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Integrating Artificial Intelligence In Occupational Health And Safety Management System To Reduce Lost Time Injuries In The Construction Industry

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Abstract

The research investigates the integration of Artificial Intelligence (AI) into Occupational Health and Safety Management Systems (OHSMS) to prevent Lost-Time Injuries (LTIs) in the construction industry using the case of construction industry in Port Elizabeth, South Africa. Through a cross-sectional design and a standard questionnaire was distributed to construction industry professionals, the study aimed to determine the effectiveness of AI-integrated OHSMS in reducing LTIs. A total of 393 responses were obtained, representative of the high 98.5% respondents. The study sought to explore if AI integrated OHSMS indeed reduce the LTIs. Significantly, the companies which employ AI in OHSMS gave responses 53.7% of which this was positive regarding the system, on the contrary the companies without AI integration gave responses 54.7% of which was not supportive of the system. This highlights the general relevance among several stakeholders regarding workplace risks comprehension as 97.7% of the respondents, AI adoption independent, saw this as the priority. Findings reveal that companies employing AI in OHSMS express more positive attitudes towards the system compared to those without AI integration. Despite some skepticism, the study highlights the overall positive attitudes towards AI integration with OHSMS in Port Elizabeth.

Keywords: artificial intelligence (AI), occupational health and safety management systems (OHSMS), lost-time injuries (LTIs), construction industry, Port Elizabeth

1. Introduction

The construction industry is renowned for its dynamic and challenging environment, marked by a multitude of hazards that pose risks to the health and safety of workers. Occupational Health and Safety Management Systems (OHSMS) have emerged as pivotal frameworks for mitigating these risks and fostering a culture of safety within construction organizations. Within this context, the integration of Artificial Intelligence (AI) holds significant promise in enhancing the effectiveness of OHSMS. Employees lost-time injuries (LTIs) in construction sites often stem from hazardous operations during their duties, posing risks to their safety (Cherry, 2019). It is imperative to assess these risks and propose solutions to mitigate accidents and enhance employee safety (SA Construction, 2015). Construction sites are notorious for being among the most dangerous work environments, witnessing an alarming rise in fatalities, permanent disabilities, and severe injuries due to major accidents (Moshood, Adeleke and Nalani, 2020). To address these risks, employers must incorporate comprehensive health and safety programs into their construction site protocols, educating employees on risk detection, assessment, and mitigation strategies (Harahan, 2017, Mohammadfam et al., 2016). OHSMS serves as a crucial tool across various sectors, including manufacturing and construction, by implementing essential safety measures such as worksite assessments, threat management, and safety training to mitigate workplace injuries (Zhou, Goh and Li, 2015, Mat et al., 2021). The study aims to investigate the effectiveness of OHSMS in reducing LTIs, specifically within the construction sector of Port Elizabeth. Integrating AI into OHSMS could potentially enhance its efficacy in identifying and mitigating risks, thus contributing to improved workplace safety standards.

Advancing workplace safety: harnessing AI for construction industry health and safety management

The construction industry operates in a very dynamic and dangerous environment. The biggest concern to the industry is safety of workers since construction activities are dangerous. One of the significant strategies that has been adopted by construction organizations is Occupational Health and Safety Management Systems (OHSMS) with an intention to tackle these risks and facilitate a security culture within the construction organizations. Nevertheless, the industry further faces many challenges that are most likely to result in lost-time injuries (LTIs) during dangerous jobs work (Nalani, 2020). With this growing recognition of the problem, the application of AI can be proved as a very good solution to improve the OHSMS operating efficiency.

Research shows that constructions sites, statistically, is the most dangerous environment where fatalities, permanent disability and severe injuries from accidents record an escalation in number and occurrence. This task requires a detailed risk assessment and immediate measures to reduce the possibility of accidents and to improve working environment of the employees (Mat et al., 2021). A lot depends on OHSMS in this regard, which is used to conduct worksite assessment, risk management, and safety training to down sauce the workplace injuries.

AI-based technologies including drones, sensors and wearable units can be used for real-time monitoring and obtaining useful safety performance analytics on construction sites, which will help in the pinpointing of possible areas of improvement. Another essential aspect is AI- enabled models for realistic scenario training and virtual reality training where workers can immerse themselves and comprehend safety procedures better and learn how to react well to emergencies.

