BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF ENVIRONMENTAL SCIENCE

An assessment of the knowledge, attitudes and practices of construction practitioners towards the adoption of industry 4.0 technologies as a strategy to prevent/ minimize the occurrence of fatalities, injuries and diseases in Zimbabwe's construction sector: A Case Study of Bindura University

By

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DECLARATION

To be compiled by the student

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I Tinotenda G Bongo do hereby declare that this work-related project is my original work and has not been submitted before. All the information derived from the other sources is indicated in the project.

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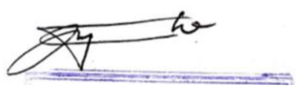
This dissertation is suitable for submission to the faculty and has been checked for conformity with the faculty guidelines.

Signature of the supervisor  Date 30/05/2025

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DEDICATION

I dedicate this dissertation to my family and friends, who have been my biggest source of strength during this journey with their unwavering support and encouragement. I appreciate you supporting me along the journey, encouraging me, and believing in me. I will always be thankful for your sacrifices and love, which made this accomplishment possible.

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ABSTRACT

The construction industry's workplace safety and health is a critical issue, especially in Zimbabwe, where high injury and fatality rates continue despite safety regulations and conventional methods. This is because of the changing nature of risks and the growing complexity of operations. Despite the construction industry's substantial economic contribution, little is known about how Industry 4.0 technology might improve worker safety, especially given the knowledge, attitudes, and practices of construction workers. This study is to explore these facets at Bindura University's Department of Physical Planning and Construction through assessing their present level of comprehension of these technologies, the willingness to use them in the workplace, and the current industry 4.0 technological practices. By understanding these factors, the research seeks to identify gaps and support safer practices in Zimbabwe's construction sector. A descriptive cross-sectional study was carried out and data was collected using research questionnaires. 61 research questionnaires were administered amongst the participants. The questionnaire consisted of 4 sections namely, demographic information, knowledge, attitudes, practices (KAP) section. Data was analyzed using Microsoft Excel 2013 and SPSS version 23.

A total of 56 respondents participated in the study, with 67.9% being men and 32.1% women. There was a 91.8% participation rate against a targeted sample size of 61. Participants between the ages of 18 and 30 made up the largest group (67.9%). Knowledge scores were poor at 39.4%, and attitudes were negative at 43%. Practices were very poor, scoring only 21%. Of the respondents, 28.6% demonstrated an awareness of BIM and its potential to enhance planning and collaboration before starting a building project. Despite 67.9% believing that human labor will be entirely replaced by robots, 58.9% recognized that Industry 4.0 technologies could improve construction safety. However, 73.2% exhibited a negative overall attitude toward adopting these technologies, and 94.6% reported not using BIM in their daily work. Construction practitioners at Bindura University displayed poor knowledge, negative attitudes, and inadequate practices regarding Industry 4.0 technologies. Despite acknowledging the potential benefits of these technologies for improving safety, many respondents expressed concerns about job security, lacked practical experience with them and also less showed confidence in the ability to adapt to technological changes. This illustrates how urgently focused training and awareness campaigns are needed. Through workshops and other ongoing initiatives, the government in collaboration with construction companies must help current practitioners better understand and foster a more positive attitude toward the adoption of technology in the construction industry. It must also change educational curricula to better prepare future practitioners thus meeting education 5.0 which routes for continual learning and adoption of new technologies. Legislators must also establish tax breaks or grants for construction companies using Industry 4.0 technologies.

ACRONYMS AND ABBREVIATIONS

BUSE	-	Bindura University of Science Education
FAES	-	Faculty of Agriculture and Environmental Science
FOC	-	Faculty of Commerce
FSE	-	Faculty of Science and Engineering
KAP	-	Knowledge, Attitude and Practices
BIM	-	Building Information Modeling
PPE	-	Personal Protective Equipment
AI	-	Artificial Intelligence
SLR	-	Systematic Literature Review
GDP	-	Gross Domestic Product
SHEQ	-	Safety Health and Environment Quality
IoT	-	Internet of Things

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CHAPTER 1: INTRODUCTION

1.0 Background of the study

Humans have always welcomed technological developments in machinery to improve corporate operations, boost revenue, and cut expenses (Thames, 2016). With 374 million non-fatal injuries and 1.9 million work-related deaths recorded worldwide in 2021, there is an urgent need for new technologies, such as Industry 4.0. This strategy improves safety and health management by utilizing digital technologies to link people, processes, and physical devices (ILO, 2021). It is concerning to note that one worker dies from a work-related incident every 15 seconds, and 153 workers are injured every 15 seconds. Workplace fatalities are far greater in developing countries than in wealthy ones; for instance, the incidence of work-related deaths in Africa is 11.1 per 100,000 workers, whereas the rate in Europe is 3.9 (ILO, 2021). By improving workplace safety and productivity, Industry 4.0 seeks to revolutionize corporate operations, particularly in developed countries (Ślusarczyk, 2018). This "Fourth Industrial Revolution" is centred on important technologies including digital twins, cloud computing, big data, the Internet of Things (IoT), and additive manufacturing (Turkyilmaz et al., 2021). The "Plattform Industrie 4.0," a program started in Germany in 2011, has impacted similar endeavours in the USA, Japan, and Europe (Issa et al., 2018).

Approximately 26.3% of Zimbabwe's value added (as a percentage of GDP) comes from the construction industry, making it a significant sector, according to the World Bank's 2023 collection of development indicators. The industry is steadily recovering and expanding as of October 2023, because of a rise in housing and infrastructure projects including the 2022 Beitbridge Border Post improvement and the Kunzi Dam near Goromonzi (Murwira, 2024). The government's efforts to improve metropolitan road networks, residential housing, and public infrastructure have increased demand. The industry's full potential is, however, hampered by several obstacles, including extravagant production costs, obsolete equipment, and serious worker safety and health concerns. Construction has one of the highest rates of occupational injuries and fatalities due to a variety of risks, including noise, heat stress, dust exposure, and operating heavy machinery (Abukhashabah, 2020). There were 5,007 accidents and 65 fatalities in 2017 alone (Mushava, 2018). Furthermore, the number of occupational illnesses and injuries has increased significantly, from 2,443 to

133,000 (Mhlanga, 2018). Limited access to cutting-edge technology, limited funding for modernization, and a workforce that lacks the skills to apply innovations all contribute to these difficulties (Moreira, 2016; Matt et al., 2018).

Accidents in the construction industry are on the rise, even though health and safety regulations are in place under the Factories and Works Act Chapter 14:08 and relevant Rhodesian Government Notices from 1948, which were updated in 1976 (ILO, 2013). Employee safety and health are managed by a combination of Zimbabwean legislation, such as the National Social Security Authority (68 of 1990), the Labour Act (16 of 1985) and even some of the ratified ILO Conventions. These rules specify what is deemed dangerous or detrimental to health and safety, and breaking them can result in harsh consequences, such as imprisonment. Violating these laws can have serious consequences for many enterprises, endangering their operations and the production capacity of construction firms. For proactive health and safety management, this backdrop emphasizes how urgently the construction industry must improve and invest in more efficient safety measures (Makalesi, 2021). With estimated benefits worth USD 114.55 billion in 2021, implementing Industry 4.0 technology is anticipated to transform corporate operations through eco-friendly practices, sustainable growth, and enhanced safety (Musarat M. A., 2022). According to Alaloul et al. (2018), these technologies have revolutionized several industries throughout the globe by incorporating cutting-edge digital tools into traditional production and operational processes. Increased automation, improved data analytics, and improved connection are characteristics of this shift, which will promote efficiency, production, and safety.

The construction value chain is changing as a result of digital technologies like blockchain, augmented reality, 3D printing, and artificial intelligence (Locatelli, 2014). Building Information Modeling (BIM), for instance, produces digital models that improve decision-making and cooperation while lowering errors and boosting productivity. Employee safety can be continuously monitored by wearable IoT devices, which can notify workers of possible dangers (Dallasega, Frosolini, & Matt, 2016). According to Oesterreich and Teuteberg (2016), big data analytics can forecast equipment breakdowns, allowing for prompt maintenance to prevent mishaps. Furthermore, workers' training can be enhanced via augmented and virtual reality, giving them the necessary abilities for safe operations (Musarat, 2023). When combined, these developments can greatly lower the number of accidents and health problems, creating a safer working environment.

