (Moraka & M Jansen van Rensburg, 2015, p. 669).

Historically safety has been a major challenge in the mining sector due to the labour intensity of production. In the early 1980's, a fire broke out at the Kinross gold mine, which resulted in 177 fatalities. Due to lack of technology, the gas could not be detected, which meant that the people could not be evacuated in time as per the accepted procedures. The second biggest incident was in the Vaal Reefs underground gold mine in South Africa where a locomotive fell into the shaft area whilst a mine cage with 104 miners was transporting people on a level below. This resulted in the cable winder breaking and fatally wounding the employees in the mine cage (Seymour, 2005, pp. 19-31).

Although South Africa has some of the deepest underground mines, fatalities have declined from 90 in 2017, 81 in 2018, 51 in 2019 to 60 in 2020 (Safety in Mining, n.d.). This is mainly due to improvements in technology applications in the industry. These included, inter alia, mandatory human detector systems in all moving machinery, underground gas detectors and advanced braking systems to prevent inadvertent movement of the machinery. While the technology in the industry has not been fully implemented, there is still potential for integrating wearables in the industry. Initially collecting data for research purposes from the workforce whilst executing their jobs had been very difficult. From previous studies challenges to collect reliable data included, efforts to measure and summarise postures and activities of maintenance and repair workers at mine sites using goniometers and in-shoe pressure sensors with externally worn goniometers failing due to harsh conditions (Dempsey et al., 2018, pp. 1-11).

On August 5, 2010, there was a huge mine accident in a privately-owned San José copper mine in Chile, leaving 33 workers trapped 700 m underground. Their rescue was not solely due to the use of basic mining equipment alone. Zephyr Technology's BioHarness™ BT and Panasonic Toughbook® U1 and CF-29 computers had an important role in the rescue mission. Biomec, a Santiago, Chile-based company used technology (BioHarness BT from Annapolis-based Zephyr Technology) to monitor the miners' condition whilst underground (Arnold, 2011).

Panasonic's ultra-mobile Toughbook U1 was deemed appropriate given its suitability for operation in extremely muddy, humid, and wet conditions. On October 13, Florencio Avalos the first mine employee trapped underground was rescued to surface. With the Toughbook the doctor could read the vital signs and treat the mine workers as they surfaced. The rescued mission was considered an incredibly challenging operation but resulted into a success through the use of reliable digital technology equipment (Arnold, 2011).

Majority of our mining organisations have detailed information to trace the number of accidents and incidents, the rate of reoccurrences, and other measures (Lööw, 2022, pp. 143-154).These reports are collected post the incident or accident which has limited effect on the current environment if not analysed correctly and in silo departmental data collection. A gap for advanced analytics that involves combining the correct data has been identified.

This study will explore how digital wearables can be utilised to improve safety. In short, the study explores how data in real time can be used to better understand impending hazards or conditions that contribute to mining incidents. Using the data predictive models can be designed to target peak operational risk scenarios based on employee groups and intervene before incidents occur (Deloitte, 2019).

2. IDENTIFICATION OF RESEARCH GAPS

This research will explore the application of digital wearables on safety in the South African mining industry. This refers to the use of computer based or digital strategies, which incorporate systems and digitised data to improve safety and transform mining practices.

The main purpose of digital wearables is for miners to integrate isolated data collection and provide employees within the organisation with access to consistent, reliable, and real-time data. For example, the Bio-Harness™ is a belt secured across the chest, used to monitor the critical vital signs (ECG, heart rate, breathing rate, skin temperature) and is said to combine the information with the individual's physical activity using an accelerometer (activity and posture). The vital signs data is then transmitted wirelessly to the individuals monitoring the data, thus critical decisions can be made based on an individual's physiological and medical status (Pokapū Akoranga Pūtaiao, University of Waikato., 2012).

However, studies indicate that there are challenges pertaining to the interaction between humans and modern technology in South Africa. Lagging infrastructural development is also a major constraint in our mining industry (Barnewold & Lottermoser, 2020, pp. 1-12).

2.1 PROBLEM STATEMENT

The challenges in the execution of digital transformation technologies in the mining industry are not yet sufficiently understood (Zulu et al., 2021, pp.185-200). Digitalisation offers the opportunity to obtain solutions in real time. Real time data analysis can be used to predict outcomes and develop solutions to problems in real time. For example, mining companies can predict high-risk safety areas gathered from data analytics.

The lack of digitisation strategies usage presents an opportunity to investigate the sources of failure and the readiness of digital transformation technologies within mining organisations in South Africa. This offers an opportunity to incorporate managerial, organisational, and human dimensions, appropriate innovative business models, people skills and change processes to enhance the effectiveness of the digitisation process to improve safety (Zulu et al., 2021, pp.185-200).

2.2 RESEARCH OBJECTIVES

The primary objective of this study is to determine how digital wearables can be used to indicate impending hazards by providing data that mines can use to improve safety.

2.3 DEFINITIONS OF TERMS

2.3.1 Digital transformation

Digital transformation describes the change in organisations or business model due to introduction of digital technologies. In the mining industry digitalisation can be described as the use of computer based or digital devices, which incorporates systems and real time digital data that can be used improve safety and transform mining (Barnewold & Lottermoser, 2020, pp. 1-12).

2.3.2 Digital Ubuntu

Digital Ubuntu defines a collection of people joining forces to resolve problems digitally. In South Africa, 'ubuntu' is a term used to describe how people think and behave collaboratively and communally. Digital Ubuntu describes the implementation of digitization as an ecosystem that is utilised to resolve digital issues (Mangaroo-Pillay et al., n.d., pp. 1-12).

