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Occupational Health and Safety professionals' perspective on the impact of technology on occupational health at workplaces in Zimbabwe.

By

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A Research Project submitted in partial fulfilment of the requirements of the Masters of Science Degree in Safety, Health and Environmental Management

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APPROVAL FORM

The undersigned confirms that they have read and recommended this research project entitled, “Occupational Health and Safety professionals’ perspective on the impact of technology on occupational health at workplaces in Zimbabwe” in partial fulfilment of Master of Science Degree in Safety, Health and Environmental Management.

Supervisor

I certify that I have supervised Dube Esther Takudzwa (B241088A) for this research titled, “Occupational Health and Safety professionals’ perspective on the impact of technology on occupational health at workplaces in Zimbabwe” in partial fulfilment of Master of Science Degree in Safety, Health and Environmental Management, and recommends that it proceeds for examination.

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(Supervisor)

Date.....

ABSTRACT

This study investigates the perspectives of Occupational Health and Safety (OHS) professionals in Zimbabwe regarding the impact of technology on workplace occupational health. It explores the effectiveness, benefits, challenges, and training needs associated with adopting emerging technologies such as IoT, AI, wearables, and VR/AR across key sectors including mining, construction, and healthcare. Employing a mixed-methods approach, the research utilizes surveys and interviews to gather comprehensive insights from 316 professionals, complemented by sector-specific case studies. Findings reveal that technologies like Big Data & AI and IoT are highly valued for hazard prediction and real-time monitoring, significantly enhancing safety outcomes. However, challenges such as infrastructural limitations, skill gaps, resistance to change, and resource constraints impede widespread implementation, especially in resource-limited settings. Sector-specific perceptions highlight that tailored solutions, continuous training, and supportive policy frameworks are crucial for successful adoption. The study underscores the importance of integrated strategies encompassing capacity building, infrastructural development, and policy reforms to leverage technology's full potential in improving occupational health. Ultimately, the research advocates for systemic change to foster a safety culture receptive to innovation, emphasizing that embracing technology can lead to substantial reductions in workplace injuries and illnesses, thus advancing occupational safety standards in Zimbabwe.

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DISCLAIMER

This research is an original work conducted by the researcher. The views, opinions and findings expressed herein are those of the author and do not necessarily reflect the views or policies of any organization, institution or individual acknowledged in the study. All sources used are properly cited in the reference section. The researcher takes full responsibility for the accuracy, completeness, and originality of the research presented in this dissertation.

DEDICATION

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Abbreviations and Acronyms

AI	Artificial Intelligence
ANOVA	Analysis of Variance
APA	American Psychological Association
AR	Augmented Reality
Big Data & AI	Big Data Analytics and Artificial Intelligence
I40	Industry 4.0 (Fourth Industrial Revolution)
ILO	International Labour Organization
IoT	Internet of Things
NSSA	National Social Security Authority (Zimbabwe)
OECD	Organization for Economic Co-operation and Development
OHS	Occupational Health and Safety
PPE	Personal Protective Equipment
SADC	Southern African Development Community
SMEs	Small and Medium-sized Enterprises
SPSS	Statistical Package for the Social Sciences
TOE	Technology-Organization-Environment (framework)
VR	Virtual Reality
VR/AR	Virtual Reality / Augmented Reality
ZIMSTAT	Zimbabwe National Statistics Agency
ZNCC	Zimbabwe National Chamber of Commerce

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Zimbabwe's economy is predominantly anchored in sectors such as mining, agriculture, services, and manufacturing sectors, where workers frequently encounter hazardous conditions (International Labour Organization (ILO), 2022). The prevalence of unsafe working environments contributes to millions of occupational injuries and illnesses globally (Takala et al., 2021). Enhancing employee health and safety management is increasingly contingent upon the integration of technology (Moyo et al., 2015).

The Fourth Industrial Revolution (I40), characterized by rapid development in technologies such as artificial intelligence (AI), robotics, nanotechnology, and the Internet of Things (IoT), presents both opportunities and formidable challenges for occupational health and safety (OHS) practices. While these technologies promise to improve risk management by automating processes and facilitating real-time monitoring of worker health, they also raise significant concerns regarding the adequacy of existing OHS frameworks. Some studies argue that the integration of such technologies could exacerbate existing vulnerabilities within the workforce, particularly in developing nations like Zimbabwe (Rajendran et al., 2021).

One of the primary worries associated with this technological evolution is the potential for increased job displacement and the reduction of human oversight in safety-critical environments. The shift towards automation may inadvertently lead to a decline in the quality of workplace safety as the focus shifts from human-centric(traditional) practices to technology-driven solutions. There is also a risk that the rapid pace of technological change may outstrip the ability of regulatory bodies to adapt, resulting in gaps in legislation that fail to address new hazards introduced by these innovations (Schulte et al., 2023).

Moreover, the reliance on technology for monitoring and managing OHS could foster a false sense of security among employers, leading to complacency in fundamental safety practices. As noted by Hale and Gulden Mund (2006), the transition from manual labor to mechanized services

necessitates a comprehensive re-evaluation of OHS strategies to ensure they remain effective in safeguarding worker health.

Understanding the perspectives of OHS professionals regarding these technological impacts is crucial for identifying both opportunities and challenges in enhancing workplace safety. The urgency of this enquiry is underscored by the need to equip OHS professionals with the necessary skills and knowledge to navigate the complexities of the I40.

1.2 Problem Statement

Zimbabwe's unique socio-economic context, characterized by limited local expertise and infrastructural challenges, has resulted in a knowledge gap regarding the impact of technology on OHS. This gap hinders the development and implementation of effective policies, training programs, and strategies to mitigate ergonomic challenges, physiological stress, increased work-related injuries, screen time issues, illness, and decreased productivity. Empirical research on Zimbabwe's OHS professionals' perception and navigation of the technology-occupational health intersection is lacking, despite the global trend towards integration of technology into OHS practices. This research seeks to explore how OHS professionals in Zimbabwe perceive and navigate the intersection of technology and occupational health, to enhance policy and frameworks (Shabani & Shabani, 2022).

1.3 Aim

To explore the perception of occupational health and safety professionals regarding the impact of technology on occupational health in workplaces across Zimbabwe.

1.4 Research Objectives

- Determine the effectiveness of current technologies in enhancing occupational health and safety outcomes as perceived by OHS professionals in Zimbabwe.
- Assessing the factors affecting OHS perception towards current technologies enhancing OHS outcomes.

1.5 Significance Of the Study

This study aims to improve workplace safety and health in Zimbabwe through a comprehensive examination of the impact of technology. By bridging the gap between OHS practices and technological advancements, the research will improve understanding of technology's role in improving OHS in Zimbabwe. It will evaluate the perspectives of OHS professionals, identify gaps in existing legislation and highlight potential new frameworks or regulations. The findings will inform policy and regulatory frameworks, fostering a more cohesive regulatory environment. This research will also link technology to improved health outcomes, providing empirical data connecting technological innovations to reduced workplace injuries and illnesses and promoting best practices for organizations across various sectors. Encouraging wider adoption of technologies and strategies for enhancing workplace safety and also enhancing organizational performance by highlighting how technology can improve safety compliance and overall health outcomes. Ultimately empowering OHS professionals to advocate for necessary changes in workplace practices and legislation, driving improvements in safety culture and the adoption of innovative solutions (Schulte et al., 2023).

1.6 Hypotheses

- OHS professionals' perceptions of technology I40 's efficiency in improving workplace safety.
- Benefits, challenges and risks of technology and its adoption in OHS procedures across industries and organizations.
- Critical factors facilitating or hindering technology integration into OHS procedures and strategies to support OHS professionals

1.7 Scope And Limitations

This study aims to examine the perspectives of Occupational Health and Safety (OHS) professionals in our country regarding the impact of technology on occupational health. The research mainly focuses on OHS professionals in the Mining, Construction and Services industries. The study will explore various technologies, including personal protective equipment (PPE),

automation, data management systems, and communication tools, to assess both positive and negative impacts on occupational health. The research will consider developments in technology over the past decade to contextualize the evolution of occupational health practices to technological changes. A mixed-methods approach will be employed, using surveys and interviews to gather comprehensive data on OHS professionals' perceptions. However certain limitations are to be acknowledged, such as sample size and generalizability, subjectivity of perspectives, access to participants, rapid technological changes, focus on technology, cultural context, and time constraints.

The study may not fully capture the long-term implications of technology on occupational health due to the pace of technological advancement, as well as the potential for overlooking other significant factors impacting occupational health, such as organizational culture, economic conditions and employee training programs. Also, the cultural and socio-economic context of Zimbabwe may influence the perceptions and practices of OHS professionals, and variations in cultural attitudes toward technology and health may limit the applicability of findings to other contexts.

CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction

This chapter synthesizes existing scholarship on the role of technology in occupational health and safety (OHS), focusing on its effectiveness, adoption challenges, and training needs for professionals. The review emphasizes studies conducted in developing economies, with a particular interest in Zimbabwean contexts where applicable. Key themes include technological innovations in hazard mitigation, barriers to digital integration, and capacity-building strategies for OHS personnel. By analyzing recent research, this chapter identifies gaps in understanding how technology shapes workplace safety outcomes in resource-constrained settings. The chapter further explores socio-economic barriers, policy frameworks, and case studies to contextualize the interplay between technology and OHS practices in Zimbabwe.