Adoption may be hampered by obstacles such as reluctance to change, a lack of knowledge, and inadequate training when implementing Industry 4.0 technology (Pedro P. Senna, 2022).

In the construction department of Bindura University, for instance, the usage of personal protective equipment (PPE) such as safety harnesses is mostly dependent on user behaviour and understanding, putting workers at risk for severe injuries from falls. It is essential to use real-time monitoring technologies, such as wearable sensors that use the YOSAP-LSTM model to identify falls with 98.66% accuracy, to notify employees of dangerous situations and to enable prompt emergency responses (Doil Kim, 2025). Bindura University is well-positioned to explore these technologies, serving as a microcosm for the broader challenges faced by Zimbabwe's construction sector in adopting Industry 4.0. Additionally, cultural attitudes towards technology may affect practitioners' willingness to embrace these innovations (Islam et al., 2018). Therefore, a KAP survey is used to obtain information on a population's knowledge, attitudes, and practices regarding general and/or topics, such as cloud computing, digital twins, AI, building information and modelling and automation and robotics, using Bindura University as a case study, is essential. This research aims to enhance understanding of how Industry 4.0 technologies can improve safety, identify knowledge gaps, and support the development of targeted training programs for safe and effective adoption in Zimbabwe's construction sector.

1.1 Problem Statement

Workplace accidents, particularly in the construction sector, are on the rise in Zimbabwe, resulting in a dramatic increase in work-related injuries, illnesses, and fatalities (NSSA, 2023). Furthermore, construction-related activities, mishaps, and incidents concerning quality, safety, and the environment also result in decreased output, damage to the environment, and poor craftsmanship (SAIOSH, 2019). These industries have been resolutely slow to implement novel solutions that have a high likelihood of offering a long-term plan for occupational safety risk treatment, despite the rapid improvements in technology (Islam et al., 2018). Furthermore, there is a limited understanding of the present attitudes, knowledge, and willingness of construction firms to employ these 4.0 technologies (Kumar, 2022). This lack of clarity hinders the construction manufacturing sector's ability to successfully use Industry 4.0 solutions. The knowledge, attitudes, and willingness of construction workers to embrace these technologies is a research gap that has to be filled to enable a seamless transition to industry 4.0 technologies with the appropriate interventions and support systems.

1.2 Aim of the Study

To assess the level of knowledge, attitudes, and practices among construction workers regarding the implementation of Industry 4.0 technologies as a means of preventing or reducing the incidence of disease, injuries, and fatalities in Zimbabwe's construction industry, using Bindura University of Science Education as a case study. This study examines how workers view industry 4.0 technologies and their willingness to implement them in the workplace, particularly for quality, safety, health, and environmental management. The construction sector needs this study to enable proactive SHEQ management, which will reduce or eliminate injuries and avert fatalities as well as property and environmental damage, supporting Zimbabwe’s vision 2030 creating a resilient economy that prioritizes worker safety and health.

1.2.1 Objectives of the study

i. To assess the knowledge of Industry 4.0 technologies among employees in the construction industry.

ii. To examine the attitudes of construction employees regarding the effectiveness of Industry 4.0 technologies in enhancing safety and minimizing occupational hazards.

iii. To assess the practices of construction industries to adopt Industry 4.0 technologies as a strategy for improving safety and reducing the occurrence of fatalities, injuries, and diseases.

1.2.2 Research questions

i. What is the current level of knowledge of employees in the construction industry on industry 4.0 technologies?

ii. What are the current attitudes of construction employees regarding the effectiveness of Industry 4.0 technologies in enhancing safety and minimizing occupational hazards?

iii. What are the current practices of construction industries in the juncture to adopt Industry 4.0 technologies as a strategy for improving safety and reducing the occurrence of fatalities, injuries, and diseases?

1.3 Justification of the Study

The majority of Zimbabwean construction companies have put in place a variety of safety and health management systems, including some of the industry 4.0 technologies. Nevertheless, the current systems are insufficient to address the changing nature of risks and the growing complexity of the construction sector, as well as to reduce the consistently increasing number of occupational accidents, injuries, and fatalities. These conventional methods are therefore inadequate to manage the evolving nature of risks and the increasing complexity of the operations of the construction sector, necessitating the adoption of industry 4.0 technologies, which seek to enhance human-machine interaction. The foundation for understanding how to support this transition will be established by this study.

However, there are limited and poorly understood applications of Industry 4.0 technologies to safeguard workers' safety and well-being from common occupational setup hazards, particularly in developing countries like Zimbabwe, due to gaps in knowledge, attitudes, and practices among construction industry workers. It is imperative to assess the current level of comprehension of Industry 4.0 technologies among construction workers. Understanding and comprehension of new technologies are crucial for their successful use, claim researchers such as Kivrak et al. (2020). A lack of knowledge could make practitioners hesitant to adopt these developments, which would prevent safer standards from being established. Positive attitudes are required for the intention to adopt new technologies, according to Ajzen's Theory of Planned Behavior (1991). As with other safety standards or strategies, industry 4.0 technology adoption must consider the attitudes of construction practitioners regarding the adoption of the technologies to be successful, as human behaviour is a critical contributing factor. According to a study by Luria et al. (2018), precautionary measures can greatly minimize workplace accidents and injuries, and these attitudes may be influenced by prior technological experiences as well as cultural norms. According to Khosravi and Ghapanchi (2016), understanding these attitudes can help guide actions to improve the environment for technology adoption.

Additionally, the use of safety measures has a direct positive effect on occupational health outcomes. Considering the ability of these industry 4.0 technologies to reduce fatalities, injuries and diseases, it aligns with the UN's SDG goal number 8 and also Zimbabwe's vision 2030 national plan which promotes decent work and economic growth. This study aims to identify gaps and limitations in the deployment of safety technologies by evaluating the current practices of construction practitioners. This will provide practical insights for enhancing workplace safety.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The construction industry is one of the most hazardous industrial sectors in the world, with increasing incidences of occupational accidents and ill health leading to deaths and injuries (Moreira, 2016). As technological advancements improve over time, there is a growing interest in assessing the potential of these advanced technologies, referred to as Industry 4.0, in enhancing occupational health and safety measures (Alaloul, Liew, Amila, Abdullah, & Mohammed, 2018). This review of the literature attempts to investigate the current understanding, perspectives, and behaviours of construction professionals regarding the use of Industry 4.0 technologies in the construction sector. The goal is to provide practical insights into the adoption of Industry 4.0 technologies to enhance workplace safety.

2.1 Knowledge of Industry 4.0 Technologies

A thorough understanding of industry 4.0 technologies is essential for their successful deployment. Studies have indicated that construction professionals differ in their knowledge and understanding of Industry 4.0 technology. According to a Malaysian study, scholars have greater knowledge and comprehension of construction engineering than industry participants (Nadia Safura Zabidin, 2024). The article claims that this is because academic research is by its very nature information-seeking, revealing a knowledge gap that calls for continuous education and training programs to enhance construction practitioners' understanding of industry 4.0 technology.

Tayal et al. (2024) consistently argue in their study on the adoption and implementation of industry 4.0 technologies that there are numerous research gaps in the integrated application of technology and sustainability because of a lack of knowledge among stakeholders and insufficient information. Furthermore, by examining common barriers including implementation costs, illiteracy, and inadequate long-term planning, the study determined the challenges associated with putting these technologies into practice.

Between 2013 and 2021, 170 articles from the top 22 construction journals in the Scopus database were examined using a systematic literature review (SLR) technique that included a bibliographic coupling analysis (BCA) and co-citation network analysis of keywords (Larissa Statsenko, 2023).

Their study emphasizes the necessity of using technology to address persistent problems in the construction industry, like worries about worker safety. The study found that while there is a lot of research on the industrial Internet of Things (IoT), cloud computing, big data, and analytics with the most references in Construction 4.0 more research is required on the applications of augmented and virtual reality, vertical and horizontal integration, and autonomous robotics.