2.3.3 Digital Wearables

Wearables refer to clothing, gear and other accessories incorporating computer and advanced electronic equipment. Wearables are becoming prominent tools in the mining industry, due to high technological progress and introduction of 4IR globally (Tulip, n.d.).

2.3.4 Advanced analytics

Advanced analytics leverages algorithms and artificial intelligence to identify opportunities that humans miss. The main purpose of analytics is to process data, pick up trends and patterns from the data, and find any correlations between the data. Mining companies can benefit from such information to identify operational bottlenecks or waste patterns and make operations more efficient. These insights can help predict potential trends and patterns, learn useful lessons from the trends and generate future actions (Tulip, n.d.).

2.4 ASSUMPTIONS

- Interviewees will agree to answer questions honestly and accurately.
- Interviewees understand the concepts of the digital wearables which forms the basis of the analysis in this paper.

2.5 LIMITATIONS

The limitations of the study are:

- The focus is on the application of digital wearables in South Africa mining organisations only.
- Only frontline operations and inter departmental functions at managerial level will participate in the survey.

2.6 CONTRIBUTIONS OF THE STUDY

The study will indicate the potential of digitisation (digital wearables) to provide consistent, reliable, and real-time data to enhance mine safety.

CHAPTER 2

3. REVIEW OF RELATED LITERATURE

3.1 Theoretical foundation

The Fourth Industrial Revolution (4IR) indirectly drives the world to evolve with technological evolution, due to technology somewhat becoming an essential part of our daily lives and operational processes in industry (Mangaroo-Pillay et al., n.d., pp.1-12).

In a recent study, Kinzel explained the need for human interaction with technology to ensure adequate skill sets to address the emerging needs of 4IR. Kinzel presented the human factor engineering (HFE) design concept to provide a bridge to addressing concerns regarding the growing human non-technical skills. The purpose of HFE is to ensure technology works for people and to improve human interactions with technology to enhance safety performance and processes (Mangaroo-Pillay et al., n.d., pp. 1-12).

HFE has several components (Mangaroo-Pillay et al., n.d., pp.1-12) which include:

• Engineering psychology – The human mind as it relates to design

• Ergonomics – Factors related to physical work and designing for it

• Human computer integration – User experiences and software

• Macro-ergonomics – The design of teams and organisations

• Cognitive engineering – Management of systems, aided by decision aids and automation

• Human systems integration – People's interactions with all systems

3.2 Information technology capabilities and firm performance

Although studies have shown that information technology has been identified as a differentiator and contributor to growth and performance, the specific strategies that connect IT to financial benefits have not been identified (Bharadwaj, 2000, pp. 169-196).Thus, a clear understanding of the IT basics forms the major value chain of the system implementation.

3.3 Diffusion of innovations (DOI)

The foundation of safety lies in information management and exchange. DOI is described as a distribution of a dynamic process whereby an innovation is communicated over a variety of networks over a period of time to a group of members of a social system (Peixoto et al., 2015, pp.1-18).

The DOI process is derived from four elements which include, an idea or innovation; channels of communication to spread knowledge of the innovation; time during which diffusion takes place; and a social system of potential adopters in which this occurs involving interpersonal communication relationships. The theory denotes that DOI does not only highlight the importance of communication, but also of acceptance (or rejection) of innovations by members of the social system (Peixoto et al., 2015, pp.1-18).

3.4 The Technology Acceptance Model

The technology acceptance model proposes that perceived ease of use and perceived usefulness predict the acceptance of information technology (Qingxiong & Liping, 2004, pp. 59-72).

Research on the theoretical acceptance model revealed traits and attributes that influence users' decision to accept technology. These factors include beliefs and attitudes. This model is very important for actual use of an acquired system like information analysis (Chuttur, 2009, pp. 1-25).

3.5 Socio-technical systems theory

As mentioned above, the role of technology can no longer be disregarded as it is becoming an essential part of our daily lives (Mangaroo-Pillay et al., n.d., pp.1-12).

Due to human requirements becoming dependent on technology, the relationship between the two has mutual benefits that each dimension can provide. To create synchronisation between the two dimensions, socio-technical systems theory was designed to formulate and connect the joint optimisation of each domain (Mangaroo-Pillay et al., n.d., pp. 1-12).

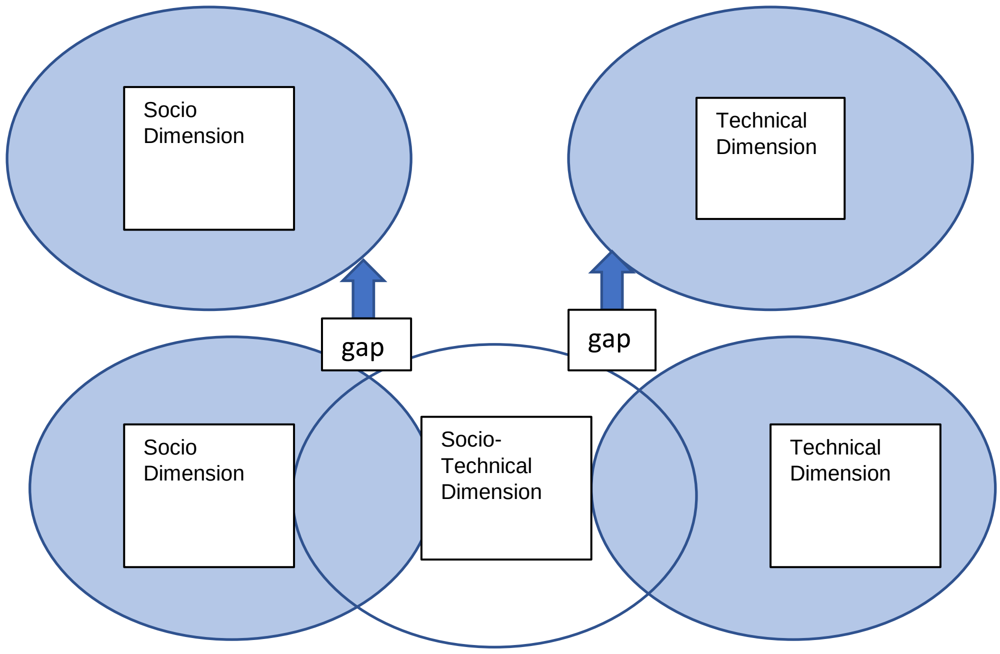

FIGURE 1: Socio-technical gap (Mangaroo-Pillay et al., n.d., pp.1-12).