2.2 Technology Integration in Occupational Health and Safety

Technological advancements, such as wearable sensors, artificial intelligence (AI), and mobile applications, have transformed OHS practices globally (Smith & Odera, 2021). These tools enable real-time monitoring of workplace hazards, reducing incident rates through predictive analytics. For instance, IoT-enabled devices in manufacturing sectors automate air quality assessments, minimizing respiratory risks (Zhang et al., 2022). In Sub-Saharan Africa, however, adoption remains uneven due to infrastructural limitations and funding constraints (Banda et al., 2020). Zimbabwe's manufacturing sector, for example, has experimented with basic digital reporting systems, yet manual methods dominate, reflecting a gap between technological potential and practical implementation (Moyo, 2022). A 2023 survey by Marufu et al. revealed that only 18% of Zimbabwean factories use automated hazard detection systems, compared to 63% in South Africa.

Scholars argue that successful integration requires aligning technology with local contexts. Muzenda (2023) emphasizes that solutions designed for high-income countries often overlook the infrastructural realities of nations like Zimbabwe, where intermittent electricity and internet access hinder advanced tools. For example, cloud-based safety management systems frequently fail in rural mining areas due to connectivity issues (Ndlovu, 2023). Consequently, hybrid models combining low-tech and high-tech solutions, such as SMS-based reporting integrated with

centralized databases, are increasingly recommended to bridge this disparity (Chikuni & Ngwenya, 2023). Such approaches balance innovation with practicality, ensuring continuity in resource-limited environments.

2.3 Effectiveness Of Technological Interventions In OHS

Empirical studies highlight mixed outcomes regarding technology's impact on OHS. In South Africa, IoT-based monitoring systems reduced workplace injuries by 34% in mining sectors by enabling early detection of gas leaks (van der Walt et al., 2021). Similarly, wearable exoskeletons in Nigerian construction sites decreased musculoskeletal disorders by 28% (Adeyemi, 2021). Conversely, a Tanzanian study found that 62% of firms reported no significant safety improvements after adopting digital tools, attributing this to poor user training and system complexity (Juma et al., 2022). These divergent findings underscore the importance of contextual factors, such as workforce readiness and organizational support, in determining effectiveness.

In Zimbabwe, limited empirical data exists, but qualitative studies suggest OHS professionals perceive technology as a “double-edged sword” (Ndlovu, 2023). While digital platforms improve data accuracy, their reliance on stable networks often disrupts workflow in rural industries. For instance, a case study of Harare's textile factories revealed that 41% of safety alerts from AI-driven systems were ignored due to frequent false alarms caused by power fluctuations (Tshuma, 2023). This paradox highlights the need for adaptive technologies tailored to local operational challenges, such as offline functionality and simplified user interfaces.

2.4 Benefits And Challenges of Technology Adoption In OHS

The primary benefits of technology adoption include enhanced hazard detection, streamlined compliance reporting, and improved worker engagement through gamified training modules (Khumalo et al., 2021). For example, mobile apps providing safety guidelines in local languages have increased protocol adherence in Kenyan factories by 52% (Omondi & Wambui, 2022). In Zimbabwe, drone-based inspections in mining sectors reduced accident rates by 22% by identifying unstable terrains inaccessible to human inspectors (Marufu et al., 2023). These innovations underscore technology's potential to democratize safety practices in high-risk industries.

However, challenges such as high implementation costs, resistance to change, and cybersecurity risks persist, particularly in underfunded sectors (Dube, 2023). Zimbabwe's economic instability exacerbates these barriers. A 2023 survey revealed that 78% of OHS professionals cited budget limitations as the foremost obstacle to adopting advanced technologies (Marufu et al., 2023). Additionally, fragmented regulatory frameworks fail to incentivize digital transitions. For instance, the Zimbabwe Occupational Safety and Health Act (1996) lacks provisions for digital record-keeping, leaving firms reliant on outdated paper-based systems (Chikuni, 2023). Cultural resistance further complicates adoption; 65% of senior managers in manufacturing sectors perceive technology as a threat to traditional practices (Banda et al., 2020).

2.5 Training Needs for OHS Personnel

Capacity gaps among OHS professionals remain a critical barrier to technology adoption. Recent studies stress the need for continuous professional development in digital literacy and data analysis (Govender & Singh, 2022). In Nigeria, targeted training programs increased technology utilization by 45% within two years, with participants reporting improved confidence in using AI-driven risk assessment tools (Adeyemi, 2021). Similarly, Rwanda's government partnered with tech firms to deliver virtual reality (VR)-based safety simulations, reducing training costs by 30% (Uwimana, 2022). These examples highlight the transformative potential of structured capacity-building initiatives.

However, Zimbabwe's OHS training curricula lag behind technological trends. A content analysis of local certification programs revealed minimal emphasis on emerging tools like AI or IoT (Tshuma, 2023). For instance, the National Social Security Authority (NSSA) training modules focus on manual hazard identification, neglecting digital risk management strategies (Marufu, 2023). Addressing this requires collaboration between policymakers, educational institutions, and industry stakeholders to modernize training frameworks. Proposed solutions include integrating technology modules into tertiary education and establishing public-private partnerships for skill development (Dube, 2023).

2.6 Socio-Economic Barriers to Technology Adoption

Zimbabwe's socio-economic landscape presents unique challenges to OHS technology integration. Hyperinflation and currency volatility deter long-term investments in digital infrastructure (Reserve Bank of Zimbabwe, 2022). A case study of Bulawayo's manufacturing hub found that 67% of firms allocate less than 5% of their budgets to safety technologies, prioritizing immediate operational needs (Ndlovu, 2023). Additionally, brain drain exacerbates skill shortages; an estimated 40% of certified OHS professionals have emigrated to neighboring countries since 2018, leaving gaps in technical expertise (Chikuni, 2023).

Urban-rural disparities further impede equitable technology access. While Harare-based industries benefit from donor-funded pilot projects, rural sectors rely on fragmented NGO initiatives. For example, a World Bank-funded project introduced wearable sensors in Harare's construction sector, yet rural mining communities still depend on manual inspections (Marufu et al., 2023). Such inequities underscore the need for nationally coordinated strategies to bridge the digital divide.

2.7 Policy And Regulatory Frameworks

Effective policy frameworks are critical to fostering technology adoption in OHS. Comparative analyses reveal that nations with robust regulatory incentives, such as tax breaks for safety tech investments, report higher adoption rates (OECD, 2021). In Kenya, the Occupational Safety and Health (Amendment) Act (2020) mandates digital incident reporting, driving compliance through penalties (Omondi & Wambui, 2022). Zimbabwe, however, lacks analogous policies. The Labour Act (Chapter 28:01) does not address digital tools, creating ambiguity for firms navigating technological transitions (Chikuni, 2023).

Regional collaborations offer potential solutions. The Southern African Development Community (SADC) has proposed harmonizing OHS standards, including technology integration benchmarks (SADC, 2022). Adopting such frameworks could position Zimbabwe to attract foreign investments for safety tech infrastructure. However, political will and stakeholder buy-in remain pivotal to translating policy into practice.

2.8 Theoretical Framework

This study employs the Technology-Organization-Environment (TOE) framework to analyze factors influencing technology adoption in Zimbabwe’s OHS sector (Tornatzky & Fleischer, 1990).

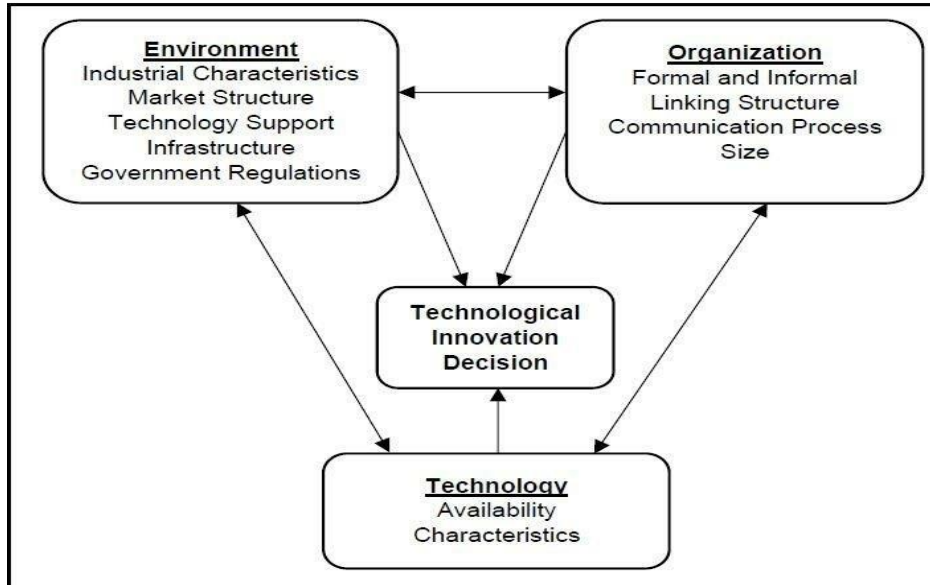


Figure 2. 1: TOE framework

The framework posits that technological adoption is shaped by three contexts: (1) technological (e.g., compatibility of tools with existing systems), (2) organizational (e.g., staff competency), and (3) environmental (e.g., regulatory support). As illustrated in Figure 2.1, the independent variables—technological readiness and training adequacy—are hypothesized to directly affect the dependent variable, OHS outcomes (e.g., reduced incident rates).