In 2024, Menegon-Lopes and da Silva Filho examined how stakeholders in the construction industry perceived technology advancement. According to their findings, 79% of respondents said technological innovation was crucial for the industry, but only a tiny percentage saw the use of the technology significantly increase during the previous five years. Remarkably, 39% of respondents thought the rate of innovation was modest, while 36% thought the adoption was below average. This shows that although the need for innovation is becoming more widely acknowledged, implementation is still happening slowly. There was optimism about future developments, particularly among smaller businesses, which showed more willingness to embrace new technologies than did big companies. The need for greater awareness and education is highlighted by the startling finding that more than half of the respondents (57%) were not familiar with important concepts like Industry 4.0 and Construction 4.0. Furthermore, respondents were more likely to expect benefits like increased productivity and product quality than safety improvement from the deployment of technology. The report emphasizes how critical it is to close these gaps to promote a more creative and knowledgeable construction industry (Menegon-Lopes Julia, 2024).

Bolpagni, (2022) sheds light on the evolving roles of traditional construction workers while emphasizing the importance of cultivating the skills necessary to successfully navigate the complex dynamics of Industry 4.0. Among the basic methods and ideas for the built environment that are covered in detail in the book are Building Information Modeling (BIM), computational design, artificial intelligence, big data, cloud computing, data analytics and visualization, lean construction, advanced project management, quality management, health and safety, and legal standpoints. Bolpagni also examines how technology and methods such as BIM and digital twins are changing the built environment and providing unprecedented opportunities to improve safety standards and operational effectiveness. This highlights the significance of these technologies in modernizing construction processes and addressing industry issues.

Taher, (2021) argues for a thorough approach to information sharing by examining the possible changes that could arise from the adoption or use of Industry 4.0 technology in the construction sector. Construction technologies 4.0 adoption is hampered by several factors, according to the study, including implementation costs, technical acceptability, high requirements, inadequate long-term planning, and ignorance. The study found that while a small proportion of highly skilled employees are amenable to adopting new technology, a sizable fraction of workers are reluctant to pick up new skills, possibly as a result of poor knowledge. According to Taher, given these results, educational and training initiatives ought to operationalize the technology while simultaneously bringing attention to its long-term benefits for improving worker safety and productivity.

Poizot Li Lee's study supports Taher's findings by highlighting the difficulties faced by construction workers, particularly their ignorance of these technologies. Utilizing a mixed-methods approach, the study integrates qualitative insights from interviews with quantitative data from wearable devices. Wearables were not widely accepted or used effectively since many employees were unsure of their features and advantages. According to Lee (2023), closing this knowledge gap is crucial to optimizing these devices' effects on worker well-being and revolutionizing building processes, even though they have the potential to enhance health monitoring and proactive risk management.

Demirkesen and Tezel's (2021) study examines the main obstacles to industry 4.0 implementation in construction firms. To determine if there were statistically significant replies among groups of respondents, the researcher employed a questionnaire given to construction companies and the Mann-Whitney U test on the data gathered. According to the study's findings, the main obstacles to the adoption of construction 4.0 in projects are implementation costs, unclear benefits and gains, and resistance to change. They draw attention to the problems of complexity and cost, which are often caused by the inexperience and ignorance of practitioners. In most industries, a lack of standardization, regulatory concerns, and contractual responsibilities also hindered the adoption of Industry 4.0 technologies. Therefore, specialized training sessions and educational activities are required to gain the skills required to maximize these outcomes.

2.2: Attitudes towards Industry 4.0 technologies

How construction professionals feel about Industry 4.0 technology is heavily influenced by an array of perceived benefits and related challenges. Tayal et al. (2024) state that resistance to change is one of the most persistent barriers, primarily due to concerns about the high implementation costs and fear of losing one's job. This reluctance to fully embrace digital transformation may stem from uncertainty about the immediate advantages that these technologies will offer to people as well as companies.

Arana-Landín (2023) goes into additional detail about the psychological repercussions of this resistance, pointing out that the adoption of Industry 4.0 technology may cause employees to feel more anxious and agitated. As automated technologies and artificial intelligence replace jobs that were previously performed by people, this is sometimes motivated by concerns about job redundancy and a loss of control over future work dynamics. These concerns prevent individuals from embracing new technologies, even though they have the potential to improve workplace safety and health.

The study conducted by Zabidin, Belayutham, and Ibrahim (2023) found that academics and construction professionals in Malaysia have different perspectives, understandings, and behaviours regarding industry 4.0 technology. According to the study, despite their awareness of the various ways Industry 4.0 could affect the area they work in, construction professionals' perceptions are impacted by implementation obstacles such as expensive costs, unwillingness to change, and a lack of subject-matter expertise. This makes construction experts hesitant, even though they are aware of the long-term benefits of using industry 4.0 technologies. The study continued by highlighting the need for specific interventions to shift mindsets, such as capacity-building programs and change management strategies, to encourage the broad use of new technologies in this industry.

The study by Olaniyan (2019) examined the obstacles that Nigerian construction project managers face when using cutting-edge technology, exposing important issues that impede the sector's advancement. 150 project managers were surveyed for the study, and 72% of them said that a key difficulty in implementing new technologies was a lack of training, while 65% said that a big obstacle was a lack of funding. Interestingly, the study found that just 40% of workers in the construction industry were confident in their capacity to adjust to new technologies. Concerns over the rate of technological change were raised by respondents' comments. One manager said, "We are often overwhelmed by the constant need to learn new tools without adequate support." These results highlight the need for focused interventions, such as financial incentives and training courses, to boost worker confidence and encourage the adoption of new technologies, which will ultimately increase project efficiency in Nigeria's construction sector.

Taher (2021) asserts that a mix of hesitancy and conviction shapes the attitudes among construction professionals regarding Industry 4.0 technologies. Even though many practitioners agree that new technologies have the potential to increase efficiency and safety, there is a noticeable hesitancy to fully embrace them because of several obstacles. These include the industry's unwillingness to change, a lack of technological know-how, and expensive implementation costs. Taher continues by saying that the construction sector has embraced these technologies more slowly than other industries, particularly manufacturing and the automotive sector, due to rooted customs and a lack of knowledge about the long-term advantages.

Professionals in the building, engineering, and architectural disciplines are hesitant to enter the field, claim Shafei (2022) and Taher (2021). The hesitation of 4.0 technologies, which stems from their poor decision-making and lack of knowledge, impedes progress in the construction sector. The study examined 22 papers using the PRISMA approach and identified four key trends about the strengths, weaknesses, risks, and possibilities of these technologies. Quantitative findings showed that 68% of the reviewed papers focused on adoption and implementation, while only 32% talked about how to incorporate Construction 4.0 technology with decision-making frameworks. The survey also discovered that 25% of the obstacles were caused by inadequate long-term planning, 30% by a lack of experience, and 45% by high implementation costs.

2.3: Current Practices in Adoption of Industry 4.0 Technologies

Manufacturing, construction, and logistics have advanced significantly as a result of the broad use of Industry 4.0 technologies. According to Petrillo et al. (2018), Industry 4.0 approaches combine cyber-physical systems, big data analytics, and the Internet of Things (IoT) to build smart factories. These technologies increase productivity and decrease downtime by facilitating automation, predictive maintenance, and real-time data sharing. About 75% of European countries have invested in industry 4.0 apps, according to a PWC report, with only 25% of them primarily focused on boosting productivity and reducing operating expenses.

The German federal government created the term in 2011 to support its high-tech policy. Without any discernible distinction, it integrates a wide variety of transdisciplinary concepts (Oesterreich, 2016). Geissbauer, Vedso, and Schrauf (2016) conducted a Global Industry 4.0 Survey with over 2,000 participants from 26 countries, highlighting the transformative potential of Industry 4.0 technology in increasing efficiency and innovation. The survey states that in 2016, 33% of organizations globally rated their level of digitalization as advanced; by 2020, that percentage is predicted to increase to 70%. Big data analytics, IoT integration, and cyber-physical systems were important strategies that led to $421 billion in cost savings and $493 billion in revenue growth yearly. Germany led the way with its focus on smart factories, and China's advancements in robotics and artificial intelligence demonstrated 35% increases in productivity, underscoring the impact of digital transformation on a global scale.