Figure 1 above shows, the change in societal and technological needs which has resulted in a socio-technical dimension that attempts to synchronise two domains. Mumford conducted a cultural analysis which included technology, the natural and urban environments, the individual and the surrounding community. According to Mumford the technology gap appears simple, but the relationship between people, processes, and technologies is indeed complex. Feedback from the analysis indicates that language formation and social organisation increased usage of tools and willingness. Organisations consists of individuals with diversified beliefs and cultures, which alters the characteristics of the company's culture, thus essential to accommodate the multiple characteristics within technology adoption. Society has become advanced, and our reliance on technology has become even greater (Mangaroo-Pillay et al., n.d., pp. 1-12).

3.6 Objectives

The study will test the hypotheses identified in this chapter to determine the ability of the mining industry to successfully use digitisation namely wearables to enhance safety standards in the South African mining industry. Hypotheses were derived to carefully examine the effect of socio technical gap through training and the acceptance of technology adoption from the respondents.

3.6.1 Improve safety challenges through digital technology

Research has shown that mining organisations have faced challenges which include flexibility to adopt to technological, social, and structural changes which were introduced by disruptive digital innovations across industries (Lazarenko et al., 2021, pp.1-9).

The adoption of technology in the mining organisations has improved the work environment, through the reduction of accident frequency trends during the 1900s. The current challenge of digital implementation is that some of the potential of technology to improve the work environment remains unrealised due to inter alia technology introducing new risks alongside the benefits it brings. The second challenge is that technology is treated in isolation.

Majority of our mining companies have detailed information to trace the number of accidents and incidents, the rate of reoccurrences, and other measures (Lööw, 2022, pp. 143-154).However, there is a lack of advanced analytics to ensure the optimal benefits from this data.

This study will test the following hypothesis:

H1: *Digital technology can be used to track impending hazards and improve safety.*

3.6.2 Data controls in health and safety can be used to eliminate or minimize incidents

According to Deloitte Mining 2019 integrated report an intelligent mine is a connected, integrated, automated yet human-centred system, with intelligent mining solutions that incorporate stages of the mining value chain including safety. This will simplify communication processes between management and the staff across the different functions (Deloitte, 2019). An integrated system will create the closed cycle in order to optimise the mining value chain. The development of a robust ERP system enables active information communication across functions in real time to monitor and actively react to health and safety incidents (Smidt & Jokonya, 2021, pp. 1018-1026).

Thus, the study will test the following hypothesis:

H2**:** *Real time data can be used to generate active controls in health and safety to eliminate or minimise incidents.*

3.6.3 Information and efficiency of information flow

The majority of the digital transformation programs are said to fail, mainly due to poor attention given to the management aspect of the digital strategy implementation. These include inadequate skills and competencies for analytics, poor collaboration and silo operation across functions resulting in complications in integrating new principles to current safety technologies. Challenges also include establishing suitable digital culture which includes testing, collaboration, employee involvement, and training (Lazarenko et al., 2021, pp. 1-9).

Thus, the study will test the following hypothesis:

***H3**: Safety Improvement is achieved through adoption of technology which increases the amount of information efficiency flow.*

3.6.4 Training can improve human interaction with technology to ensure adequate skill sets to address the emerging needs of technology

Human computer interaction consists of three parts: the user, the computer itself, and the way they work together. The inability to adapt the skill set towards the digital economic growth will result in high incident rates. The lack of human interface with robotics will result in a huge gap for the workforce to be relevant within the digital era. A paradigm shift will favour workers with digital skills, where digital skills are in high demand. Digitalisation will bring new challenges that employers and employees need to address (de Groen, et al., 2017, pp.1-79).

In one of the studies to evaluate the readiness of the industry towards digitalisation which covered 80 specialists from a cross-section of mining organisations found that the mining industry will face a skills shortage in the future. 82% indicated that the mining industry will face a challenge recruiting people with relevant management skills with 75% of the respondents arguing that 'the mining industry itself was responsible and not doing enough' to equip the workforce with the appropriated skills set for the future. The industry will have to acquaint the workforce with the relevant skills towards human interaction with technology (Chirgwin, 2021, pp. 1-10).

Thus, the study will test the following hypothesis:

***H4**: Training can improve human interaction with technology to ensure adequate skill sets to address the emerging needs of 4IR.*

3.6.5 Incidents and prevalence in injuries resulting from the physically demanding manual tasks

Collecting human data from the workforce whilst performing their duties has previously said to be extremely challenging. New wearable technologies characteristics are described as the ability to collect human performance data, monitor ambient conditions, extend human capabilities, or mitigate the negative effect of activity on the body during work and leisure activities are developing at a rapid pace. Whilst digital wearables can be used to actively measure ergonomics of the workers the data can also be used to prevent musculoskeletal injuries and incorrect posture due to confined space (Dempsey et al., 2018, pp. 1-11).