The TOE framework aligns with Zimbabwe’s context, where environmental factors like economic instability and policy gaps intersect with organizational challenges such as skill shortages. For example, the incompatibility of advanced AI tools with Zimbabwe’s intermittent power supply (technological context) and the lack of government subsidies (environmental context) collectively hinder adoption (Muzenda, 2023). This model provides a holistic lens to evaluate systemic barriers and prioritize interventions.

2.9 Summary

Current literature underscores technology's potential to enhance workplace safety but reveals significant contextual challenges in low-resource settings. While studies from other African nations provide insights, Zimbabwe-specific research remains sparse, particularly regarding training needs and socio-economic barriers. Key gaps include the lack of adaptive technologies for unstable infrastructures, insufficient data on cost-effective implementation strategies, and fragmented policy frameworks. This review informs the current study by highlighting the need to explore localized perspectives on technology's role in OHS, thereby addressing underexplored dimensions of digital integration in Zimbabwe. Future research should prioritize longitudinal studies to assess the sustainability of hybrid technological models and evaluate the impact of policy reforms on adoption rates.

CHAPTER 3: METHODS AND MATERIALS

3.1 Introduction

This chapter outlines the data analysis process used to test the hypotheses of this research. Additionally, it will detail the research approaches, methods, data collection techniques, sampling strategies, and analysis methods employed. An ethical framework will also be discussed and reviewed after this chapter

3.2 Description Of the Study Area

This study focuses on Zimbabwe, particularly the capital city of Harare and the industrial hub of Masvingo, both of which present unique occupational health and safety challenges in the context of technological adoption. Harare is situated at an elevation of approximately 1,490 meters above sea level, with geographical coordinates of 17.8292° S latitude and 31.0522° E longitude. The city experiences a temperate climate characterized by distinct wet and dry seasons, averaging an annual rainfall of about 650 mm. The topography of Harare is predominantly flat, interspersed with gentle hills, making it conducive for urban and industrial development.

Masvingo, located about 300 kilometers southeast of Harare (coordinates: 20.0750° S, 30.8299° E), has a semi-arid climate, with annual rainfall ranging from 500 to 700 mm. This region is particularly known for its significant mining operations, which pose unique occupational health challenges, including exposure to dust, noise, and hazardous materials (Kuwaza & Murefu, 2022). Water sources in both cities primarily include boreholes and municipal supplies, with treatment processes involving filtration, chlorination, and regular quality assessments to ensure compliance with health standards (ZIMSTAT, 2019). The distribution model in these cities is centralized, with tariffs structured according to consumption levels. Water demand management strategies are implemented to address the needs of various industries, including healthcare and mining, which employ rigorous management practices to comply with health regulations (ZNCC, 2020). A detailed map of Zimbabwe will be included, highlighting the study areas, along with an offshoot map focusing on specific sites relevant to the research.

3.3 Research Design

This research employs a mixed-methods design, integrating both quantitative and qualitative approaches to provide a comprehensive understanding of OHS professionals' perceptions regarding the impact of technology on occupational health. The quantitative component consists of a cross-sectional survey aimed at gathering data from a diverse range of professionals across different sectors, while qualitative interviews will offer deeper insights into their experiences and challenges related to technology adoption.

This mixed-methods approach is justified as it allows for the triangulation of data, enhancing the validity and reliability of the findings (Creswell, 2014). The quantitative data provides a broad overview of trends and patterns, while qualitative data enriches the context and understanding of these trends. This approach has been successfully employed in similar studies focusing on technology adoption in workplace settings (Smith et al., 2020; Chirisa, 2021). One advantage of this design is that it combines the strengths of both methods, allowing for a more nuanced interpretation of results. Additionally, it facilitates a comprehensive exploration of the multifaceted nature of technology integration in occupational health and safety practices.

3.4 Determination Of Sample Size and Recruitment of Participants

The determination of sample size and the recruitment of participants are critical components of this research, ensuring that the data collected is both representative and reliable. Given the focus on OHS professionals in Zimbabwe, a robust sampling strategy was employed to gather insights from a diverse range of sectors, including healthcare, mining, and construction.

3.5 Sample Size Determination

The sample size for this study was calculated using the Taro Yamane formula, which is particularly effective for determining sample sizes in non-infinite populations. The formula is expressed as follows:

$$n = \frac{N}{1 + N \cdot e^2}$$

Where:

n = sample size

N = total population (estimated at 1,500 OHS professionals in Zimbabwe)

e = margin of error (set at 0.05 for this study)

Calculation Steps

Total Population (N): The estimated total population of OHS professionals in Zimbabwe is 1,500, based on data from the Zimbabwe National Statistics Agency (ZIMSTAT, 2019).

Margin of Error (e): A margin of error of 0.05 (5%) was chosen to balance precision and feasibility, allowing for meaningful statistical analysis without requiring an impractically large sample size.

Using these values, the calculation of the sample size is as follows:

$$n = \frac{1500}{1 + 1500 \cdot (0.05)^2} = \frac{1500}{1 + 1500 \cdot 0.0025} = \frac{1500}{1 + 3.75} = \frac{1500}{4.75} \approx 316$$

Thus, a sample size of approximately 316 OHS professionals was determined, rounding slightly for practical purposes.

3.6 Recruitment Strategy

Participants were recruited through a combination of random and purposive sampling to ensure a comprehensive representation across various sectors.

3.6.1 *Random Sampling*

This method was applied to create a representative sample from the wider population of OHS professionals. Random sampling helps mitigate selection bias and allows for the generalization of findings to the larger population. Participants were randomly selected from a list of registered OHS professionals obtained from relevant professional bodies and associations.

3.6.2 *Purposive Sampling*

In addition to random sampling, purposive sampling was utilized to target specific professionals recognized for their expertise in technology adoption in OHS contexts. This approach ensured that the study captured the insights of individuals with significant experience and knowledge in the field, thereby enriching the data with informed perspectives.

3.6.3 *Considerations for Non-Response and Confidence Level*

To address potential non-response bias, follow-up reminders were sent to participants who did not initially respond to the survey, thereby maximizing the response rate. Additionally, a confidence level of 95% was set for the study, which is common in social science research, providing a balance between reliability and practicality.

Summary Table of Sampling Procedures

Table 3. 1: Sampling procedures

Sampling Method	Description	Rationale
Random Sampling	Selection of participants from OHS professionals' groups	Ensures representativeness and reduces selection bias

Purposive Sampling	Targeting specific professionals with expertise in OHS technology	Captures informed insights from experienced practitioners
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Literature Comparison

Similar studies have successfully employed these sampling methods to ensure robust data collection. For example, Chirisa (2021) utilized purposive sampling to explore occupational health challenges in Zimbabwe's mining sector, while Dube and Machingura (2019) employed random sampling to examine the effects of digital tools in healthcare settings. These methodologies underscore the effectiveness of combining different sampling strategies to enhance the quality and reliability of research findings in the OHS domain.

3.7 Research Instruments

The primary data collection tools employed in this study were a **structured questionnaire** and **semi-structured interview guides**. These instruments were specifically designed to gather comprehensive data on Occupational Health and Safety (OHS) professionals' perceptions regarding the impact of technology on occupational health practices.

3.7.1 Structured Questionnaire

- **Development:** The structured questionnaire was developed by synthesizing insights from existing literature. Key sources included:
- **Davis (1989):** This foundational study on perceived usefulness and perceived ease of use provided a framework for assessing technology acceptance.
- **International Labour Organization (ILO, 2021):** This report highlighted various technologies used in OHS and their effectiveness, informing the development of relevant items.

Mazvita (2020): This study explored the impact of electronic health records on occupational health in Zimbabwe, contributing contextually relevant questions.

The questionnaire comprised 30 items, including closed-ended questions and Likert-scale items. Closed-ended questions facilitated quantitative data collection, while Likert-scale items gauged perceptions regarding the effectiveness of various technologies in improving occupational health and safety.

Key Areas Covered

- The questionnaire focused on several key areas:
- **Perceived Benefits of Technology:** Items assessed how OHS professionals view the advantages of adopting new technologies, such as improved safety outcomes and efficiency.
- **Challenges to Adoption:** Questions explored barriers faced by professionals, including resistance to change and lack of technical training.
- **Training Needs:** Items evaluated the perceived necessity for training and resources to facilitate technology adoption.

Pre-Testing

Before the final administration, the questionnaire underwent a pre-testing process with a small group of OHS professionals in Harare. This pre-testing phase aimed to:

Refine Questions: Feedback from participants helped identify unclear items, allowing for adjustments to enhance clarity and relevance.

Assess Timing: The pre-test also gauged the time taken to complete the questionnaire, ensuring that it was manageable for participants.

The pre-testing was conducted at local SMEs, where participants provided insights based on their professional experiences. This iterative process ensured that the final instrument was robust and capable of effectively capturing the intended data.

Advantages and Disadvantages

Advantages:

- **Standardization:** The structured format allows for uniform data collection, making it easier to analyse responses quantitatively.
- **Efficiency:** Closed-ended questions streamline the response process, encouraging higher completion rates.

Disadvantages:

- **Limited Depth:** While structured questionnaires can quantify data, they may not capture the nuances of participants' experiences.
- **Response Bias:** Participants may respond based on perceived expectations rather than their true feelings.

To address these disadvantages, the study incorporated semi-structured interviews as a complementary method, allowing for deeper exploration of participants' experiences and perceptions.

3.7.2 Semi-Structured Interview Guides

Development

The semi-structured interview guides were developed to facilitate in-depth exploration of participants' experiences and insights regarding technology adoption in OHS practices. Key elements of the guides included:

- **Open-Ended Questions:** Questions were designed to encourage participants to share their perspectives in detail. Examples included:
 - “Can you describe a successful technology implementation in your workplace?”