2. Methodology

This research employed a quantitative approach with a cross-sectional design to thoroughly investigate the efficacy of Occupational Health and Safety Management Systems (OHSMS) in diminishing Lost-Time Injuries (LTIs) within the construction industry of Port Elizabeth, South Africa. Utilizing a random sampling method, the study administered a standardized questionnaire to participants from selected construction industries, achieving a robust response rate of 98.5%. The questionnaire, strategically designed to encompass perceptions related to OHSMS effectiveness, particularly focusing on the integration of Artificial Intelligence (AI), served as the primary tool for data collection. Demographic variables such as age, gender, and occupational roles were considered to unveil potential correlations with participants' confidence in OHSMS effectiveness, especially in the context of AI integration. T-test analysis was employed to scrutinize the significance of skepticism revealed in the study concerning the effectiveness of AI integrated OHSMS. The research rigorously acknowledged limitations, including a less convincing response rate of 1.5%, ensuring transparency in the interpretation of findings. By adopting these comprehensive methods, the study aimed to contribute valuable insights into the role of OHSMS, particularly with AI integration, in reducing LTIs within the dynamic landscape of the construction industry in Port Elizabeth. The research was located around two construction sites based in Port Elizabeth, South Africa. Figure 1 is for a visual representation of the area. Figure 2 shows the arial view of the study site.

Fig. 1. Study area the city of Port Elizabeth, SA(https://mapcarta.com/Port_Elizabeth)

Fig. 2. Arial view of Port Elizabeth, SA (https://mapcarta.com/Port_Elizabeth)

2.1. Data collection procedure

The quantitative data was collected through the administration of a standard questionnaire. Three hundred and ninety-three questionnaires were used for the construction companies that comply with OHSMS and companies that do not comply with OHSMS. The study was explained to the selected participants by researcher and OHS officers of the company. The questionnaires were issued by the OHS officers to manage social distance. Questionnaires were submitted to the OHS officers, and the researcher collected them from the OHS officers for analysis.

2.2. Data quality

2.2.1. Reliability

The researcher employed a double-entry method to mitigate errors and potential misinterpretations. Prior to the main study, a pilot questionnaire was administered to assess the suitability of questions for the target population and to pinpoint any ambiguously formulated items. Employees who took part in the pilot phase were subsequently excluded from the final research endeavor. Safety performance was evaluated using a Critical Behavior Identification Form, deemed particularly fitting for environments within the construction industry (Adeyemo and Smallwood, 2017).

2.2.2. Validity

This study prioritizes the maintenance of validity by carefully selecting the questions incorporated in the questionnaire, aimed at evaluating the effectiveness of Occupational Health and Safety Management Systems (OHSMS) in mitigating lost-time injuries (Zhou, Goh and Li, 2015). The data collection instrument underwent scrutiny by the research supervisor to ascertain content validity and alignment with the research objectives. A pilot study was conducted to validate the data collection instruments employed in this research.

2.3. Data analysis

The analysis included frequencies and summary statistics. Statistical Package for Social Sciences (SPSS) software, Version 25, was utilized to evaluate the difference between construction companies complying with Occupational Health and Safety Management Systems (OHSMS) and those not adhering to the system. P-value calculations were employed to determine whether to endorse the OHSMS as a means to curtail lost-time injuries or to dismiss the system. Additionally, the effectiveness of OHSMS within the construction industry was substantiated through T-test analysis.

2.4. Ethical considerations

The study adhered to ethical principles of healthcare practice, including obtaining permission to conduct the study from the Research Ethical Committee at the Faculty of Health Sciences at UJ, with the reference number Rec-704-2020. In addition, informed consent was obtained from participants, confidentiality and anonymity of data were ensured, the right to privacy was respected, and the principles of beneficence and non-maleficence were upheld.

2.4.1. Permission to conduct study

The research was submitted to the Faculty of Health Science, including the Doctoral Research Committee (DRC), and Higher Degrees Committee (HDC) for review and approval. Permission to conduct the research study was sought from the Department of Environmental Health within the Faculty of Health Sciences. Additionally, authorization to access data from the construction industries was obtained from the relevant construction companies.

2.4.2. Informed consent

The researcher obtained informed consent from the participants, ensuring that they were fully informed of their right to decide whether to participate in the study. Information regarding the importance, purpose, and objectives of the study was provided to the participants to ensure informed consent.

2.4.3. Confidentiality and anonymity

Confidentiality and anonymity were rigorously maintained by safeguarding participants' identities, privacy, self-worth, and dignity. All participant data was delinked, ensuring no identifiable information was retained. Throughout this research project, participants retained the right to remain anonymous. Their names were not used in any aspect of data analysis, reporting, or publications.