Thus, the study will test the following hypothesis:

H5:*Digital technology reduces incidents and injuries resulting from physically demanding manual task.*

3.7 CONCLUSION

The factors noted above will be tested to inform an understanding of the impact of digitalisation on safety in the mining industry and to identify the major change management challenges and interventions needed for the adoption of transformation to improve safety in the mining industry.

CHAPTER 3

4. RESEARCH METHODOLOGY

Quantitative research method was adopted in the research as it describes the investigation and use of numerical data by means of specialised statistical techniques, to respond to questions like who, how much, what, where, when, how many, and how. The method is defined as an approach that explains a problem through data collection in numerical form. Quantitative methods can be categorised as; survey research, correlational research, experimental research and causal-comparative research (Oberiri, 2017, pp. 40-47).

The method used to conduct the study was a questionnaire in the form of a survey based on a Likert-type scale. Likert scale is used to measure ‘attitude’ in a scientifically accepted and validated manner. Attitude is choice in behaviour/reaction in relation to a specific belief and thoughts around an object, a subject or a concept (Joshi et al., 2015, pp. 396-403).

The original Likert scale describes a set of statements (items) presented for a real or an ideal situation under study. Respondents need to respond to a questionnaire based on their level of agreement (from strongly disagree to strongly agree) with the given statement (items) on a metric scale. The collective statements will thus definite the extent of the attitude towards the issue, hence, requirement for the statements to be interlinked with each other (Joshi et al., 2015, pp. 396-403).

4.1 SAMPLING AND DATA COLLECTION

A sample group of mine employees from various mine operations, selectively frontline operators and department functions at the managerial level forms the basis for this study. Participants, based on relevance, were picked randomly from various functions within the industry. Target respondents will be selected from junior level to managerial level to receive respondent participation that will give a clear indication of the digital understanding and acceptance throughout the mines. The target audience indicate the gaps in the successful application of digitisation.

Emails were sent directly to the participants explaining the purpose and how the survey will be conducted. The participants had the option of anonymity and waiver of confidentiality if required. The survey questionnaire was designed to take approximately 30 minutes of the interviewee's time. The interviewee will have a choice to complete the survey on their own or refer to the interviewer for assistance.

Due to a low survey response here were only 51 respondents which included mine management employees, middle management and junior level working on the site. Out of the 51 respondents 26 were employed in the surface mining sector which accounts for 51% of the total sample. 18 respondents are employed in the underground sector and they accounted for 35% of the total. The remaining 7 respondents identified as working in neither underground nor surface which could mean they were in charge of multiple operations.

4.2 RESEARCH DESIGN

The five independent constructs include effects of digital wearables, data analytics (passive data vs active data), inadequacy of information, disintegrated data sources, acceptance of technology and human interface taken from the literature review. These constructs will be studied using a questionnaire based on a Likert-type scale.

The survey questionnaires refer to statements relating to a specific construct as stipulated in section 2. A series of the questions from the survey are be added below.

H1: *Digital technology can be used to track impending hazards and improve safety.*
a. I am satisfied with the level of digital technology in my organisation. **b.** I believe that integrating digital technology into safety is important towards eliminating potential incidents.
H2**:** *Real time data can be used to generate active controls in health and safety to eliminate or minimise incidents.*
a. I am well informed with statistical knowledge of the safety incidents in my organization. **b.** I believe that real time information will help us identify the likelihood of similar hazards.
H3*: Safety Improvement can be achieved through adoption of technology which increases the amount of information efficiency flow.*

My organisation does a good job of helping me understand how previous incidents will affect my work and re-occurrences.
H4*: Training can improve human* interaction with technology to ensure adequate skill sets to address the emerging needs of 4IR.
a. Training towards digital transformation will help me understand how digital technology will affect my organization's productivity. **b.** I am satisfied with the level of training towards digital transformation in my organisation.
H5: *Digital technology reduces incidents and injuries resulting from physically demanding manual tasks.*
I believe digital wearables will have greater effect than a physical checklist.

4.3 VALIDITY AND RELIABILITY

Together with the comprehensive and readability test the questionnaire content validity will measure the relevance representation of the construct.

4.4 DATA ANALYSIS

The influence on the dependent variable was populated into the SPSS model to test if the data is a good fit. The data was exported to SPSS and used to run different tests on the sample (Lee, n.d., pp.143-178).

4.4.1 Descriptive stats

There are many statistical methods that can be utilised to assessment normality in the distribution of data. For the purposes of this research normality will be determined by considering skewness and kurtosis in the distribution of the data. These tests are accurate in both small and large samples (Hae-Young, 2013, pp. 52-54).

4.4.2 Cronbach's Alpha

Cronbach's alpha is a measure of the internal consistency of tests and measures. Cronbach alpha >0.5 is said to be the minimum acceptable figure, whilst a Cronbach alpha figure of >0.80 is defined as good (Lee, n.d., pp. 143-178).

4.4.3 Pearson's Correlations between latent factors or /Constructs

The bivariate Pearson correlation can be used to verify (Denis, 2018, pp. 41-45):

- if there is a statistically significant linear relationship amongst two continuous variables.
- the strength of a linear relationship (i.e., how close the relationship is to being a perfectly straight line).
- the direction of a linear relationship (increasing or decreasing).

The following rules are applied to show correlation of the constructs where:

- -1: perfectly negative linear relationship.
- 0: no relationship.
- +1: perfectly positive linear relationship.

The strength of the correlation of the variables be further described by the following scales:

- $1 < | r | < .3$ … small / weak correlation.
- $.3 < | r | < .5$ … medium / moderate correlation.
- $.5 < | r |$ ……… large / strong correlation (Denis, 2018, pp. 41-59).