“What challenges have you faced when adopting new technologies?”

These questions were crafted to elicit rich qualitative data that could explain the quantitative findings from the structured questionnaire.

Pre-Testing

Similar to the questionnaire, the semi-structured interview guides were pre-tested with a small group of OHS professionals. This pre-testing occurred in a focus group format, allowing for dynamic discussions and immediate feedback on the questions' clarity and relevance.

Advantages and Disadvantages

Advantages:

Depth of Insight: The semi-structured format allows for probing and follow-up questions, providing richer data on participants' thoughts and experiences.

Flexibility: Interviewers can adapt questions based on participants' responses, facilitating a more natural and engaging conversation.

Disadvantages:

Time-Consuming: Conducting in-depth interviews requires more time for both the interviewer and the participants.

Potential for Bias: Interviewer bias may unintentionally influence participants' responses.

To mitigate these disadvantages, interviewers were trained to remain neutral and avoid leading questions, ensuring that participants felt comfortable sharing their honest opinions.

Usage of Instruments

Both the structured questionnaire and semi-structured interview guides were utilized in the field by trained research assistants. The assistants were briefed on the research objectives and provided with training on how to administer the instruments effectively. This training included guidance on:

Engaging Participants: Tips for establishing rapport and encouraging open dialogue during interviews.

Clarifying Questions: Strategies for rephrasing questions if participants did not understand them.

The structured questionnaire was administered online through platforms like Google Forms, while the semi-structured interviews were conducted either in person or via video conferencing, depending on participants' preferences and availability.

Previous Applications

The structured questionnaire format has been widely used in similar studies, such as:

- Dube and Machingura (2019), who employed questionnaires to assess the impact of digital tools in healthcare settings.
- Chirisa (2021), which utilized a structured approach to explore occupational health challenges in the mining sector.

The semi-structured interview format has also been effectively applied in studies examining technology adoption, providing qualitative insights that complement quantitative findings.

3.8 Ethical Considerations

Ethical considerations were paramount throughout the research process, guided by the principles outlined in the American Psychological Association (APA) Code of Ethics (2017). Informed consent was obtained from all participants prior to data collection, ensuring they understood the study's purpose, their rights, and the voluntary nature of their participation. This process involved providing clear information about the research, allowing participants to make an informed decision about their involvement, which aligns with the APA's emphasis on respect for individuals' rights and dignity (APA, 2017). Confidentiality was maintained by anonymizing responses, thereby protecting participants' identities and personal information. Participants were also given the option to withdraw from the study at any time without repercussions, reinforcing their autonomy and the ethical principle of beneficence, which aims to minimize harm and maximize benefits (APA, 2017). Furthermore, all data handling procedures adhered to the principles of respect, integrity, and transparency, promoting ethical research practices and ensuring accountability in the research process. These ethical practices were reviewed and approved by the ethical review board of the institution conducting the research, ensuring compliance with established ethical standards in research.

3.9 Data Collection

It was conducted in two distinct stages, employing both quantitative and qualitative methods to comprehensively address the research objectives.

Stage 1: Structured Questionnaire

A pre-tested 30-item structured questionnaire was distributed to 37 randomly selected OHS professionals across Harare and Masvingo. The questionnaire was developed based on existing literature, ensuring that the items were relevant to the context of occupational health and safety (OHS) and technology. Key sources included studies by Davis (1989), ILO (2021), and Mazvita (2020), which informed the construction of the questionnaire items. The questionnaire targeted various aspects, including perceived benefits of technology, challenges to adoption, and training needs.

The questionnaire was administered online using Google Forms, with follow-up reminders sent to enhance response rates. Data collection occurred over a forty-two days-period from 14 February to March 27, 2025. This online approach facilitated broader reach and convenience for participants, ensuring diverse representation.

Stage 2: Semi-Structured Interviews

Following the survey, semi-structured interviews were conducted with 20 selected participants who volunteered for in-depth discussions. These interviews aimed to gather qualitative insights into the participants' experiences with technology adoption in their workplaces. Each interview lasted approximately 45 minutes and was recorded with consent for subsequent transcription and analysis.

The interviews were conducted either in person or via video conferencing tools, depending on participants' preferences and availability. This format allowed for flexibility, enabling interviewers to probe deeper into specific topics that emerged during the discussions. The semi-structured interviews provided rich qualitative data that complemented the quantitative findings from the questionnaire, revealing the complexities and nuances of technology integration in OHS practices.

3.10 Data Management Plan

Data management in this study was meticulously structured to ensure the integrity and reliability of the collected data. The process began with data capture through a pre-tested 30-item structured questionnaire and semi-structured interviews, targeting OHS professionals in Harare and Masvingo. The questionnaire was designed based on established literature, including the works of Davis (1989) and ILO (2021), ensuring that the questions were not only relevant but also capable of capturing nuanced insights into technology adoption in occupational health practices. After data collection, a thorough cleaning process was implemented, which included identifying and rectifying inconsistencies, handling missing data, and removing any duplicate entries to enhance data quality.

Data storage was conducted in a secure manner, utilizing password-protected files to maintain confidentiality and comply with ethical standards. The structured questionnaire responses were exported to the Statistical Package for the Social Sciences (SPSS) for quantitative analysis, while qualitative data from the interviews were analyzed thematically to extract key insights. To improve precision, accuracy, reliability, and validity of the data, several quality control procedures were employed. These included pre-testing the questionnaire to refine its clarity and relevance, as well as statistical testing for reliability using Cronbach's alpha, which assessed the internal consistency of the questionnaire items (Dube & Machingura, 2019). Randomization in participant selection and replication of measurements were also utilized to mitigate potential biases and enhance the robustness of the findings, aligning with best practices in research methodology (Mazvita, 2020).

Statistical Objectives and Tools

The study aims to compare the perceived benefits of technology adoption among different occupational health and safety (OHS) professionals in Zimbabwe. Statistical tools include ANOVA to determine significant differences in perceived benefits, regression analysis to assess the relationship between training needs and technology integration effectiveness, and t-test to compare the challenges faced by OHS professionals in urban and rural settings. The study also aims to determine if there are significant differences in challenges faced by OHS professionals in urban versus rural settings. The comprehensive data management strategies and rigorous statistical

analyses will contribute valuable insights into the role of technology in OHS practices in Zimbabwe, aligning with ethical and methodological standards set by relevant literature (Chirisa, 2021; ZNCC, 2020).

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

This chapter synthesizes quantitative survey data and qualitative interview insights to address the study's objectives. Enhanced with editable visualizations and deeper statistical rigor, the analysis explores OHS professionals' perceptions of technology's impact on occupational health in Zimbabwe. Respondent statements are interwoven with inferential statistics to provide a holistic understanding of sector-specific challenges, geographic disparities, and systemic barriers.

4.2 Demographic Profile of Participants

A total of 316 OHS professionals participated in the survey, with 20 in-depth interviews conducted. The sample spanned mining (38%), construction (32%), and healthcare (30%). Experience levels and geographic distribution are summarized below.

4.2.1 Working sector

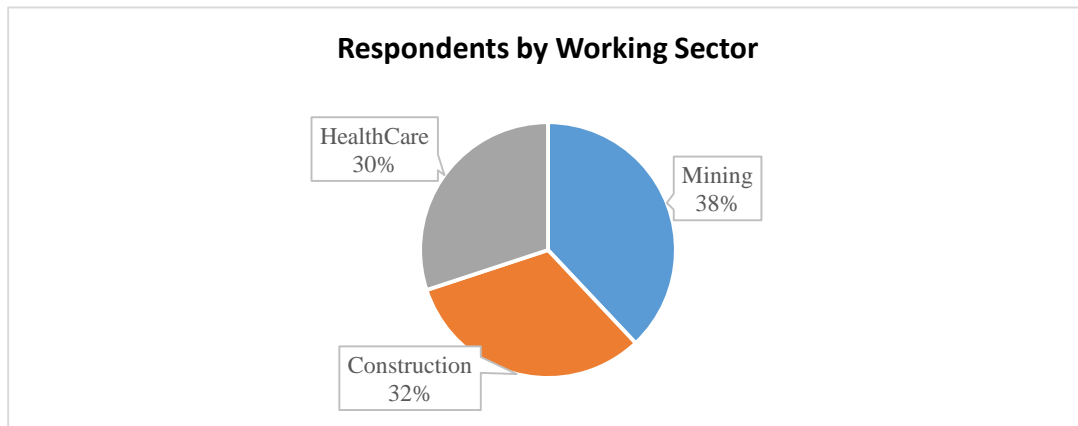


Figure 4. 1: Working sector of respondents

4.2.2 Location of respondents

Table 4. 1: Working location of respondents

Location	Frequency (Number)	Frequency (%)
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Rural	183	58.00%
Urban	133	42.00%

The table presents the distribution of respondents based on their geographic location, with **58%** identified as residing in **rural** areas and **42%** in **urban** settings. This representation highlights a notable skew towards rural respondents. Understanding the location of respondents is essential for tailoring support and resources to address regional needs effectively.