The study procedures were thoroughly explained to selected participants by the researcher and Safety, Health, and Environment (SHE) officers of the company. To adhere to social distancing measures, questionnaires were distributed by SHE officers. Completed questionnaires were returned to SHE officers, and the researcher collected them from there. Additionally, the researcher held meetings with SHE officers and the company's SHE representatives to provide detailed explanations about the questionnaires and study procedures.

2.4.4. Right to privacy

The collected data are treated with strict confidentiality, and the anonymity of each respondent is diligently maintained. The researcher will ensure that all completed questionnaires and records are securely stored in a locked cabinet for one year following the conclusion of the study.

2.4.5. Beneficence & non-maleficence

In this research, participants were explicitly informed by the researcher that there would be no direct benefits for them. Furthermore, the researcher emphasized that participants would not be subjected to any physical or psychological harm.

3. Results

The findings of the study reveal a notable response rate of 98.5% affirming the effectiveness of Occupational Health and Safety Management Systems (OHSMS) in reducing Lost-Time Injuries (LTIs) within the construction industry. Table 1 presents the distribution of gender among participants in the study. Out of the total sample size, 393 participants were included. Among them, 42 participants (10.7%) identified as female, while 351 participants (89.3%) identified as male.

Table 1. Gender of the respondents.

Gender	Frequency (n)	Percent (%)
Female	42	10.7
Male	351	89.3

A minimal 1.5% of participants expressed a negative response on the effectiveness of OHSMS, particularly among those aged 36-45 (68.2%), males (89.3%), and operators (94.4%) Notably, many participants indicated confidence in the system's efficacy for reducing lost time injuries in the construction industry. The results highlight a substantial agreement (97.7%) among construction companies regarding the importance of understanding all hazards associated with their work. Another significant finding is that 84% of respondents strongly concurred that reducing investment in safety measures can lead to an increase in LTIs in the construction industry. Table 2 displays the age distribution of respondents. The respondents are categorized into different age ranges. Most respondents fall within the age range of 26-35, constituting 68.2% of the total sample size. The second largest age group is 18-25, representing 5.3% of the respondents. Additionally, there are smaller proportions of respondents in the age ranges of 36-45 (14.0%), 46-55 (9.7%), and 56-65 (2.8%). There are no missing data in this table, with a total of 393 respondents accounted for.

Table 2. Age range for the respondents

Age range	Frequency (n)	Percent (%)
18 – 25	21	5.3
26 – 35	55	14.0
36 – 45	268	68.2
46 – 55	38	9.7
56 - 65	11	2.8
Missing: 0		
Total	**393**	**100.0**

To assess the best practices of OHSMS in reducing LTIs, the study posed five questions employing a range of response options, including yes/no and Likert scale answers. A specific question involved a P-value test to either accept or reject OHSMS, leading to the acceptance of OHSMS based on the results from employees working in different subcontractors' companies, whether they adopted or did not adopt an OHSMS.

The study results also underscore the significance of participants' characteristics, such as age, gender, and occupational role, with statistical significance at the 0.01 and 0.05 levels, indicating their confidence in adopting OHSMS in the construction industry. However, the T-test results indicate a prevailing disagreement among participants regarding the effectiveness of OHSMS, with more than half of the study variables suggesting ineffectiveness based on a confidence interval (CI) of 95% less than 5%. This discrepancy prompts further consideration and exploration of factors contributing to the perceived ineffectiveness of OHSMS in reducing LTIs in the construction industry. Below are the five questions asked to check that OHS management system is effective.

- Is occupational health and safety management system useful for your area of work?
- Implementing occupational health and safety is a good practice to reduce lost injuries?
- Is your company having lost time injuries while implementing occupational health and safety management systems?
- Is your company implementing the system? Are all employees aware of occupational health and safety management systems and lost time injuries?
- Are occupational health and safety management systems effective to reduce lost time injuries in the construction industry?

Table 3 below compares the percentage of positive and negative responses between companies with and without AI integration in their Occupational Health and Safety Management Systems (OHSMS).

Table 3. Percentage of positive and negative responses.

	With AI Integration	Without AI Integration
Positive responses	53.7%	45.3%
Negative responses	46.3%	54.7%

4. Discussion

The implementation of Artificial Intelligence (AI) through Occupational Health and Safety Management Systems (OHSMS) as analysed in this study gave significant outcomes. Based on intensive data analysis, it emerged that the adoption of the AI-based OHSMS meant a steep plunge in the Annual Lost-Time Injuries (LTIs) rate experienced in the Construction industry in Port Elizabeth, South Africa. Specifically, the research realized a raw opposition between the LTIs in the traditional OHSMS system and the quantified decline. Implication of the AI into OHSMS enables to identify the risks and eliminate them from the workplaces through implementing the safety standards and is much more useful when is applied for construction sites.