4.4.4 T-test

The one-sample t-test is utilised to assess if a sample comes from a specific population, as we do not have access to complete population information. For example, we may want to know if a particular sample of college students is similar to or different from college students in general (University Emory , 2024).

4.5 ETHICAL CONSIDERATIONS

Private emails will be sent directly explaining the purpose and how the survey will be conducted with the option of anonymity and waiver of confidentiality if required.

CHAPTER 4

5. ANALYSIS OF SURVEY RESULTS

5.1 Descriptive stats

The raw data was cleaned and verified with 40 responses reported as clean. Tests of Kurtosis and Skewness were performed in SPSS and can be analysed from the descriptive statistics provided below. Acceptable values of skewness fall between − 3 and + 3, and kurtosis is appropriate from a range of − 10 to + 10 This implies the data falls within the normal distribution. Therefore, the data can be assumed relevant to the research question (Griffin et al., 2013, pp.155-183).

The table below show that there is a high kurtosis due to outliers in the questionnaire. These represent the natural response in the questionnaire that deviate from the population response.

The outliers have characteristics of being extremely higher or lower data point in comparison to the nearest data point and the rest of the neighbouring co-existing values in a data graph or dataset you're working with. Outliers are values that stand out significantly from the overall pattern of values in a dataset or graph. As can be seen in Table 2 below. hypothesis **H1b; H2b; H4a** resemble the above-described characteristics of outliers, whereby the majority respondents to the questionnaire had agreed based on the nature of question with a minute few in disagreement with the motion, thus a pattern of extreme high data points causing outliers (Lemonaki, 2021).

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
H1a	40	1	5	3,15	1,350	-0,221	0,374	-1,172	0,733
H1b	40	1	4	1,23	0,698	3,478	0,374	11,887	0,733
H2a	40	1	3	1,35	0,622	1,617	0,374	1,563	0,733
H2b	40	1	5	1,23	0,800	3,986	0,374	15,950	0,733
H3	40	1	5	3,00	1,769	0,000	0,374	-1,846	0,733
H4a	40	1	5	1,28	0,816	3,612	0,374	13,541	0,733
H4b	40	1	5	3,28	1,552	-0,313	0,374	-1,485	0,733
H5	40	1	5	3,25	1,794	-0,200	0,374	-1,814	0,733

Valid N (listwise)	40								

TABLE 1: Descriptive Stats

H1: *Digital technology can be used to track impending hazards and improve safety.*

H2**:** *Real time data can be used to generate active controls in health and safety to eliminate or minimise incidents.*

H3*: Safety Improvement can be achieved through adoption of technology which increases the amount of information efficiency flow.*

H4: *Training can improve human* interaction with technology to ensure adequate skill sets to address the emerging needs of 4IR.

H5: *Digital technology reduces incidents and injuries resulting from physically demanding manual tasks.*

H1a	H1b	H2a	H2b	H3	H4a	H4b	H5
1	1	1	2	4	4	5	3
5	1	1	1	5	1	5	2
2	1	1	1	1	1	2	2
2	1	1	1	2	1	1	1
1	1	2	1	5	1	5	5
2	1	2	1	1	1	1	1
5	1	1	1	1	1	5	1
1	1	1	1	5	1	1	5
2	1	1	1	2	1	1	5
3	1	1	1	2	1	5	1
4	1	3	1	4	1	4	1
4	1	1	1	1	1	4	3
5	1	1	1	5	1	5	5
3	1	1	1	1	1	1	1
5	2	1	2	2	1	3	3
4	4	2	1	4	1	4	3
4	1	1	1	2	2	3	5
2	2	2	1	5	1	2	5
1	1	1	1	5	5	1	5
2	1	1	1	1	1	2	1
4	1	1	1	1	1	2	5
4	1	2	1	4	1	4	5

2	1	1	1	1	1	1	1
3	1	2	1	3	2	4	1
3	1	1	5	1	1	5	2
5	1	1	1	5	1	5	5
2	1	1	1	1	1	2	1
1	2	3	1	1	1	1	1
4	1	1	1	1	1	4	1
4	1	1	1	5	1	4	5
3	1	2	1	5	1	5	5
5	4	1	4	4	2	2	5
3	1	3	1	5	1	5	5
3	1	2	1	5	1	5	5
5	1	1	1	1	1	3	5
4	1	1	1	5	1	2	5
4	1	1	1	1	1	5	5
4	1	1	1	5	1	4	5
1	1	1	1	5	2	4	3
4	1	1	1	3	1	4	2

TABLE 2: Clean Data

5.1.2 Cronbach's Alpha

The results imported from SPSS in *Table 3* below shows Cronbach's alpha of 0.519 which is declared as “0.5 < α < 0.8 for moderate (acceptable) reliability”. The table 4 also reflects the “Cronbach's Alpha if Item Deleted” which indicates what the reliability would be if one of the items is left out. The value of the “Cronbach's Alpha if Item Deleted” in the table is lower than the Cronbach's Alpha indicating the relevance of the items in the questionnaire. Thus, the test items will not be removed as reliability is still within the boundaries as seen below, we will continue to test the 8 reliable hypotheses.