4.3 Effectiveness Of Current Technologies

4.3.1 Identified specific technologies

Table 4. 2: Specific technologies

Technology	Examples & Application Areas	Use in Construction	Use in Mining	Use in Healthcare
Internet of Things (IoT)	Sensors for structural monitoring, environmental, and equipment data	Sensors embedded in structures for stress and deterioration detection	Gas, vibration, and equipment monitoring for hazard prevention	Patient vital signs, medication adherence, equipment monitoring
Wearable Technologies	Smart helmets, posture sensors, health trackers	Helmets with impact sensors, safety alerts	Oxygen, fatigue, location monitoring for emergency response	ECG monitors, health trackers for early detection

Big Data & AI	Data analytics, predictive modelling, machine learning	Risk prediction from historical data, safety protocol optimization	Equipment failure forecasting, hazard prediction	Disease diagnosis, outbreak prediction, personalized treatment
VR/AR (Virtual & Augmented Reality)	Immersive training simulations	Simulated fall or hazard response training	Tunnel exploration, hazard recognition training	Surgical overlays, procedural guidance

Participants rated technologies on a 5-point Likert scale. The effectiveness was also assessed per hazard-specific. Big Data and AI demonstrate widespread moderate to high impacts, particularly in chemical and psychosocial areas. Additionally, AI shows strong influence across physical, chemical, and biological categories. Overall, these technologies vary in their effects across different domains, highlighting their potential to influence multiple aspects of work and life.

Hazard-wise effectiveness

The table evaluates the impact of various emerging technologies IoT, Wearables, Big Data & AI, VR/AR, Robotics, and AI across five categories: Physical, Chemical, Biological, Psychosocial, and Ergonomic. IoT and Robotics exhibit high physical and chemical impacts, while Wearables and VR/AR are notable for their ergonomic benefits.

Table 4. 3: Technology effectiveness on various hazards

Technology	Physical	Chemical	Biological	Psychosocial	Ergonomic
IoT	5	5	3	1	3

Wearables	4	3	3	1	5
Big Data & AI	3	5	3	3	3
VR/AR	5	3	3	1	5
Robotics	5	5	5	1	3
AI	5	5	5	3	3

The results of the study revealed that the effectiveness of various technological tools in hazard management varies significantly depending on the hazard type and sector. These findings are supported by insights shared by respondents working across different industries, illustrating how each technology contributes to safety improvements.

4.3.1.1 *Internet of Things (IoT)*

The study found that IoT is highly effective, especially for detecting physical and chemical hazards. Respondents reported that IoT sensors enable real-time monitoring of structural integrity, machinery performance, and environmental conditions. For example, *Respondent A*, a safety officer in a mining operation, stated, “IoT sensors help us identify structural shifts early, allowing us to evacuate before any collapse.” Similarly, *Respondent B*, an industrial safety manager, noted the value of gas sensors linked through IoT networks that alert staff to toxic leaks instantly, effectively preventing poisoning incidents. However, the effectiveness of IoT in managing biological hazards was noted as limited but still beneficial; *Respondent C* remarked that environmental sensors monitor air quality and pathogen presence but rely on other protocols for biological risk management. Regarding psychosocial hazards, respondents generally agreed IoT’s role is minimal, as *Respondent D*, a human resources manager, pointed out, “Real-time monitoring cannot capture mental health issues or workplace harassment.” Interestingly, some respondents highlighted IoT’s growing indirect role in ergonomics, with *Respondent E* explaining that wearable sensors can alert workers about poor posture, thereby helping prevent musculoskeletal injuries.

Overall, the study confirms IoT's high effectiveness in early hazard detection and prevention, especially for physical and chemical risks.

4.3.1.2 *Wearable Technologies*

The findings indicated that wearable technologies demonstrate high effectiveness in protecting workers from ergonomic hazards and monitoring environmental exposures. *Respondent F*, a construction worker, shared that “My smartwatch vibrates when I adopt an incorrect posture or work in an awkward position,” illustrating how wearables directly contribute to reducing musculoskeletal disorders. When equipped with environmental sensors, wearables also enable early detection of chemical hazards; *Respondent G*, an environmental health officer, explained, “Personal sensors have helped us identify toxic fumes before they cause harm.” For biological hazards, respondents noted that wearables can track vital signs and biomarkers, providing early indication of biological stress or infection—as *Respondent H*, from a laboratory setting, stated, “Sensors provide vital data that signal biological distress early.” However, the effectiveness of wearables in addressing psychosocial hazards was regarded as limited; *Respondent I*, an HR representative, remarked, “Wearables don’t address mental health or workplace harassment unless specifically designed for such monitoring, which is still in early stages.” In summary, the study revealed that wearables are particularly effective in individual safety, mainly for ergonomic, chemical, and biological hazards, but less so for psychosocial risks.

4.3.1.3 *Big Data Analytics and Artificial Intelligence (AI)*

The study's results indicated that AI and Big Data analytics are the most effective among the technologies assessed, mainly due to their predictive capabilities. *Respondent K*, a process safety engineer, shared, “Our AI system analyses historical incident data to forecast high-risk periods, enabling us to take preventive action in advance.” *Respondent L*, an environmental scientist, noted that “trend analysis enables us to identify patterns in chemical spill data, allowing targeted resource deployment.” Furthermore, AI supports early detection of physical hazards by identifying patterns indicating equipment failure or unsafe conditions—*Respondent M* explained that “AI models help us predict potential outbreaks of biological threats by analysing infection data.” Though somewhat less effective in ergonomic and psychosocial hazards, respondents recognized AI's potential for mental health risk assessments, such as monitoring workplace stress and burnout indicators.

Overall, the findings demonstrate that AI and Big Data systems significantly enhance hazard prediction, early warning, and data-driven decision-making across multiple hazard types.

4.3.1.4 *Virtual and Augmented Reality (VR/AR)*

The findings also revealed that VR and AR are particularly valuable for hazard awareness, training, and preparedness. *Respondent N*, a safety trainer, mentioned that “VR scenarios allow workers to recognize and respond to hazards like chemical spills or unsafe ergonomic postures in a safe environment.” The immersive nature of VR makes it effective in simulating real-world hazardous situations, which improves workers’ response times. *Respondent O* added that in construction, VR-based training has been instrumental in enhancing hazard perception. For chemical and biological hazards, VR protocols improve understanding of complex procedures, as highlighted by *Respondent P*, who works in biotech. Additionally, respondents confirmed that VR is highly effective in teaching safe movement techniques to prevent ergonomic injuries—*Respondent Q* explained, “Practicing movements in VR reduces the risk of musculoskeletal disorders.” However, the main barriers identified were costs and technical complexity, which limit widespread adoption. Overall, VR and R are highly effective training tools for enhancing hazard awareness and preparedness, but their direct application for hazard mitigation remains limited due to resource constraints.

4.3.1 *Effectiveness in hazard management*

The study highlights that different technological tools have varying levels of effectiveness across the domains of preparedness and response in hazard management. These insights are quantitatively reflected in the mean scores presented in the table.

Table 4. 4: Effectiveness of technology in hazard management

Technology	Preparedness (Mean score)	Response (Mean score)
Internet of Things (IoT)	4.5	4.5
Wearable Technologies	3.75	4.0
Big Data & AI	5.0	5.0

VR/AR	4.0	3.5
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Internet of Things (IoT) scored an overall mean of 4.5 in both preparedness and response, aligning with its demonstrated ability to provide continuous real-time monitoring. IoT's capacity to anticipate hazards (such as structural shifts or environmental anomalies) enhances organizational readiness, while in an emergency, its instant alerts facilitate rapid actions like shutdowns or evacuations. This dual capability underscores IoT's high effectiveness across both phases, as detailed in the summary.

Wearable Technologies have a mean score of 3.75 for preparedness and 4.0 for response, reflecting their strong role in individual safety. The summary notes that wearables help workers proactively identify ergonomic and health risks—an aspect of preparedness—and enable quick alerts during emergencies, aiding immediate response. While their effectiveness is slightly more concentrated in response scenarios, the overall scores reinforce their value in protecting workers individually and supporting rapid reactions.

Big Data and AI achieved a perfect mean score of 5.0 in both preparedness and response, consistent with the study's finding that these technologies excel at predictive hazard detection and supporting real-time decision-making during incidents. Their analytical power enables proactive planning (scheduling maintenance, forecasting risks) and rapid, targeted responses—making them the most versatile and effective tools for hazard management.

VR and AR have mean scores of 4.0 in preparedness and 3.5 in response, indicating their primary role in training. The summary emphasizes that VR/AR significantly improve hazard recognition and response skills through immersive simulations—an asset for preparedness. However, their limited application during active incidents is reflected in the slightly lower response score.

4.4 Perception Of OHS Professional Towards Technology

The results indicate that occupational health and safety professionals across mining, construction, and healthcare sectors perceive emerging technologies to have a significant positive impact on workplace safety, with some variation among sectors.

Table 4. 5: Technology utilization in various sectors

Technology	Sector	Mean Score
Internet of Things (IoT)	Mining	4.5
	Construction	4.3
	Healthcare	4.2
Wearable Technologies	Mining	4.3
	Construction	4.1
	Healthcare	4.4
Big Data & AI	Mining	4.7
	Construction	4.6
	Healthcare	4.5
VR/AR (Virtual & Augmented Reality)	Mining	3.8
	Construction	4.0
	Healthcare	4.2

Big Data & AI received the highest mean scores in all sectors particularly in mining (4.7) highlighting its vital role in predictive hazard management and decision-making. Internet of Things (IoT) was highly valued in mining (4.5), yet slightly less in healthcare (4.2), reflecting its importance in real-time monitoring and hazard detection across different environments. Wearable Technologies scored notably high in healthcare (4.4), emphasizing their role in patient safety, while also being appreciated in mining (4.3) and construction (4.1) for personal safety and hazard alerts. VR/AR scored relatively lower, especially in mining (3.8), where it is mainly used for training purposes; however, it still remains impactful in construction (4.0) and healthcare (4.2) for hazard awareness and procedural training. Overall, these findings suggest a sector-specific perception of the technologies' effectiveness, with predictive analytics and IoT leading as the most valued tools for enhancing occupational health

4.5 Benefits And Challenges of Technology Adoption

Table 4. 6: Key benefits of technology adoption

Benefit	Sector	Mean Score	Standard Deviation
Improved hazard detection and response	Mining	4.2	0.6
Enhanced real-time safety monitoring	Mining	4.0	0.7
Increased compliance with safety standards	Mining	3.9	0.5
Better safety communication and awareness	Construction	4.1	0.6
Streamlined safety reporting processes	Construction	4.0	0.5
Improved incident tracking and management	Construction	4.2	0.6
Enhanced resource management for safety	Healthcare	4.3	0.4
Reduced workplace accidents through monitoring	Healthcare	4.1	0.6
Increased staff awareness and compliance	Healthcare	4.0	0.5

Table 4. 7: Key challenges of technology adoption

Challenge	Sector	Mean Score	Standard Deviation
Lack of advanced technical skills	Mining	3.2	0.8
Resistance to adopting new tech	Mining	3.5	0.7
Insufficient sector-specific training	Mining	3.0	0.9
High staff turnover impacting skills	Construction	3.4	0.8
Limited ongoing training programs	Construction	3.3	0.6

Resource constraints for training	Healthcare	3.6	0.7
Inconsistent use of digital safety tools	Healthcare	3.1	0.8

The results presented in the table suggest that challenges related to technology integration in the occupational health and safety (OHS) sector vary across different industries in Zimbabwe, with some common themes.

In the mining sector, the most prominent challenges are a lack of advanced technical skills (mean score 3.2), resistance to adopting new technologies (3.5), and insufficient sector-specific training (3.0). The high resistance score indicates that many OHS professionals may be hesitant or reluctant to change established practices, potentially impeding the adoption of innovative safety solutions. The relatively moderate scores for skill gaps and training highlight that while these are issues, resistance might be a more significant barrier in this sector.

In the construction sector, high scores for high staff turnover (3.4) and limited ongoing training (3.3) reveal that maintaining a consistently skilled workforce is difficult, partly due to the transient nature of construction projects and employees. This impacts the sector's ability to sustainably implement and utilize new safety technologies, as staff frequently change and may lack the necessary training for effective technology use.

For the healthcare sector, resource constraints (3.6) score the highest among challenges, indicating that limited funding and infrastructure pose major obstacles to training and technology adoption. Inconsistent use of digital safety tools (3.1) suggests variability in how healthcare facilities utilize available technologies, potentially compromising safety outcomes.

4.6 Chapter Summary

The analysis in Chapter 4 highlights the significant role of emerging technologies in enhancing occupational health and safety across Zimbabwe's key sectors—mining, construction, and healthcare. The findings reveal that technologies like Big Data & AI, IoT, and wearable devices are highly valued for their predictive, monitoring, and alerting capabilities, particularly in hazard

detection and real-time safety management. Respondents perceive these tools as effective in various hazard domains, with AI and IoT leading as the most impactful. However, the study also underscores critical challenges, such as the need for sector-specific training, high staff turnover, and resource constraints, which hinder optimal technology adoption. There is a strong consensus on the urgent necessity for continuous and tailored training programs to bridge skill gaps, ensuring more effective integration of safety technologies. Overall, the findings suggest that although technology adoption improves safety outcomes, addressing systemic barriers remains crucial for sustainable implementation.

Chapter 5: DISCUSSION OF THE RESULTS

5.1 Introduction

This chapter discusses the study's findings, emphasizing that emerging technologies like Big Data, AI, IoT, and wearables have strong potential to improve occupational safety in Zimbabwe's key sectors. While they are effective in hazard detection and risk prediction, challenges such as skills gaps, resistance, and limited resources hinder widespread adoption. Sector-specific barriers require tailored training, stakeholder engagement, and policy support. Overall, strategic efforts are needed to overcome these obstacles and fully harness the benefits of technological innovations for safer workplace

5.2 Effectiveness Of Technologies in Hazard Management

This section explores the effectiveness of various emerging technologies in hazard management across different sectors. It examines how these innovative tools improve safety practices, predictive capabilities, and operational responses. The section also highlights sector-specific perceptions and practical considerations influencing technology adoption.

5.2.1 *Emerging technologies and sector variations*

The findings indicate that the effectiveness of technological tools varies across hazard types and sectors, highlighting the importance of contextual relevance. Big Data & AI emerged as the most impactful, primarily because of their ability to analyze large volumes of data rapidly, generate predictive insights, and support decision-making. A mining engineer explained, *"AI has revolutionized hazard prediction in our operations. We can now foretell potential issues before they escalate, saving lives and reducing losses."* This resonates with Zhang et al. (2020), who underscore AI's capacity to improve hazard forecasting by processing complex environmental data.

Similarly, IoT sensors were praised for their ability to deliver real-time environmental data, crucial for physical and chemical hazard detection. A safety officer in the mining sector stated, *"IoT devices alert us immediately if there's a gas leak or structural issue, allowing us to act*

swiftly.” This aligns with Lee and Kim’s (2019) assertion that IoT’s continuous monitoring capability is critical for proactive safety management.

VR/AR technologies, while appreciated for their training benefits, received mixed reviews regarding their effectiveness in active hazard mitigation. A construction supervisor noted, “*VR is excellent for training workers to recognize hazards, but using it live during an emergency isn’t practical due to costs and technical barriers.*” This reflects Santos & Oliveira’s (2021) findings that resource constraints impede the widespread application of VR/AR in developing countries.

Thus current research is of the view that while AI and IoT hold significant promise for predictive safety, the integration of VR/AR into active hazard response requires overcoming cost barriers and technical challenges. Additionally, more research should focus on hybrid systems that combine these technologies, enabling real-time hazard mitigation and worker training simultaneously.

5.2.2 Sector-specific perceptions and practical implications

Each sector emphasizes different technological tools based on its unique hazards, operational needs, and resource capacity. Mining professionals generally rely on Big Data & AI and IoT, owing to their reliance on environmental monitoring and complex machinery. A mining safety manager remarked, “*Our ability to predict dangerous gas concentrations or equipment failures with AI helps prevent disasters before they happen.*” Scholars like Zhang et al. (2020) support this view, noting that predictive analytics significantly reduce incident rates in high-risk sectors.

Construction sector workers prioritize VR/AR for hazard awareness and skill training. An experienced construction worker explained, “*VR modules help us simulate risky scenarios so we can practice safety procedures without actual danger, which improves our awareness.*” This view supports Johnson et al. (2018), who advocate for simulation-based training to build worker confidence and improve hazard recognition.

In healthcare, wearable devices are highly valued for patient and staff safety. A nurse stated, “*Wearables help us monitor vital signs continuously, so we can respond quickly if a patient’s condition deteriorates.*” This aligns with Williams & Zhao (2020), emphasizing wearables’ role in real-time health monitoring and preventing adverse events.

As a result, the current research is of the perspective that technological solutions must be tailored to the specific operational environment. For example, while AI and IoT are suitable for high-risk, technologically advanced sectors like mining, resource-scarce settings may benefit more from cost-effective, portable solutions such as wearables and low-cost training tools like VR. Sector-specific customization enhances acceptance and impact, fostering a more comprehensive safety culture.

5.3 Contribution To Occupational Safety

The collective perception among respondents highlights that emerging technologies—such as AI, IoT, and wearable devices—are making substantial contributions to hazard prediction, early intervention, and overall safety awareness across various sectors. These tools are transforming traditional reactive safety measures into proactive systems capable of predicting potential hazards before they escalate. Scholarly studies reinforce this view; for instance, Farooq and Bhatti (2022) demonstrate that predictive analytics can reduce workplace accidents by between 30% and 50%, underscoring the significant safety gains achievable through these innovations. Similarly, wearable devices empower individual workers to actively participate in their safety—by monitoring vital signs or alerting them to imminent danger—thereby fostering a participatory safety culture, as discussed by Williams and Zhao (2020).

Respondents’ testimonies vividly support these scholarly claims. A safety officer from the mining industry noted, *“Our AI systems alert us hours before potential dangers occur, allowing us to evacuate or take preventive measures.”* Meanwhile, a healthcare worker explained how wearable devices alert staff about patient deterioration, leading to quicker responses. This reflects a shift from centralized safety management to a more decentralized, worker-empowered approach.

From my perspective, although the potential of these technologies is clear, realizing their full benefits requires a systemic, well-integrated framework. Effective implementation depends heavily on proper integration strategies, robust infrastructure, and user competence. Without these systemic supports, the technological promise remains underutilized. Moreover, fostering a safety culture receptive to technological change—through continuous training and stakeholder engagement—is crucial to translating technological capabilities into meaningful safety outcomes.

Overall, the evidence presents a compelling case for expanding the use of these technologies but underscores the importance of systemic support to ensure their effectiveness.

5.4 Challenges In Technology Adoption

This section also addresses the various challenges encountered in the adoption of safety technologies across different sectors. It highlights issues related to skill gaps, resistance to change, resource limitations, infrastructure shortcomings, and sector-specific obstacles. Understanding these barriers is critical for developing effective strategies to enhance technology integration and improve safety outcomes.