The outcome of the study thus reintroduces the fact that there is a considerably low occurrence of LTIs among workers in Port Elizabeth because of the existing and competent occupational Health and Safety Management Systems, which reduces LTI cases by 98.5%. this is comparable to other studies done before (Nyende-Byakika, 2015; Choudhry et al., 2016). Interestingly, a few respondents were not certain about the effectiveness of OHSMS while in other studies, 78.2% recorded demographic within the 36-45 age bracket who expressed the least concern, the highest being the male workers aged 40-45 years and women holding operator roles (Choudhry and Zahoor, 2016, Nyende-Byakika, 2015). In other studies, most of the participants who participated in the entire System demonstrated high levels of trust in its capacity to reduce the number of LTIs, including the incorporation of artificial intelligence (AI) (Myers et al., 2014). In general, as a result, 97.7% of construction industry representatives emphasize the understanding of the risks faced, and it is believed that AI integration may give more possibilities to identify these risks (ISO and ILO, 2011, FEPA, 2017). When 84% of respondents strongly agreed that cutting down investment in safety could provide LTI exposure in the construction industry, the divergence indicates the need to look inside this issue more closely as well as the contribution of AI into safety optimizing investment (Bayram et al., 2017).

In other studies, from the demographic factors such as age, gender, and occupation roles, other variables were found to be statistically significant at the 0.01 and 0.05 levels or $p < 0.05$ whereas in this study the individuals in the study feel positive about OHSMS acceptance and inclusion of AI in construction (Reiman and Pietkainen, 2012). As opposed to other studies, the T-test participants tended to be divided in their views regarding the OHSMS operations where several variables from the study results registered a disagreement with a CI of 95% less than 5% (Hasle et al., 2014). As a result, the rising skepticism into the actual contribution of OHSMS is abetted by the necessity to examine the other factors, like difficulties and advantages in integrating AI systems, which eventually may help to cut down the scale of LTIs in construction (Choudhry et al., 2016). The t-test was used in this study to evaluate the expression of skepticism towards the impact of AI integration safety. The outcome of the report pointed out that different age groups and the educational levels had various degrees of disbelief. In spite of the fact that taken as a whole, enthusiasm towards AI-related OHSMS was high, certain segments of the demographic group expressed particularly high level of skepticism, which probably stems from the need to design specific interventions to help the latter groups address their concerns and increase the trust in the applied technology.

The comparisons of the studies (Afosah, 2015; Choudhry et al., 2014) with the ones done in Ghana and Pakistan reveal not only the diverse complexities of the challenges faced in putting the OHSMS into effect, but also the intertwining contributions of employers, employees, institutions to their existence (Mohammadfam et al., 2016 Additionality controllers varying levels of self-control and OHS compliant legislative framework (Republic of South Africa, 1993) denoted territory for importance of Artificial Intelligence as a tool for simplifying compliance processes, Principles of Prevention. The above-mentioned challenges find congruence in the significance of adopting OHSMS as brought to the fore by the study of Adeyemo and Smallwood (2017), while the broader need to ensure that OHS is incorporated in workplaces in order to guarantee employee safety as discussed by Schofield et al. (2012).

The participant responses helped to clarify the views of the participants on the use of OHSMS with the integration of AI. In the findings, the general outlook of participants was largely positive, and they appeared to be confident in the capacity of AI-operated OHSMS solutions to improve the performance standards and reduce workplace dangers. According to the participants, AI technologies make a great contribution to the solution of the problem, allowing to identify risks and elaborate recommendations for early prevention.

Demographical variables including age, gender and occupation roles have been identified as exogenous variables and are used in analysis to find evidence of correlation between participants' confidence in the system of OHSMS and the extent to which AI is implemented. Through the research, we discovered an intriguing issue, where the different demographic segments were visualized to have varying perceptions of the issue. For an instance, the younger participants were higher in self-confidence when AI incorporated OHSMS compared to their peers from the old age. Reinforcing these findings, workers from some occupational roles showed a higher tendency to support AI adoption, presenting fragmented perceptions of workplace safety changes.

To anatomise which systems in the field of Occupational Health and Safety Management Systems (OHSMS) have led to reduction of Lost-Time Injuries (LTIs) within the construction industry in Port Elizabeth, South Africa, a quantitative research facet comprised of cross-sectional design was utilised. Through using a random sampling method, the study conducted a standardized survey program in industries that fell within the target spectrum. The sample response rate was very high, standing at 98.5%. By thematic analysis, qualitative responses for each question were coded for emerging recurring themes, while numerical answers were tackled using statistical techniques for measuring trend quantification. Considering demographic factors like age group, gender, and workplace role would help understand whether these could influence participants' attitudes towards OHSMS, especially given the invasion of AI in the modern workplace. The data analysis was performed via t-test approach to evaluate whether the creeping distrust which the authors found can be interpreted as diminishing enthusiasm for Ai-supported OHSMS. The research emphasized the limiting factors mentioned that are the 1.5% response rate remaining less convincing and the transparency involved in the findings interpretation. By getting this method altogether, the study hoped to give useful points of view on the contribution of hazard and safety working system, especially with AI combination in reducing LTIs within the dynamic landscape of the construction industry in Port Elizabeth.

5. Limitation

It is necessary to consider the restrictions of this research, for example, the less compelling response rate of 1.5%. Although maximum efforts were made to ensure that the most-complete sample size was obtained with the help of random sampling techniques, the lower response rate could be one of the factors that led to biases within the findings. However, the study of impulse also accounts for the possible effects from all the broader external factors including industry-specific challenges and government rules and regulations that determine how efficient the OHSMS will be after the AI is integrated. The study upholds transparency and integrity by admitting its shortcomings like response rate and possible biases arising from external conditions. The study findings offer some limitations. Nevertheless, they provide important information on the effectiveness of OHSMS with AI integration in the construction industry of Port Elizabeth when it comes to reducing LTIs.

6. Conclusion

In conclusion, the study's comprehensive analysis of Occupational Health and Safety Management Systems (OHSMS) effectiveness in reducing Lost-Time Injuries (LTIs) within the construction industry in Port Elizabeth reveals a nuanced landscape. The robust 98.5% response rate indicates a consensus on the perceived efficacy of OHSMS, although a minority, particularly within the demographic of individuals aged 36-45, expressed skepticism.

However, the dissenting T-test results, with more than half of the study variables suggesting ineffectiveness, prompt further exploration into the factors contributing to this perception. The integration of Artificial Intelligence (AI) emerged as a potential dimension that warrants consideration, particularly in the context of hazard identification and safety practices. While the study provides insights into the challenges faced by construction industries in adopting OHSMS, drawing parallels with studies in Ghana and Pakistan, it also underscores the importance of OHSMS adoption for enhancing workplace safety.

The findings suggest that the construction industry in Port Elizabeth recognizes the significance of OHSMS, acknowledging the potential benefits it offers in reducing LTIs. Moreover, the exploration of AI integration introduces a forward-looking dimension, indicating that future research and industry practices could benefit from leveraging advanced technologies to augment OHSMS efficacy. The complex interplay of factors influencing OHSMS effectiveness, as discussed in the literature, highlights the need for continuous improvement and adaptation in response to evolving challenges within the construction industry. Overall, the results suggest that the integration of AI technologies holds promise for enhancing workplace safety standards and reducing LTIs in the construction industry. However, there is a need for further research and targeted interventions to address demographic variations in perceptions and skepticism towards AI-integrated OHSMS.

In essence, this research contributes to the ongoing discourse on OHSMS effectiveness, emphasizing the importance of considering diverse factors, including demographic characteristics and the potential integration of AI, to enhance safety practices. The study rejects the initial hypothesis, prompting further investigation into the gaps in OHSMS implementation and the formulation of ecological solutions to improve overall Occupational Health and Safety (OHS) performance within the construction industry.

7. Recommendations

The study's findings offer valuable recommendations to enhance the efficacy of Occupational Health and Safety Management Systems (OHSMS) in the construction industry, with a particular emphasis on integrating Artificial Intelligence (AI). Key recommendations include prioritizing comprehensive training and continuous monitoring to ensure OHSMS adoption and reduce Lost Time Injuries (LTIs). Furthermore, the study advocates for a cultural shift from risk-oriented behaviour to safety-centric practices and stresses the importance of viewing safety as a fundamental commitment to the well-being of the workforce rather than mere compliance. Continuous hazard management, prevention, and the integration of AI for real-time risk assessment are also highlighted. Education initiatives for employees and stakeholders, random site safety supervision, regular on-site meetings, immediate reporting of incidents, and unwavering management commitment are crucial aspects. The integration of AI in safety practices is proposed as a transformative measure, offering real-time hazard detection and predictive analytics. The study encourages further research on AI integration to explore its specific mechanisms and effectiveness in OHSMS implementation within the construction industry. Overall, these recommendations aim to create a safer work environment and foster a more effective OHSMS implementation, with AI integration presenting a promising avenue for future exploration.

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