Reliability Statistics	
Cronbach's Alpha	N of Items
0,519	8

TABLE 3: Cronbach’s alpha

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
H1a	14,60	19,426	0,178	0,510
H1b	16,53	21,794	0,168	0,510
H2a	16,40	22,810	0,029	0,534
H2b	16,53	22,102	0,084	0,527
H3	14,75	13,526	0,516	0,336
H42	16,48	22,563	0,018	0,541
H4b	14,48	16,512	0,353	0,435
H5	14,50	14,256	0,435	0,386

TABLE 4: Cronbach's alpha if items are deleted

5.1.3 Pearson's Correlations between latent factors or Constructs

Table 5 indicates the correlation of the variables. The correlation between the below constructs gives us evidence of low association, variables show correlation which indicates between 0,582 to 0,00 in direction and relationship. This satisfies one of the assumptions to run the one sample t-test the data is independent (i.e., not correlated/related), this means that there is no relationship between the observations (Laerd Statistics, 2018).

Correlations									
		H1a	H1b	H2a	H2b	H3	H4a	H4b	H5
H1a	Pearson Correlation	1	0,181	-0,186	0,110	0,000	-,341*	,420**	0,175
	Sig. (2-tailed)		0,264	0,250	0,498	1,000	0,031	0,007	0,281
	N	40	40	40	40	40	40	40	40
H1b	Pearson Correlation	0,181	1	0,168	,366*	0,104	0,024	-0,130	0,077
	Sig. (2-tailed)	0,264		0,299	0,020	0,523	0,885	0,425	0,637
	N	40	40	40	40	40	40	40	40
H2a	Pearson Correlation	-0,186	0,168	1	-0,162	0,233	-0,144	0,110	-0,034
	Sig. (2-tailed)	0,250	0,299		0,317	0,148	0,376	0,499	0,833
	N	40	40	40	40	40	40	40	40
H2b	Pearson Correlation	0,110	,366*	-0,162	1	-0,091	0,138	0,093	-0,004
	Sig. (2-tailed)	0,498	0,020	0,317		0,578	0,394	0,566	0,978
	N	40	40	40	40	40	40	40	40
H3	Pearson Correlation	0,000	0,104	0,233	-0,091	1	0,231	,336*	,582**
	Sig. (2-tailed)	1,000	0,523	0,148	0,578		0,152	0,034	0,000
	N	40	40	40	40	40	40	40	40
H4a	Pearson Correlation	-,341*	0,024	-0,144	0,138	0,231	1	-0,081	0,127
	Sig. (2-tailed)	0,031	0,885	0,376	0,394	0,152		0,617	0,435
	N	40	40	40	40	40	40	40	40
H4b	Pearson Correlation	,420**	-0,130	0,110	0,093	,336*	-0,081	1	0,159
	Sig. (2-tailed)	0,007	0,425	0,499	0,566	0,034	0,617		0,328
	N	40	40	40	40	40	40	40	40
H5	Pearson Correlation	0,175	0,077	-0,034	-0,004	,582**	0,127	0,159	1

	Sig. (2-tailed)	0,281	0,637	0,833	0,978	0,000	0,435	0,328	
	N	40	40	40	40	40	40	40	40
*. Correlation is significant at the 0.05 level (2-tailed).									
**. Correlation is significant at the 0.01 level (2-tailed).									

TABLE 5: Pearson Correlation

5.2 One sample T test

5.2.1 Traditional T-Test

Table 6 below shows the SPSS assumption check for equality of variance, using the one-way T-test with a significant p-value (< .05) rejecting the hypothesis.

One-Sample Test							
	Test Value = 1.2						
	t	df	Significance: One-Sided p	Significance: Two-Sided p	Mean Difference	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper
H1a	9,134	39	0,001	0,001	1.950	1,52	2,38
H1b	0.227	39	0,411	0,822	0,025	-0,20	0,25
H2a	1,525	39	0,068	0,135	0,150	-0,05	0,35
H2b	0,198	39	0,422	0,844	0,025	-0,23	0,28
H3	6,437	39	0,001	0,001	1.800	1,23	2,37
H4a	0,581	39	0,282	0,564	0,075	-0,19	0,34
H4b	8,454	39	0,001	0,001	2,075	1,58	2,57
H5	7,228	39	0,001	0,001	2,050	1,48	2,62

TABLE 6: The SPSS one-way T-Test

6. DISCUSSION OF RESULTS

6.1 Digital technology can be used to track impending hazards and improve safety

***H1a:* I am satisfied with the level of digital technology in my organisation.**

The p-value related to the ability of digital wearables to improve safety using data analytics is 0,000 which makes it significant. The hypothesis is thus rejected as most people were not satisfied with the level of technology from their organisations. From previous literature which was related to the slow adoption of digital technology in the industry it has been observed that some of the challenges of digital technology implementation in the mining industry is mainly IT/ICT-related, these described as the lack of required digital skill sets and digital disconnection. Studies have also shown that the minerals, mining, and metals industries have been found to be rated at a digital intensity index (DII) of around only 10 per cent with the problematic zones highlighted from IT/ICT infrastructural constraints and abilities. The review noted the importance of ICT/IT as an integral enabler of digital transformation initiatives and should not be seen as a solution of its own (Zulu et al., 2021, pp.185-200).

***H1b*: I believe that integrating digital technology into safety is important towards eliminating potential incidents.**

The study found out that there is a p-value of 0,822 which is higher than the acceptable threshold of 0,05. The hypothesis is insignificant therefore accepted.

Majority of the respondents believed that technology could improve safety and eliminate potential hazards. The mining sector has acknowledged that although there have been improvements in safety due to digitalisation, there has been implementation challenges pertaining to digitised safety drives over the few decades. A study on how the Fourth Industrial Revolution is building value in our mining industry and where it's headed was conducted through a survey where more than 30% of the respondents believed there will be improvement in health and safety performance over the next five years due to the positive impact of digital technology. Whilst 25% of the respondents expect no improvement over the next five years (Verhaeghe et al., 2021). Although there is technology there is still the human dimension, technology dimension and the gap which does not necessarily mean the wearable on its own will eliminate potential incidents. More research will be required to look further into the gaps.