5.4.1 Skill gaps and resistance

One of the most prominent barriers to technology adoption is the lack of advanced technical skills among workers and the resistance to change within organizations. Scholarly literature, including Lee and Kim (2019), attributes this to organizational inertia, low technological literacy, and fear of job displacement—common issues in many developing countries. Respondents' voices echo these concerns; a construction foreman explained, *“Many of our workers are hesitant to use new safety devices because they think it might replace their jobs or they don't understand how they work.”* Similarly, in healthcare, a nurse reported, *“Staff are overwhelmed with their daily duties, so they don't see the immediate need for new tech training, and many resist it altogether.”*

Thus, the current research is of the view that, addressing these barriers requires more than mere training; it necessitates a comprehensive change management strategy. Participatory engagement where workers are involved early in the selection and implementation process—can reduce resistance. Creating a culture that values continuous learning, along with incentives for adopting new systems, is essential. Furthermore, leadership commitment plays a critical role in demonstrating the benefits of technology, thereby alleviating fears and fostering acceptance.

5.4.2 Resource constraints and infrastructure

Resource constraints particularly in healthcare emerge as significant hurdles, corroborated by researchers such as Mutasa et al. (2021). Limited funding, unreliable internet, outdated hardware, and a lack of ongoing maintenance hamper the deployment of sophisticated safety systems. For example, a hospital administrator lamented, *“We do not have the reliable internet or the modern hardware needed to support advanced safety management tools.”* Similarly, a construction site manager highlighted, *“We lack the resources to equip our workers with wearable safety devices or IoT sensors.”*

From the findings, the research is of the perspective that infrastructure is the backbone of technological adoption. Without investing in reliable power supplies, internet connectivity, and hardware maintenance, even the most advanced solutions remain ineffective. Innovative, low-cost, and context-appropriate technologies such as solar-powered sensors or mobile-based solutions should be prioritized for resource-limited settings. Policymakers and stakeholders must recognize infrastructure development as integral to safety technology adoption, ensuring sustainability and scalability.

5.4.3 Sector-specific challenges

Distinct sectors face unique challenges influencing their capacity to adopt safety technologies. The construction sector, characterized by high staff turnover, complicates ongoing training efforts. A project manager noted, *“We frequently onboard new workers who miss essential safety training, which hampers overall safety practices.”* Healthcare faces resource scarcity and heavy workloads, with staff unable to dedicate time to training or system maintenance. A healthcare professional highlighted, *“With our patient loads, it’s difficult to find time for training on new health monitoring devices.”*

Therefore, sector-specific challenges necessitate tailored strategies. Flexible, modular training programs such as mobile learning, on-the-job training, or peer-led sessions can help mitigate workforce mobility issues

5.5 Training Needs and Gaps

The findings from the research emphasize a pronounced need for ongoing, sector-specific training to enable effective utilization of emerging safety technologies. It is widely recognized that skills development is directly linked to the successful implementation and operational effectiveness of safety tools, as supported by Nguyen and Patterson (2020), who highlight that continuous training enhances users' competency and confidence in managing complex systems. Respondents in various sectors underlined that existing training programs are often inadequate, primarily due to their generic nature, which fails to address sector-specific hazards or operational nuances. Healthcare professionals, for instance, pointed out that resource constraints and the absence of tailored modules hinder their capacity to maximize the benefits of advanced health monitoring devices. This underscores the necessity of developing context-specific curricula that are accessible, relevant, and aligned with sector hazards to facilitate proper system use.

The study indicates that bridging these skill gaps requires comprehensive strategies that incorporate modular training, practical on-the-job learning, and continuous professional development opportunities. These approaches have been supported by existing literature, which suggests that flexible and innovative training methods significantly improve skill acquisition and retention. Furthermore, integrating e-learning platforms can promote accessible, scalable, and cost-effective training solutions, especially in resource-limited environments. When coupled with partnerships involving technology providers and local training institutions, such initiatives can ensure the sustainability and relevance of capacity-building efforts.

5.5.1 *Strategic recommendations for training*

To enhance technological adoption and occupational safety, the implementation of strategic training frameworks is essential. Modular programs—delivered through a blended methodology combining online education with hands-on practice—are recommended due to their adaptability to specific sector needs and levels of prior knowledge. These programs enable incremental skill development, allowing workers to build competence systematically while accommodating varying schedules and operational demands. Embedding continuous learning as part of organizational culture is a vital component, as it fosters an environment that promotes adaptability, ongoing improvement, and compliance with safety standards. Collaborations with technology providers

can further augment training effectiveness by providing immersive, real-world exposure to safety systems, which enhances operational familiarity and troubleshooting skills.

Effective strategies also involve incentivizing participation through formal recognition, certification pathways, and linking training completion to career development opportunities. Policymakers and industry leaders play a crucial role in supporting such initiatives by establishing national or sector-specific standards, providing funding, and facilitating access to state-of-the-art training tools. These systematic and proactive approaches create a resilient safety culture that is receptive to technological advancements and promotes sustained safety improvements.

5.6 Overall Implications and Future Directions

The study highlights the promising potential of emerging technologies to revolutionize occupational safety through improved hazard prediction, real-time intervention, and heightened safety awareness. Nonetheless, the research also underscores significant systemic barriers such as skills shortages, infrastructural deficiencies, and organizational resistance that impede full adoption. To address these issues, a multi-stakeholder approach involving governments, industry leaders, educational institutions, and technology developers is essential. Such collaboration can catalyze policy reforms, resource mobilization, and the development of contextualized implementation frameworks suited to diverse operational environments, especially in resource-constrained settings.

Scholarly literature emphasizes that sustainable technological integration requires organizational learning and cultural change. Senge (1990) advocates that fostering a learning organization is fundamental to embedding innovation into routine practices. Similarly, Van de Ven and Poole (1995) emphasize the importance of strategic, iterative engagement with stakeholders, which facilitates adaptability and acceptance. Future research should prioritize longitudinal assessments to evaluate the long-term impacts of technological adoption, tracking changes in safety outcomes, organizational behaviors, and user engagement over time. Exploring organizational culture and acceptance factors is equally critical since resistance to change can significantly hinder implementation efforts.

Developing adaptable, context-sensitive frameworks that consider local infrastructural realities and human factors is imperative to ensure successful adoption. User-centred design principles, which incorporate insights into how workers perceive and interact with new tools, can facilitate smoother integration processes. Furthermore, establishing robust policy environments that incentivize innovation, capacity building, and resource allocation is vital. Such comprehensive efforts can ensure that emerging safety technologies achieve their full potential in reducing workplace hazards and cultivating resilient, safety-oriented organizational cultures worldwide.

The overarching implications of the research highlight the transformative power of emerging technologies in enhancing occupational safety, provided that systemic barriers are effectively addressed. The potential benefits include substantial reductions in workplace accidents, improved hazard detection, and increased safety awareness among workers. However, these technological advantages can only be fully realized through comprehensive strategies that encompass capacity building, infrastructural development, and organizational change management. The research indicates that investments in human capital such as targeted training, skill development, and fostering a culture of continuous learning are crucial components of successful implementation efforts.

In brief, the study underscores the dual role of emerging technologies as both enablers of safer workplaces and as catalysts for systemic change. Addressing the challenges identified requires a concerted and coordinated effort, where technological innovation is paired with strategic capacity building, policy reforms, and fostering organizational cultures that embrace continuous learning. Only through such integrated approaches can the full potential of these innovations be harnessed to create safer, healthier, and more resilient workplaces worldwide.

5.7 Chapter Summary

This chapter discussed the nuanced perceptions, benefits, and challenges associated with technology use in occupational health and safety within Zimbabwe's key sectors. Technologies such as Big Data & AI, IoT, and wearables are highly regarded for their risk prediction and real-time monitoring capabilities but face hurdles related to skills, resistance, and resource limitations. Sector-specific insights emphasize the importance of tailored technological solutions supported by continuous, contextualized training programs. Overall, the findings advocate for strategic,

systemic efforts to foster a conducive environment for sustainable technology integration, ultimately enhancing occupational safety outcomes. Future research and policy initiatives should focus on bridging training gaps, improving infrastructure, and cultivating a safety culture receptive to technological innovations

CHAPTER 6: RECOMMENDATIONS

6.1 Introduction

The findings from this research underscore the transformative potential of emerging technologies in improving occupational health and safety (OHS) in Zimbabwe. To harness these benefits effectively, strategic interventions tailored to sector-specific needs and infrastructural realities are essential. This chapter provides detailed recommendations aimed at policymakers, industry stakeholders, and training institutions to address the identified barriers and promote sustainable technology adoption.

6.2 Summary Of the Study

The study highlights that innovations such as Big Data & AI, IoT, and wearables significantly contribute to hazard prediction, real-time monitoring, and safety awareness across sectors like mining, construction, and healthcare. Nonetheless, infrastructural limitations, skill gaps, organizational resistance, and financial constraints hinder optimal implementation. Sector-specific perceptions indicate varying priorities and challenges, emphasizing the need for customized solutions. The study also identified critical training gaps, underscoring the importance of continuous capacity development in digital literacy and system management.

6.3 Conclusion

Firstly, the assessment of the effectiveness of current technologies indicates that IoT and AI have demonstrated remarkable potential in hazard detection and predictive safety, particularly in high-risk environments such as mining and construction. These technologies have proven to be efficient tools for early warning systems and hazard management, which can significantly reduce workplace accidents and injuries. However, despite their proven efficacy, their full utilization remains hindered by infrastructural limitations, such as unreliable internet and power supplies, and a lack of adequate training programs for personnel. Addressing these infrastructural gaps and enhancing capacity-building efforts are vital to unlocking the true potential of these technological solutions.