According to a study by Oesterreich (2016), a survey conducted online with 599 respondents from six countries China, Germany, India, Japan, the U.K., and the U.S. shows that the adoption of digital twins is rapidly growing among organizations worldwide. Participating organizations had to generate more than $50 million in revenue annually and have plans to implement at least one of the industry 4.0 technologies. The results illustrated that currently, only 13% of organizations utilize digital twins however, 62% are either establishing this technology or planning to do so within the following years. Digital twins are known to provide substantial economic value by simulating actual assets to improve operations and increase understanding. 54% of digital twins are made to target several constituencies, including manufacturers and service providers, even if many of them specialize to specific stakeholders. Furthermore, a tendency toward increasingly sophisticated interconnections is evident as 61% of organizations have integrated at least one pair of digital twins.

Africa is still in the early stages of adopting Industry 4.0 technology. The study by Adetunla and Madonsela (2022) looked at how these developments impacted labour relations, employment structure, and workforce preparedness. The study, which looked at how Industry 4.0 technologies affected Africa's industrial sectors, found that 40% of the eight businesses surveyed had automated operations and only 15% had adopted cutting-edge technologies like IoT and AI. The study continued by outlining the technologies' drawbacks and showing how they increase production output and profits while lowering labour demand, which raises the GDP of African nations. It also emphasized ways to use scalable, reasonably priced technology that is adapted to the African environment to move beyond conventional industrial methods.

In Nigeria, Africa's largest economy, research by Adepoju and Aigbavboa (2021) evaluated the knowledge and skills gap associated with Construction 4.0. They discovered that the average knowledge score of 136 construction experts, who were surveyed, was a moderate 3.12 out of 5. Just 29.4%, nonetheless, have been trained in Construction 4.0 technology. There are notable skills gaps in cybersecurity (2.30), data analytics (2.38), and human-machine communication (2.45). To better prepare the workforce for the needs of Construction 4.0, the authors advise improving human capital development through curriculum updates and expanded training efforts

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This chapter describes the research study area, tools, and methods used to assess the knowledge, attitudes, and practices (KAP) of construction workers in implementing Industry 4.0 technologies as a strategy of preventing or reducing diseases, injuries, and fatalities in Zimbabwe's construction industry. Two specifically chosen construction sites on the campuses of Bindura University of Science Education were the subject of the investigation. The chapter also describes the target population, study plan, sample size, and sampling techniques. It also covers the study's analysis plan, ethics, validity, reliability, and research instruments.

3.1 Study Area

The study was carried out at BUSE, which is situated at precisely 17.3251°S 31.3326°E in Bindura Town. The University is around 87 kilometers northeast of Harare. One of its four campuses is the Main Campus (FOC), which is situated at 741 off Trojan Road along Chimurenga Road. The Department of Physical Planning and Construction, led by Director Mr. Kamutando, is responsible for the University's two construction sites, which are situated at FAES and FSE. The provincial capital of Mashonaland Central Province is Bindura, a tiny town with a serene semi-urban setting.

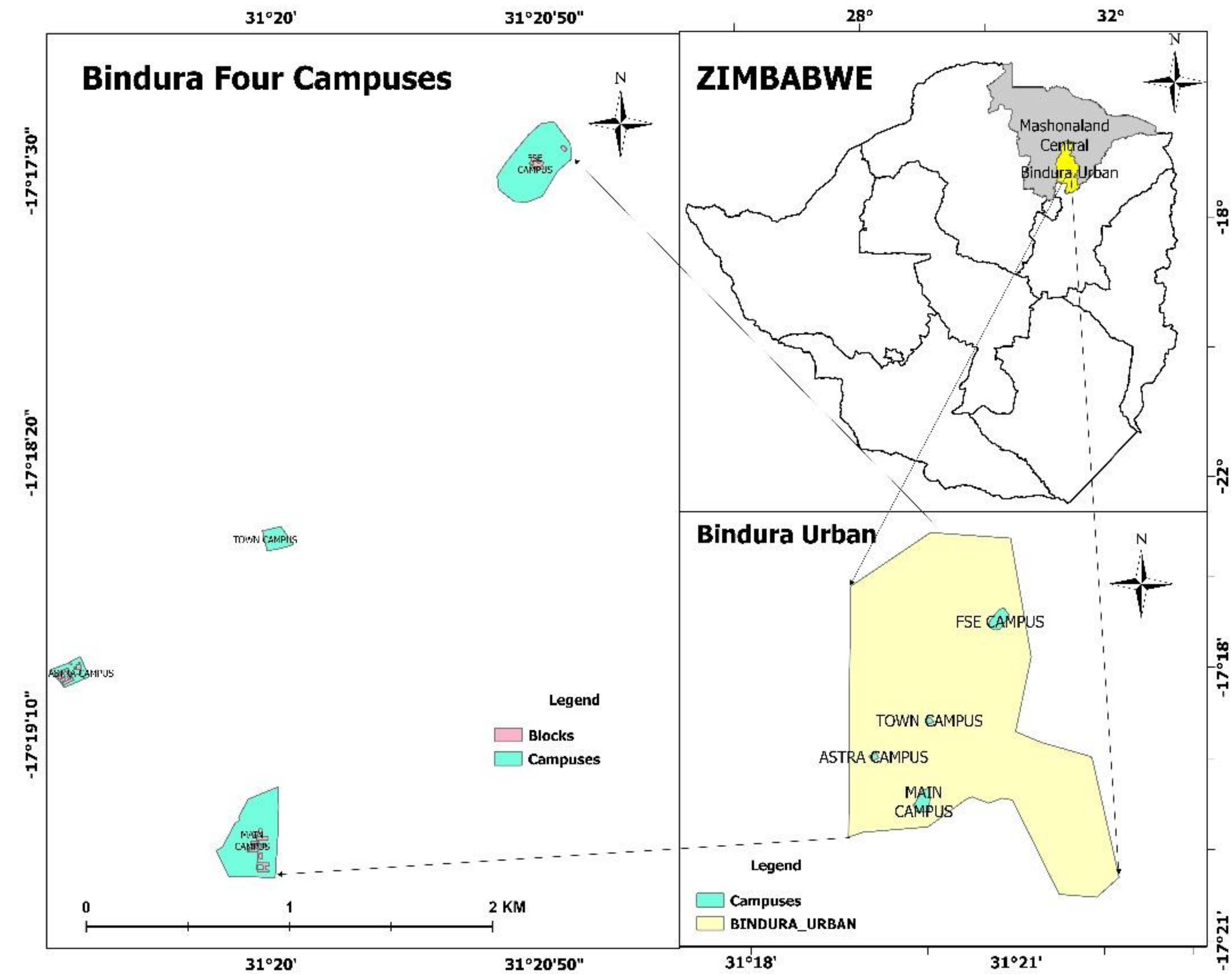

Figure 1.0: Map showing Bindura University Campuses

3.2 Study Design

The study design used in the research was cross-sectional. A descriptive cross-sectional study design observes a population at a certain point in time to paint a picture of the relationship between variables (Wang X, 2020). This study offers insights on the awareness and attitudes of construction practitioners about industry 4.0 technologies, which can be used to identify demographic characteristics or evaluate relationships between factors that can assist influence safety and health initiatives and policies. Since the study was descriptive, the data was collected through the use of questionnaires which were analyzed using both qualitative and quantitative tools. A cross-sectional survey makes it possible to gather data from a large number of people at once, which saves time and money for examining Industry 4.0 adoption in Zimbabwe's construction industry (Zuleika Puspa, 2022). Furthermore, these are useful for providing initial insights which may warrant future research using longitudinal studies. A sample of 70 participants was used to collect data during the research.

3.3 Data Sources

Both primary and secondary sources were consulted by the researcher. Information obtained directly from sources by researchers via questionnaires, surveys, or interviews is known as primary data. Construction practitioners at Bindura University including engineers, site managers, SHEQ Officers and workers served as the main sources of primary data. E-journals and other online sources provided secondary data.

3.4 Sampling Method

The researcher used a stratified sample technique, which separates the population into discrete subgroups or strata according to particular attributes, such as the faculties where the building is taking place (Iliyasu, 2021). Two development sites, FSE and FAES, where new infrastructure is being constructed, including the Industrial Park and the male student housing, respectively, have recently been selected by BUSE under the oversight of Mr. Kamutando, the Department of Physical Planning and Construction. Based on their sizes, the researcher then selected 61 respondents at random from the two strata out of the 72 total respondents, with 23 coming from FSE and 38 from FAES. This approach improves the sample's representativeness and makes it possible to make insightful comparisons between the different groups. Stratified sampling reduces errors and yields more reliable results by controlling heterogeneity within each stratum (Iliyasu, 2021). The more intricate statistical analysis made available by the structure of the data improves the study's overall robustness. Using simple random sampling inside each stratum, all construction practitioners in the population group have an equal chance of being chosen, reducing bias and errors (Noor, 2022).

3.5 Sample Size

The Slovin's formulae states that:

$n = N/ (1+Ne^2)$

Where,

n = sample size

N = total population

e= margin of error (expressed as a decimal that was assumed to be 0.05)

The above formula was used to calculate the sample size for a total population of 72 construction practitioners.

The estimated population of construction practitioners at the FAES site was 45 and FSE had 27 practitioners totaling 72. The proportional calculations were done using Microsoft Excel 2013 to randomly select 38 respondents from FAES and 23 from FSE to make a total of 61 respondents as illustrated in the table below:

Table 1: Sample Sizes

Campus	**Construction Site/ Faculty**	**Population of Employees on site**	**Sample Size**
Astra	FAES	45	38
FSE	FSE	27	23
TOTAL		**72**	**61**

3.6 Researcher Tools

The researcher made use of questionnaires with both closed and open-ended questions as a research tool. A questionnaire is a methodical instrument used to gather information from participants, in this context particularly employees in the construction industry. It comprises a structured series of questions intended to collect data on a range of topics pertinent to the research, including professional practices, attitudes, and experiences in the construction sector (Fife-Schaw, 2020).

The researcher distributed the questionnaires to the specified construction sites by hand and at random. The researcher carefully awaited the completion of the questionnaire by the respondents.

The questionnaire consisted of four sections:

i. Demographic Information
ii. Knowledge of Industry 4.0 Technologies
iii. Attitudes Towards Industry 4.0 Technologies
iv. Current Practices in Adoption of Industry 4.0 Technologies

After completion the questionnaires were collected by the researcher for analysis.

3.7 Reliability And Validity Of Research Instruments

Reliability is the stability and consistency of information or a metric gathered with a certain instrument. This shows how much one can rely on results to be free from random errors, allowing them to be replicated across time and among other populations of the same characteristics. Validity refers to the extent to which the research instrument accurately measures what it is intended to measure (Dobakhti, 2020). To assess the reliability and validity of the results, the researcher looked at how well they matched other assessments of the same concepts and established theories throughout time, among observers, and between test sections.

3.8 Statistical Analysis

To analyse the collected data, the researcher used two software programs Microsoft Excel 2013 and SPSS version 23. The research questionnaire comprised 13 questions to gauge the participant's knowledge, 6 questions to assess their attitudes and 8 questions to gauge their current practices regarding the adoption of industry 4.0 technologies. In that context, each correct response received a score of 1, while incorrect and l don't know responses received a score of 0. The average score for each character was calculated, and answers were categorized as "Good" if they exceeded 70%. "Fair," if the score fell between 51-69%, or "Poor" if it fell below 50%. The KAP scores were summed together to determine the total scores. Construction practitioners' knowledge, attitudes, and practices concerning the implementation of Industry 4.0 technologies as a means of preventing or reducing the incidence of fatalities, injuries, and diseases were ranked using the total KAP score. The data was analyzed and then displayed in tables.

3.9 Research Ethics

Research ethics are the moral precepts and rules that influence the way that research is conducted. It guarantees that when doing research with human subjects, gathering data, and analyzing that data, researchers follow responsible and moral procedures (Iphofen, 2020). Adhering to research ethics not only protects participants but also enhances the credibility and integrity of the research findings. Through cooperation with the Supervisor and the Chairperson of FAES, who provided the required supervision and guidance, the researcher was able to obtain formal approval from the registrar of BUSE to conduct this study. However, this approval came with restrictions, highlighting the significance of ethical considerations in the research process.

The research participants gave their consent without coercion. The researcher promised that there would be no consequences or penalties for participants who chose not to participate. To aid on to transparency, the researcher provided participants with information about the study, including its advantages, dangers, funding, and institutional approval. Everybody has the right to privacy, so the researcher protected their personal data, through ensuring that all information collected was handled confidentially. Even when anonymous data collecting was not practical, the researcher made every effort to remain anonymous.

CHAPTER 4: RESULTS

4.0 Introduction

This chapter presents the research findings and analysis of data that was collected. The chapter consists of data representation using tables and discussion guided by the research objectives.

4.1 Response Rate

The percentage rate of construction practitioners who received and responded to questionnaires is clearly illustrated in the table below:

Table 2: Summary of Questionnaire Response Rate

Construction Site	**Questionnaire Given**	**Questionnaire Responded**	**Response Percentage (%)**
FAES	38	35	57.4
FSE	23	21	34.4
TOTAL	**61**	**56**	**91.8**

A high degree of involvement and participation among respondents is shown by the response percentage rate of 91.8%, which suggests that the questionnaire was well accepted. The reliability of the results is increased by the higher level of participant response, enabling precise conclusions on the research topic. Despite the 8.2% of questionnaires that were not returned which was caused by a lack of time and interest the overall response rate offers a strong basis for analysis and the derivation of significant findings. It is anticipated that the results will add to our current understanding of the subject and offer insightful information.

4.2 Section A: Demography

Table 3: Summary of demographic characteristics

Demographic variable	Category	n = 56	% = 100
Gender	Male Female	38 18	67.9 32.1
Age	18 – 30yrs 31 – 40yrs 41 – 50yrs	38 10 8	67.9 17.9 14.3
Level of Education	Primary Secondary Tertiary	2 33 21	3.6 58.9 37.5
Duration of Employment	0 – 5yrs 6 – 10yrs	53 3	94.6 5.4
Occupation	SHEQ Officer SHEQ Officer Attache' Assistant Bricklayer Electrician General Hand Carpenter Civil Engineering Tech Civil Engineering Tech GT Boilermaker Plumber Scaffolder Site Foreman Steel Fixer Tractor Driver Bricklayer	3 1 1 2 30 3 2 2 1 1 2 1 2 1 4	5.4 1.8 1.8 3.6 53.6 5.4 3.6 3.6 1.8 1.8 3.6 1.8 3.6 1.8 7.1
Construction Site	FAES FSE	35 21	62.5 37.5

The aforementioned data shows that, with 67.9% of participants being men and 32.1% being women, males comprise a greater population. Participants between the ages of 18 and 30 made up the largest group (67.9%), followed by those between the ages of 31 and 40 (17.9%), and finally, those between the ages of 41 and 50 (14.3%). This shows that young people dominate the construction sector. The highest level of education attained by only 3.6% of participants was primary school. With 58.9% of participants having a secondary education and 37.5% having a tertiary education, most participants have at least a basic to moderate level of education. The data also shows that the majority of participants (94.6%) had worked for 0–5 years, while 5.4% had worked for 6–10 years. There is a wide range of occupations, with the majority (53.6%) employed as general hands. Bricklayer (7.1%), SHEQ Officer (5.4%), Civil Engineering Tech (3.6%), Steel Fixer (3.6), Scaffolder (3.6), Plumber (1.8), Tractor Driver (1.8), and Electrician (3.6%) have smaller representations. Most of the participants 62.5% are at the FAES construction site, while the remaining 37.5% are at FSE.

4.3 Section B: Knowledge of Industry 4.0 Technologies

Table 4: Knowledge on Industry 4.0 Technologies

Knowledge Variable	Participant Response	Number	%	Preferred Response	Score
1. Building Information Modeling (BIM) can improve planning and teamwork during conducting a construction project?	YES	16	28.6	YES	0.286
2. Are robots currently replacing all human workers on construction sites?	NO	18	32.1	NO	0.321
3. Data analytics help construction managers make better decisions through use of real-time data?	YES	38	67.9	YES	0.679
4. Do drones help improve worker safety by reducing the need for risky manual site inspections?	YES	23	41.1	YES	0.411
5. Does wearable technology track worker safety and health on construction sites?	YES	26	46.4	YES	0.464
6. Do AI-powered tools slow down construction work rather than improve efficiency?	NO	22	39.3	NO	0.393
7. Is AI limited to only designing buildings and not improving safety or productivity?	NO	28	50	NO	0.5
8. Is it possible for smart helmets and other wearable technology to identify employee weariness and stop accidents?	YES	31	55.4	YES	0.554

9. Automation and robotics in construction industry leads to higher workplace injuries rather than reducing them?	NO	17	30.4	NO	0.304
10. IoT devices and sensors (smart devices) can check machine performance, keep track of materials, and give instant updates to help with decisions.	YES	18	32.1	YES	0.321
11. The purpose of AI in construction is to replace engineers and make buildings automatically	NO	22	39.3	NO	0.393
12. Can engineers use digital twins to monitor and assess project designs using real-time data before construction starts?	YES	16	28.6	YES	0.286
13. Cloud computing can be used to create customized components and structures, reducing waste and improving efficiency	YES	12	21.4	YES	0.214
TOTAL KNOWLEDGE SCORE					**5.126**

Table 4 shows that the overall knowledge score is 5.126 out of 13, which translates to a poor total knowledge score of 39.4%.

Of the respondents, 28.6% demonstrated an awareness of Building Information Modeling (BIM) and its potential to enhance planning and collaboration before starting a building project. 67.9% of respondents, or the majority, think that robots will completely replace human labor on building sites. The majority of participants (67.9%) knew that data analytics uses real-time data to assist construction managers make better decisions. A lesser percentage of participants 41.1% were aware that drones could improve worker safety by eliminating the need for dangerous manual site inspections. 46.4% of participants, or less than half, are aware that wearable technology can monitor worker health and safety on construction sites.

The perception of AI tools slowing down work is 39.3% of responses, and half of participants (50%) still hold the misperception that AI is primarily used for building design and does not improve productivity or safety. An encouraging view of wearable technology is demonstrated by the remarkable 55.4% who think that smart helmets can improve safety by identifying worker weariness. Instead, fewer participants (30.4%) think that automation and robotics in the construction sector increase safety by lowering worker injuries rather than increasing them. Only 32.1% of participants properly answered, indicating a rather low level of comprehension of IoT devices in monitoring and decision making. Merely 39.3% were aware that artificial intelligence (AI) in construction is not meant to take duties of engineers and create buildings on its own. Of the respondents, only 28.6% were aware that engineers utilize digital twins to monitor and evaluate project designs using real-time data prior to construction commencing, indicating a low degree of knowledge in the field (71.4%). Cloud computing can be utilized to construct customized components and structures, which reduces waste and improves efficiency, however only 21.4% of participants were aware of this.

4.4 Section C: Attitudes Towards Industry 4.0 Technologies

Table 5: Attitude Towards Industry 4.0 Technologies

Knowledge Variable	Participant Response	Number	%	Preferred Response	Score
14. Do you believe that Industry 4.0 technologies can enhance safety in construction industry?	AGREE	33	58.9	AGREE	0.589
15. How do you feel about the integration of technology, such as AI and robotics, in improving safety on construction sites?	POSITIVE	22	39.3	POSITIVE	0.393
16. How confident are you in your ability to adapt to new technologies?	POSITIVE	19	33.9	POSITIVE	0.339
17. Do you believe that the benefits of using wearable technology for monitoring worker health outweigh the challenges involved in its implementation?	AGREE	23	41.1	AGREE	0.411
18. Do you believe that automation (Drones, IoT Smart sensors) in construction will improve or hinder collaboration among workers?	IMPROVE COLLABORATION	32	57.1	IMPROVE COLLABORATION	0.571
19. What is your overall attitude towards the adoption of Industry 4.0 technologies in your workplace?	POSITIVE	15	26.8	POSITIVE	0.268
TOTAL ATTITUDES SCORE					**2.571**

The overall attitude score for table 5 is 2.571 out of 6, meaning that 43% of the total attitude score is poor.

According to responses, 58.9% of respondents said that industry 4.0 technologies are improving safety practices in the construction sector. As stated by 39.3% of participants, including technology like artificial intelligence (AI) and robotics can improve safety on building sites. In terms of their ability to adjust to new technologies on construction sites, less than half (33.9%) are confident. Just 41.1% of respondents believe the advantages of employing wearable technology to track employee health exceed the difficulties in putting it into practice. While 42.9% of interviewees disagreed, a majority (57.1%) said that automation (drones, IoT smart sensors) in construction would enhance worker collaboration. While 26.8% of participants had a positive view, the majority (73.2%) expressed a negative attitude regarding the implementation of Industry 4.0 technology in their company.

4.5 Section C: Current Practices in Adoption

Table 5: Current Practices in Adoption of Industry 4.0 Technologies

Knowledge Variable	**Participant Response**	**Number**	**%**	**Preferred Response**	**Score**
20. Do you actively use BIM in your daily work to improve planning and coordination on construction projects?	YES	3	5.4	YES	0.054
21. Have robots been integrated into tasks on your construction site to reduce safety risks for workers?	YES	9	16.1	YES	0.161
22. Do you rely on data analytics for tracking project safety risks and improving decision-making?	YES	37	66.1	YES	0.661
23. Are drones regularly used on-site for inspections to prevent workers from entering hazardous areas?	YES	16	28.6	YES	0.286
24. Do workers on your site wear smart helmets or other wearable technology to monitor safety conditions?	YES	14	25	YES	0.25
25. Are IoT sensors and smart devices used on-site to track machine performance and provide real-time updates for safety?	YES	5	8.9	YES	0.089

26. Are construction workers trained on how to operate digital tools like sensors, drones, and AI-based safety monitoring systems?	YES	4	7.1	YES	0.071
27. Do you use digital twins to test construction processes and safety scenarios before actual work starts?	YES	7	12.5	YES	0.125
TOTAL PRACTISES SCORE					**1.697**

According to table 5, the total score for practices is 1.697 out of 8 which relates to the total percentage score 21% which is very poor.

The majority of participants (94.6%) claim that they do not use BIM to enhance planning and coordination in their day-to-day work, whereas only 5.4% concur. The percentage of participants who agree that robots have been included into tasks at work in order to lower safety hazards is lower at 16.1%. To monitor project safety hazards and enhance decision-making, the majority of respondents (66.1%) stated that they rely on data analytics. Just 25% of respondents acknowledged the usage of smart helmets or other wearable gear to monitor safety conditions, and only 28.6% stated drones were often used on-site for inspections to keep workers out of dangerous areas. Some of the respondents agreed that on-site smart devices and IoT sensors are used to monitor machine performance and deliver real-time safety updates. Furthermore, just 7.1% of respondents said that staff received training on using digital tools like drones, sensors, and AI-based safety monitoring systems. Before actual work begins, a small percentage of respondents (12.5%) stated that they test safety scenarios and construction processes using digital twins.

CHAPTER 5: DISCUSSION OF RESULTS

5.1 Knowledge of Industry 4.0 Technologies

The findings in Table 4 indicate that construction practitioners' understanding of Industry 4.0 technology is concerning. With a low knowledge level (39.4%) and a total knowledge score of 5.126 out of 13, it is clear that there is a lack of awareness and comprehension of modern construction technology. According to Julia Menegon-Lopes's study conducted in Brazil, a developing nation, 57% of participants claimed to know nothing about Industry 4.0 subjects, and 13% of them said they had never heard of these terms before, totalling a poor knowledge score of 30% (Menegon-Lopes Julia, 2024). Furthermore, this is consistent with a Malaysian study that indicated academicians are more knowledgeable than construction workers, suggesting the necessity of continuous education and training programs to improve practitioners' understanding of Industry 4.0 technologies (Nadia Safura Zabidin, 2024).

The ability of Building Information Modeling (BIM) to improve planning and collaboration in construction projects was acknowledged by just 28.6% of participants. This suggests a serious knowledge gap because BIM is essential to effective project management and teamwork. This supports Bolpagni's (2022) assertion that industry 4.0 technology knowledge is essential for workers in construction. The revolutionary potential of BIM, AI, and digital twins in raising operational effectiveness and safety standards in the built environment is highlighted by Bolpagni (2022). The lack of awareness may make it more difficult to apply BIM successfully in upcoming construction projects, which emphasizes the necessity of specialized education and training to make sure they can successfully update construction practices and navigate the changing environment.

The majority of respondents (67.9%) think that human labour on construction sites will be entirely replaced by robots. The lack of knowledge that automation and robots won't replace human labour, as observed by Tayal et al. (2024), which is largely a result of fear of losing jobs to automation and robots leads to resistance and a negative attitude toward the adoption of Industry 4.0 technology. Furthermore, there are still misconceptions, especially when it comes to artificial intelligence (AI). Of the participants, 50% think AI can only be used for design work, underestimating its potential to improve productivity and safety. These results are consistent with those of Menegon-Lopes, who found that just 43% of respondents were unfamiliar with these concepts of industry 4.0 and construction 4.0. The researcher continues by noting that more respondents anticipate advantages including higher productivity and better-quality products than safety enhancements from the use of technology (Menegon-Lopes Julia, 2024).

A significant 67.9% of respondents agreed that data analytics helps construction managers make well-informed decisions. This is in line with a study conducted in the United States of America among top to middle level managers at 133 US-based firms, which found that the use of data analytics on decision making is fully mediated by knowledge sharing and also produces high-quality decision making (Ghasemaghaei, 2019). Drones may improve worker safety, according to just 41.1% of respondents, which emphasizes the need for more training and application of this innovative technology to allow a more practical appreciation as there is limited application of these on site according to 71.4% of the respondents which is also a factor which limits on the knowledge.

The understanding of wearable technology's capability to monitor worker safety stands at 46.4%, while only 32.1% recognized the importance of IoT devices in tracking performance in line with a study carried out by Poizot Li Lee which employed the use of a mixed-methods approach, the research combines quantitative data from wearable devices with qualitative insights from interviews. In that regard, the majority of workers expressed uncertainty about the benefits and functionalities of wearables, which limited their acceptance and effective use (Lee, 2023). These figures suggest a critical need for targeted training programs and a comprehensive approach to information exchange thus raising awareness of the long-term advantages of using technologies to enhance productivity and safety (Taher, 2021).

With an overall knowledge score of just 39.4%, the study's findings generally showed that construction workers had an alarming lack of comprehension about industry 4.0 technology, emphasizing the need for focused training and continual educational initiatives.

5.2 Attitudes Towards Industry 4.0 Technologies

Table 5 reveals how construction practitioners feel about Industry 4.0 technology, with a total score of 2.571 out of 6, or 43%. This suggests a generally negative mindset, which is in line with research by Tayal et al. (2024), which shows that resistance to change is a major obstacle to adoption and that concerns about losing one's job and the expense of implementation are contributing factors.

The fact that 58.9% of respondents think that Industry 4.0 technologies can improve construction safety despite the low attitude score shows that they are aware of the potential advantages. Such in line with the findings of a study done in Malaysia in 2023, as construction practitioners are aware of the many ways that Industry 4.0 has the potential to impact their area, implementation barriers like high costs, reluctance to change, and a lack of subject-matter expertise affect their perceptions. However, only 39.3% feel positive about integrating AI and robotics for safety improvements, suggesting that fears and uncertainty about job redundancy and a lack of control over future work dynamics are frequently the driving forces behind this, as automated technologies and artificial intelligence take over jobs that were previously completed by humans still prevail (Germán Arana-Landín a, 2023).

A significantly lower proportion of participants (33.9%) said they were confident in their capacity to adjust to new technology, which is consistent with Taher's (2021) observation that adoption is hampered by reluctance and ignorance. Furthermore, Taher adds that the construction industry has embraced these technologies more slowly than other industries like manufacturing and the automotive sector due to embedded customs and a lack of subject-matter expertise. In agreement with Taher, Olaniyan, (2019) also revealed significant challenges that hinder progress in the industry. The research indicated that only 40% of construction employees expressed confidence in their ability to adapt to new technologies. Although, the adoption of industry 4.0 technologies in the construction is rather slow, comments from respondents on the pace of technological change, with one manager stating, "We are often overwhelmed by the constant need to learn new tools without adequate support", signify their frustration and low confidence in the ability to keep up and adapt to changes (Olaniyan Rasaq, 2019).

While more than half of the participants 57.1% believe automation will improve collaboration which aligns with a study by X Ma which asserted that the construction field is in a phase of human-machine collaboration and will remain so for a long time, a significant 73.2% showed a negative overall attitude toward adopting Industry 4.0 technologies (Ma, 2022). According to Zabidin et al. (2023), the gap between acknowledging some of the advantages and being open to change emphasizes the necessity of interventions to transform mindsets. Furthermore, these findings support those of Tayal et al. (2024), who found that uncertainty and a negative attitude toward fully embracing the digital transformation are caused by fear of losing one's job and the high cost of implementation. Arana-Landin continues by mentioning mental health issues, specifically stress and anxiety, that are linked to the implementation of these technological advancements. These results, however, contradicted a study conducted by Akinradewo in the South African construction sector, which showed a high degree of adoption willingness with the lowest tool having a MIS above the average of 3.00. This is primarily because of Zimbabwe's low employment rate and job insecurity, which makes the majority of practitioners fear being replaced by machines. This is evident in the fact that the majority of respondents (67.9%) hold this opinion, and only a smaller percentage of construction practitioners (33.9%) are confident in their capacity to adjust to these technologies (Akinradewo, 2018).

5.3 Current Practices in Adoption of Industry 4.0 Technologies

The findings as illustrated in Table 6 demonstrate a strikingly low adoption rate of Industry 4.0 technologies, with a total practices score of 1.697 out of 8, equating to only 21%. Such findings are in line with a study in Africa by Adetunla and Madonsela (2022) which highlighted that only 15% of the organizations surveyed had embraced cutting-edge technology like IoT and AI illustrating that adoption of industry 4.0 technology is still in its infancy. Additionally, this aligns with Demirkesen and Tezel (2021), who identified implementation costs and resistance to change as primary barriers to adoption.

An astounding 94.6% of respondents do not use BIM in their daily work, and only a small percentage of participants (16.1%) acknowledged that have integrated robots to reduce safety risks. Such findings align with a study done in Brazil in 2024 by Menegon-Lopes and da Silva Filho, resulting in a below-average adoption of Industry 4.0 technologies as 36% of respondents reported that only 3% of the construction professionals acknowledged a significant evolution of these technologies in the construction sector attributing a score of 5. This shows that adoption is still quite low particularly due to lack of knowledge on the ability of BIM and robots to enhance safety, high cost and a negative attitude as a less percentage of practitioners are confident of the ability to adapt to changes on daily work operations post-implementation of these technologies (Bolpagni, 2022).

On the other hand, 66.1% of respondents said they use data analytics to track safety, suggesting some use of data-driven procedures and decisions. The study results are similar to that of Smit in 2022, which reports that 62% of the surveyed construction companies have started integrating data analytics into their safety management practices thus emphasizing the potential for data analytics to reduce workplace accidents and improve compliance with safety regulations (A. N. Smit, 2022). However, the limited use of drones (28.6%) and wearable technology (25%) suggests a gap in practical application despite theoretical knowledge. Limited use of cutting edge technology such as drones and wearable technology is evident due to lack of training as highlighted with only 7.1% of the employees having received training. Lack of funding also affects use of drones and wearable technology as acknowledged by 65% of the respondents in a study by Olaniyan. One of the respondents pointed out that they are overwhelmed by the constant need to learn about new technology without adequate financial support (Olaniyan Rasaq, 2019).

A mere 7.1% confirmed that workers receive training on digital tools, further highlighting the need for educational initiatives. Although the study reveals a very low level of training on industry 4.0 technologies, a similar study also reveals a poor level of training done in Nigeria with only 29.4% of respondents having received training on Construction 4.0 technologies. Additionally, only 12.5% utilize digital twins for testing processes such findings align with that of Costello, (2019) which illustrated that currently, only 13% of organizations utilize digital twins however, 62% are either establishing this technology or planning to do so within the following years, reflecting underutilization of advanced technologies essential for improving project outcomes.

The study's findings emphasize the urgency with which construction practitioners need to increase their knowledge, implement Industry 4.0 technologies in practice, and have more positive views toward them. This includes education, participation and involvement in the use of digital tools; the use of BIM in day-to-day work to enhance planning and coordination; the use of wearable technology, drones, and other devices to monitor safety conditions, particularly in hazardous situations; and, finally, the use of digital twins to test safety scenarios and construction processes before the start of actual work. Through promoting good knowledge, and practices and transforming construction workers' attitudes, the construction industry can fully harness the potential of Industry 4.0 technologies, ultimately leading to enhanced efficiency, safety, and project success.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, the knowledge, attitudes, and practices of construction practitioners at Bindura University exhibit serious shortcomings that hinder the implementation of industry 4.0 technologies. Practitioners show a worrisome lack of knowledge on important technologies including Building Information Modeling (BIM), drones, automation, robots, and digital twins, with a knowledge score of just 39.4%. In addition to impeding successful implementation, this drawback transmits misconceptions about the role of automation and artificial intelligence in the construction industry, as the majority of workers think that these technologies can take the place of human capital in the field. This ignorance extends to negative attitudes toward industry 4.0 technologies. Additionally, just 21% of respondents use Industry 4.0 technologies in their everyday operations, indicating that there is still a significant gap in practical acceptance while acknowledging the potential benefits of these technologies, as seen by the 58.9% of respondents who believe they can improve safety. The report also emphasizes the pressing need for focused interventions to change perceptions about technology adoption. Although many practitioners acknowledge the good effects of Industry 4.0, a sizable portion have poor confidence in their capacity to adjust to new technology and fear losing their jobs, which makes them highly reluctant to adopt including other factors such as the high cost of acquiring and maintaining the technology. This disconnect emphasizes how crucial thorough continuous training initiatives and awareness efforts are to promoting a safe and innovative culture in the construction sector thus significantly contributing to education 5.0 which emphasizes on the need for developing a skilled workforce that can adapt to changes of modern technologies. The construction industry cannot fully benefit from Industry 4.0 technologies, which will ultimately increase productivity and lower workplace risks unless persistent efforts are made to improve the knowledge and attitudes of the construction workers.

6.2 Recommendations

To improve the knowledge, attitudes and practices of construction practitioners which will aid in the construction sector to fully leverage industry 4.0 technologies the industries can:

- To clear up misconceptions and improve the knowledge of professionals in this field, educational campaigns and continual training programs that emphasize the advantages and real-world uses of technologies like BIM, drones, and data analytics must be started, either with government, non-governmental, or organization support.
- To promote and facilitate the purchase and integration of Industry 4.0 technology into construction sector, the government must provide lower interest rate loans as well as subsidies.
- Stakeholder Collaboration: To establish an environment that is conducive to the adoption of technology, encourage cooperation between government organizations, industries, and educational institutions.
- Policy Advocacy: Legislators need to create grants or tax exemptions for construction companies implementing Industry 4.0 technologies.
- Mental Health Support: To address issues about stress and job displacement associated with technology adoption, mental health resources and support networks are need to be offered.
- Curriculum Redesign: To ensure that future construction practitioners are adequately equipped, the government, acting through the Ministry of Higher and Tertiary Education, must collaborate with educational institutions to update curricula to incorporate practical training on Industry 4.0 technology.

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APPENDICES

Appendix 1: Research Questionnaire

My name is Tinotenda G Bongo a final year student studying Bachelor in Science honours of Safety, Health and Environmental Management at Bindura University of Science Education. I am conducting a research for my project entitled "An assessment on the knowledge, attitudes and practices of construction practitioners towards the adoption of industry 4.0 technologies as a strategy to prevent/ minimize the occurrence of fatalities, injuries and diseases in Zimbabwe's construction sector". Please answer the following questions honestly so that this research can go successfully. Your response to this study will remain private, and its use will be limited to academic purposes. Your answers will help guide the research and advance knowledge of the industry 4.0 technologies as a means to enhance health and safety.

Part I: Demographic Information (please tick where appropriate).

1. **Gender:**

Male ☐ Female ☐

2. **Age:**

18-30yrs ☐ 31-40yrs ☐ 41-50yrs ☐ 50+yrs ☐

3. **Level of education:**

Primary ☐ Secondary ☐ Tertiary ☐

4. **Duration of employment:**

0-5yrs ☐ 6-10yrs ☐ 11-15yrs ☐ 16-20yrs ☐

5. **Occupation** ☐

Part II: Knowledge of Industry 4.0 Technologies

6. Building Information Modeling (BIM) can improve planning and teamwork during conducting a construction project?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

7. Are robots currently replacing all human workers on construction sites?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

8. Data analytics help construction managers make better decisions through use of real-time data?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

9. Do drones help improve worker safety by reducing the need for risky manual site inspections?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

10. Does wearable technology track worker safety and health on construction sites?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

11. Do AI-powered tools slow down construction work rather than improve efficiency?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

12. Is AI limited to only designing buildings and not improving safety or productivity?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

13. Is it possible for smart helmets and other wearable technology to identify employee weariness and stop accidents?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

14. Automation and robotics in construction industry leads to higher workplace injuries rather than reducing them?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

15. IoT devices and sensors (smart devices) can check machine performance, keep track of materials, and give instant updates to help with decisions.

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

16. The purpose of AI in construction is to replace engineers and make buildings automatically

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

17. Can engineers use digital twins to monitor and assess project designs using real-time data before construction starts?

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

18. Cloud computing can be used to create customized components and structures, reducing waste and improving efficiency

1 Yes ☐ **2 No** ☐ **3 I don't Know** ☐

Part III: Attitudes Towards Industry 4.0 Technologies

19. Do you believe that Industry 4.0 technologies can enhance safety in construction industry?

1 Strongly disagree ☐ **2 Disagree** ☐ **3 Neutral** ☐ **4 Agree** ☐ **5 Strongly agree** ☐

20. How do you feel about the integration of technology, such as AI and robotics, in improving safety on construction sites?

1 Very negative ☐ **2 Negative** ☐ **3 Neutral** ☐ **4 Positive** ☐ **5 Very positive** ☐

21. How confident are you in your ability to adapt to new technologies??

1 Very negative ☐ **2 Negative** ☐ **3 Neutral** ☐ **4 Positive** ☐ **5 Very positive** ☐

22. Do you believe that the benefits of using wearable technology for monitoring worker health outweigh the challenges involved in its implementation?

1 Strongly disagree ☐ **2 Disagree** ☐ **3 Neutral** ☐ **4 Agree** ☐ **5 Strongly agree** ☐

23. Do you believe that automation (Drones, IoT Smart sensors) in construction will improve or hinder collaboration among workers?

1 Improve Collaboration ☐ **2 No Change** ☐ **3 Hinder Collaboration** ☐

24. What is your overall attitude towards the adoption of Industry 4.0 technologies in your workplace?

1 Very negative ☐ **2 Negative** ☐ **3 Neutral** ☐ **4 Positive** ☐ **5 Very positive** ☐

Part IV: Current Practices in Adoption

25. Do you actively use BIM in your daily work to improve planning and coordination on construction projects?

1 Yes ☐ 2 No ☐

26. Have robots been integrated into tasks on your construction site to reduce safety risks for workers?

1 Yes ☐ 2 No ☐

27. Do you rely on data analytics for tracking project safety risks and improving decision-making?

1 Yes ☐ 2 No ☐

28. Are drones regularly used on-site for inspections to prevent workers from entering hazardous areas?

1 Yes ☐ 2 No ☐

29. Do workers on your site wear smart helmets or other wearable technology to monitor safety conditions?

1 Yes ☐ 2 No ☐

30. Are IoT sensors and smart devices used on-site to track machine performance and provide real-time updates for safety?

1 Yes ☐ 2 No ☐

31. Are construction workers trained on how to operate digital tools like sensors, drones, and AI-based safety monitoring systems?

1 Yes ☐ 2 No ☐

32. Do you use digital twins to test construction processes and safety scenarios before actual work starts?

1 Yes ☐ 2 No ☐

Thank you.