6.2 Real time data can be used to generate active controls in health and safety to eliminate or minimise incidents

<u>H2a:</u> I am well informed with statistical knowledge of the safety incidents in my organization.

The p-value related to the statistical knowledge of safety data is 0.135 higher than acceptable value of 0,05 which makes it insignificant. The respondents were satisfied and knowledgeable of the safety data in their specific organisations.

<u>H2b:</u> I believe that real-time information will help us identify the likelihood of similar hazards.

The use of real-time data to assist identify the likelihood of similar hazards by means of digital wearables has p-value of 0,844. Therefore, the hypothesis is insignificant and supported. Most respondents have agreed that the ability to have active data can be used to actively reduce and eliminate impending hazards.

6.3 Safety improvement can be achieved through adoption of technology which increases the amount of information efficiency flow

<u>H3:</u> My organisation does a good job of helping me understand how previous incidents will affect my work and re-occurrences.

The p-value related to the adoption of digital wearable technology to safety improve information flow is 0,00 which is lower than the acceptable threshold of 0,05. This hypothesis is classified significant. The hypothesis is thus rejected as most of the respondents from the questionnaire disagreed that the current status quo in safety management is efficient and that introduction to real data can assist with real time incidents that are happening and updates. This would imply that the “as-is” situation is not optimal; the flow of information will be increased through digital technology with more effort placed on the interpretation, the right receivers and coding of information to fulfil the above hypothesis to impede hazards and improve.

6.4 Training can improve human interaction with technology to ensure adequate skill sets to address the emerging needs of 4IR

<u>H4a</u>: Training towards digital transformation will help me understand how digital technology will affect my organization's productivity.

The need for training towards digital transformation to improve safety has a p-value of 0,564 therefore, the hypothesis is thus accepted. Most of the respondents believe that there is requirement for training to close the gap between technology and human interaction. As stipulated in hypothesis H1a the respondents also disagreed that they were satisfied with the level of technology in their specific organisations.

***H4b*: I am satisfied with the level of training towards digital transformation in my organisation.**

The study found out that the relationship between level of training and technology towards safety improvement p-value of 0,00 is lower than the acceptable threshold of 0,05. The hypothesis is significant and rejected. In South Africa, previous efforts and the impact of advanced technologies had their various challenges. With a number of people viewing technology as a threat, thus an opportunity exists to change the current narrative behind advanced technology adoption. Organisations need a buy-in strategy from their workforce through a balance between advanced technologies adoption and social sustainability. Various organisations have begun to strategize around a balance of adopting new technologies and employee buy-in, which is a collaboration and strategy alignment between the organisation and the workforce. An existing example is that of Jendamark, a local South African automation company, which introduced a concept 'Digital Ubuntu' to establish harmony between technology and human interaction. Digital Ubuntu is the idea of people joining forces to solve a problem digitally (Mangaroo-Pillay et al., n.d., pp.1-12).

6.5 *Digital technology reduces incidents and injuries resulting from physically demanding manual tasks*

***H5:* I believe digital wearables will have greater effect than a physical checklist.**

This study found that the relationship between reduction of Incidents and prevalence in injuries resulting from the physically demanding manual tasks is significant with the p- value is 0,000 below the acceptable p- value of 0,05. The hypothesis is thus rejected. This is somewhat surprising given the potential of digital wearables in getting real-time data. This may be related to the ability of firms to process the data. It could be the case, that a physical checklist is desirable as the status quo but with training and the acquisition of appropriate technology, digital wearables will be more beneficial. This issue warrants further investigation.

A gap still exists to introduce new wearable technologies that can collect human performance data, monitor ambient conditions, and reduce the negative effect of activity on the body during work. These technologies have the potential to advance our ability to acquire directly measured data for research purposes, reduce task and job demands on miners, and to provide health and safety information to mine workers. Examples of developed technologies include sensors which are used to monitor gas and noise levels and exoskeletons which can be used to augment and support the human body to prohibit musculoskeletal disorder (Dempsey et al., 2018, pp. 1-11). Theoretically this research article aims to identify the drivers of digital wearables/ digital technology adoption by South African Mines. The aim of the study was to investigate how digital transformation can assist in enhancing safety in South African Mines. Digital wearables adoption was unpacked in the form of the status quo of the digital technology in the industry, the gap between the digital technology, human interface and implementation in relation to applications of data analytics and what needs to be done to achieve a full operational data analytics system (Zulu et al., 2021, pp. 184-200).

7. RECOMMENDATIONS AND CONCLUSIONS

The above research was influenced by the need to prevent recurrences of safety incidents making use of digital technology to collect active data. Multiple frameworks have been used to validate the study, there are some limitations that provide a gap for future researchers. The surveyed respondents were drawn from multiple mining geographic locations. Future studies should cover vast functions of the mining industry. The survey was conducted at a time when there were systems introduced in the implementation phase. There was a general tendency by respondents to be reluctant to participate and there was a substantial effort to follow up on respondents. Future researchers may need to develop a safe way of conducting research surveys that encourage natural participation.

The research analysed the key drivers supporting the adoption of digital technology specifically focusing on the adoption of digital wearables. The key drivers were identified as information efficiency flow, reducing impeding hazards and injuries by way of training to improve human interaction with technology. The results suggest that technology can play a role in enhancing safety standards in mines. Technology will improve information efficiency but organisations lack “holistic and proactive approaches” in balancing the adoption of technology and industrial social sustainability (Mangaroo-Pillay et al., n.d., pp. 1-12).