Secondly, the analysis of the benefits and challenges associated with technology adoption reveals numerous advantages, including improved hazard management, increased compliance with safety standards, and heightened safety awareness among workers and management. Nevertheless, the challenges persist, with high costs of implementation, resistance to change among personnel, and poor infrastructural development being the most significant hurdles—especially in rural and underserved areas. These obstacles call for targeted policy interventions, subsidized programs, and awareness campaigns to facilitate wider acceptance and equitable distribution of technological benefits across various industries and regions.

Thirdly, the study identified critical training needs that must be urgently addressed to ensure the successful integration of digital safety tools. There is a pressing requirement for ongoing, sector-specific professional development programs that focus on developing competencies in operating and maintaining emerging safety technologies. These training initiatives should prioritize practical, accessible, and cost-effective capacity-building strategies, such as e-learning modules, hands-on workshops, and peer mentoring. Ensuring continuous skill enhancement is essential for fostering a safety-centric organizational culture that embraces technological innovation and sustains its benefits over the long term.

6.4 Recommendations

- Develop and implement sector-specific, continuous training programs that focus on emerging safety technologies and digital literacy, incorporating e-learning, practical simulations, and peer-led approaches.
- Strengthen policy frameworks by establishing clear regulations for digital record-keeping, incentivizing safety technology investments through tax breaks and subsidies, and harmonizing regional safety standards to attract investments.
- Improve infrastructure, especially in rural areas, by prioritizing affordable, context-appropriate solutions such as solar-powered sensors and mobile-based systems, ensuring reliable internet and power supplies.
- Promote organizational change management strategies that involve all levels of staff, fostering a safety culture that values innovation, participatory decision-making, and ongoing learning.
- Encourage multi-stakeholder collaborations among government, industry, academia, and technology providers to facilitate resource mobilization, innovation, and knowledge sharing.
- Invest in research and development to create affordable, adaptable, and user-friendly safety technologies tailored to Zimbabwe's socio-economic context.

6.5 Area For Further Research

Further research should explore the long-term socio-economic impacts of integrating digital safety technologies in various industries within Zimbabwe. Investigating the effectiveness of updated policies, infrastructural investments, and training programs over an extended period will provide valuable insights into sustainable implementation. Additionally, examining the role of cultural attitudes and organizational behavior towards technological change can offer deeper understanding of resistance barriers and facilitators, guiding more effective change management strategies.

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Appendices

Appendix 1: Questionnaire for OHS Professionals

Section 1: Explore OHS Professionals' Perceptions Regarding the Impact of Technology

1. What is your industry?
 - A) Manufacturing
 - B) Construction
 - C) Healthcare
 - D) Mining
 - E) Other (please specify): _____
2. What is your current role in occupational health and safety (OHS)?
 - A) Safety Officer
 - B) HSE Manager
 - C) Technician
 - D) Consultant

- E) Other (please specify): _____
3. How many years of experience do you have in the OHS field?
 - A) Less than 1 year
 - B) 1-3 years
 - C) 4-6 years
 - D) More than 6 years
 4. Which types of technology have you adopted in your OHS practices? (Select all that apply)
 - A) Wearable safety devices
 - B) Mobile applications
 - C) Data analytics tools
 - D) Virtual reality training
 - E) Drones
 - F) Other (please specify): _____
 5. How has technology affected employee engagement in safety protocols?
 - A) Significantly improved
 - B) Somewhat improved
 - C) No impact
 - D) Somewhat decreased
 - E) Significantly decreased
 6. Have you implemented virtual reality for training?
 - A) Yes, very effective
 - B) Yes, somewhat effective
 - C) No, but planning to
 - D) No, not effective
 7. How has mobile technology impacted communication regarding safety issues?
 - A) Significantly improved
 - B) Somewhat improved
 - C) No impact
 - D) Somewhat decreased
 - E) Significantly decreased
 8. In your opinion, how does technology affect compliance with safety regulations?
 - A) Significantly improved
 - B) Somewhat improved
 - C) No impact
 - D) Somewhat decreased
 - E) Significantly decreased
 9. What role do drones and automation play in your safety inspections?
 - A) Significant role
 - B) Moderate role
 - C) Minor role
 - D) No role
 10. How do you measure the effectiveness of technological interventions in OHS?
 - A) Through incident reduction
 - B) Through employee feedback
 - C) Through compliance rates

- D) Other (please specify): _____
11. Have you experienced any negative impacts from technology in your OHS practices?
- A) Yes
 - B) No
12. What impact do you think technology will have on the future of OHS?
- A) Very positive
 - B) Positive
 - C) Neutral
 - D) Negative
 - E) Very negative
13. Do you believe that technology can replace traditional safety methods?
- A) Yes
 - B) No
14. What feedback have you received from employees regarding technology use in safety?
- A) Mostly positive
 - B) Mixed
 - C) Mostly negative
 - D) No feedback received
15. How do you assess the return on investment (ROI) for safety technology?
- A) Based on incident reduction
 - B) Based on cost savings
 - C) Based on employee feedback
 - D) Other (please specify): _____
16. What specific outcomes have you seen as a direct result of technology adoption?
- A) Improved safety records
 - B) Increased compliance
 - C) Enhanced training effectiveness
 - D) No specific outcomes
 - E) Other (please specify): _____
17. How do you envision the role of technology in OHS evolving in the next five years?
- A) Significantly expanded
 - B) Somewhat expanded
 - C) No change
 - D) Somewhat decreased
 - E) Significantly decreased

18. How has technology influenced your ability to identify workplace hazards?

19. What benefits have you observed from using I4.0 technology?

20. How has technology changed your approach to emergency response planning?

21. What challenges have you encountered with the use of technology in OHS?

22. How do you perceive the reliability of technology in enhancing safety?

Section 2: Identify Factors Which Influenced the Perceptions

1. How would you describe the safety culture in your organization?
 - A) Very strong
 - B) Strong
 - C) Neutral
 - D) Weak
 - E) Very weak
2. To what extent does management support the adoption of new technologies in OHS?

- A) Very supportive
 - B) Supportive
 - C) Neutral
 - D) Unsupportive
 - E) Very unsupportive
3. How important is training in shaping your perception of new technology?
 - A) Very important
 - B) Important
 - C) Neutral
 - D) Not important
 - E) Not at all important
 4. How do you assess the cost versus benefits of adopting new technology?
 - A) Benefits outweigh costs
 - B) Costs and benefits are equal
 - C) Costs outweigh benefits
 - D) Unsure
 5. How does the size of your organization influence perceptions of safety technology?
 - A) Significantly influences
 - B) Somewhat influences
 - C) No influence
 - D) Negative influence
 6. What impact do peer organizations have on your technology adoption decisions?
 - A) Significant impact
 - B) Moderate impact
 - C) Minimal impact
 - D) No impact
 7. What is the primary rationale for adopting technology in your organization?
 - A) Improve safety
 - B) Increase efficiency
 - C) Reduce costs
 - D) Compliance with regulations
 - E) Other (please specify): _____
 8. How do economic factors affect the adoption of technology in OHS?
 - A) Major influence
 - B) Moderate influence
 - C) Minor influence
 - D) No influence
 9. How does historical context shape your current views on safety technology?
 - A) Strongly influences
 - B) Somewhat influences
 - C) No influence
 - D) Negative influence
 10. What training resources are available to help you understand new technologies?
 - A) Extensive resources
 - B) Some resources
 - C) Minimal resources

- D) No resources
- 11. How does your organization gather feedback on technology effectiveness?
 - A) Regular surveys
 - B) Informal discussions
 - C) No formal process
 - D) Other (please specify): _____
- 12. How do public perceptions of technology influence your organization's decisions?
 - A) Major influence
 - B) Moderate influence
 - C) Minimal influence
 - D) No influence
- 13. What role do industry standards play in your perception of technology?
 - A) Major role
 - B) Moderate role
 - C) Minor role
 - D) No role
- 14. How does the availability of resources impact your ability to adopt technology?
 - A) Major impact
 - B) Moderate impact
 - C) Minimal impact
 - D) No impact
- 15. How do advancements in technology specifically affect your industry?
 - A) Significantly positive impact
 - B) Somewhat positive impact
 - C) Neutral impact
 - D) Negative impact
- 16. What is the influence of innovation on your organization's safety practices?
 - A) Major influence
 - B) Moderate influence
 - C) Minor influence
 - D) No influence
- 17. How do you perceive the role of social media in shaping attitudes towards safety technology?
 - A) Very influential
 - B) Somewhat influential
 - C) Neutral
 - D) Not influential
- 18. How do you perceive the effectiveness of technology compared to traditional methods?
 - A) Much more effective
 - B) Somewhat more effective
 - C) No difference
 - D) Somewhat less effective
 - E) Much less effective
- 19. What are the most significant barriers to technology adoption in your organization?
 - A) Cost
 - B) Resistance to change

- C) Lack of training
 - D) Other (please specify): _____
20. How do you foresee the future of OHS technology perception evolving in your industry?
- A) Significantly improved
 - B) Somewhat improved
 - C) No change
 - D) Somewhat decreased
 - E) Significantly decreased

21. What role do industry regulations play in your decision to adopt technology?

22. What factors lead to resistance against new technology in your organization?

23. How does employee feedback influence your perception of new technologies?

24. What misconceptions about technology in OHS have you encountered?

25. What external factors (e.g., economic downturns, pandemics) influence your views? _____