South Africa, is confronted with a wicked problem of high unemployment and inequality, therefore the technology adoption must be approached with careful consideration. The approach should be designed to consider certain factors and the need to balance social sustainability when adopting new technology. 4IR adoption in South Africa can be uniquely customised through the phenomenon of ‘Ubuntu’ and how Digital Ubuntu can redefine this transformation through inclusion (Mangaroo-Pillay et al., n.d., pp.1-12).

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Appendix A

QUESTIONNAIRE

H1: *Digital technology can be used to track impending hazards and improve safety.*

I believe that integrating digital technology into safety is important towards eliminating potential incidents.

I am satisfied with the level of digital technology in my organisation.

H2**:** *Real time data can be used to generate active controls in health and safety to eliminate or minimise incidents.*

I am well informed with statistical knowledge of the safety incidents in my organization.

I believe that real time information will help us identify the likelihood of similar hazards.

H3: *Safety Improvement can be achieved through adoption of technology which increases the amount of information efficiency flow.*

My organisation does a good job of helping me understand how previous incidents will affect my work and re-occurrences.

H4: *Training can improve h*uman interaction with technology to ensure adequate skill sets to address the emerging needs of 4IR.

Training towards digital transformation will help me understand how digital technology will affect my organization's productivity.

I am satisfied with the level of training towards digital transformation in my organisation.

H5: *Digital technology reduces incidents and injuries resulting from physically demanding manual tasks.*

I believe digital wearables will have greater effect than a physical checklist.

Appendix B:

DATA SETS

H2a	H3	H2b	H5	H4a	H4b	H1a	H1b
I am well informed with statistical knowledge of the safety incidents in my organization	My organization does a good job of helping me understand how previous incidents will affect my work and re-occurrences	I believe that real time information will help us identify the likelihood of similar hazards	I believe digital wearables will have greater effect than a physical checklist	Training towards digital transformation will help me understand how digital technology will affect my organizations productivity	I am satisfied with the level of training towards digital transformation in my organization	I am satisfied with the level of digital technology in my organisation	I believe that integrating digital technology into safety is important towards eliminating potential incidents
Strongly agree	Strongly disagree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Strongly disagree	
Strongly agree	Strongly disagree	Strongly agree	Somewhat agree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Somewhat agree	Strongly agree	Somewhat agree	Somewhat disagree	Strongly agree
Strongly agree	Somewhat agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat agree	Strongly agree
Somewhat agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat agree	Somewhat agree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly agree	Strongly agree	Strongly agree
Strongly agree	Somewhat agree	Strongly agree	Strongly disagree	Strongly agree	Strongly agree	Somewhat agree	Strongly agree
Strongly agree	Somewhat agree	Strongly agree	Strongly agree	Strongly agree	Somewhat disagree	Neither agree nor disagree	Strongly agree
Neither agree nor disagree	Somewhat disagree	Strongly agree	Strongly agree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Neither agree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree

			nor disagree				
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Neither agree nor disagree	Strongly agree
Strongly agree	Somewhat agree	Somewhat agree	Neither agree nor disagree	Strongly agree	Neither agree nor disagree	Strongly disagree	Somewhat agree
Somewhat agree	Somewhat disagree	Strongly agree	Neither agree nor disagree	Strongly agree	Somewhat disagree	Somewhat disagree	Neither agree nor disagree
Strongly agree	Somewhat agree	Strongly agree	Strongly disagree	Strongly agree	Neither agree nor disagree	Somewhat disagree	Strongly agree
Strongly agree	Strongly disagree						
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Somewhat agree	Somewhat agree	Somewhat agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree	Strongly agree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat agree	Somewhat agree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree
Somewhat agree	Somewhat disagree	Strongly agree	Strongly disagree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat agree	Somewhat agree	Strongly agree
Somewhat agree	Neither agree nor disagree	Strongly agree	Strongly agree	Somewhat agree	Somewhat disagree	Neither agree nor disagree	Strongly agree
Strongly agree	Strongly agree	Strongly disagree	Somewhat agree	Strongly agree	Strongly disagree	Neither agree nor disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat agree	Somewhat agree	Strongly agree
Somewhat agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat agree
Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree

Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Neither agree nor disagree	Somewhat disagree	Somewhat disagree	Strongly disagree	Somewhat agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Somewhat disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Neither agree nor disagree	Somewhat disagree	Strongly agree
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Somewhat agree	Somewhat agree	Strongly agree
Strongly agree	Strongly agree	Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Strongly agree
Strongly agree	Strongly disagree	Somewhat agree	Neither agree nor disagree				
Strongly agree	Strongly agree						
Strongly agree	Strongly disagree						
Strongly agree	Strongly disagree	Strongly agree	Strongly disagree	Strongly agree	Somewhat disagree	Somewhat disagree	Strongly agree
Somewhat agree	Strongly disagree	Strongly agree	Neither agree nor disagree	Somewhat agree	Somewhat disagree	Strongly disagree	Strongly agree
Neither agree nor disagree	Neither agree nor disagree	Strongly agree	Somewhat agree	Strongly agree	Somewhat disagree	Strongly disagree	Strongly agree

APPENDIX C

ETHICS APPROVAL

[OFFICIAL]

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/BA0303199a/689

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	The impact of digital wearables on safety in the South African mining industry
Investigator / Researcher	Ms Nthabiseng Bapela
Nature of Project	MBA (Research Article)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed anonymity and confidentiality.
Issue Date of Certificate	2022-10-14
Expiry date	Date of submission of the project / research report
Chairperson	Prof Anthony Stacey +27 11 717 3587 +27 82 880 4531 anthony.stacey@wits.ac.za

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.

Signature

09 /Jan /2023
Date: