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Implementation of Smart Helmets to Enhance Safety in Construction Projects in Malaysia

Nur Ilham Abdul Aziz[1], Aryani Ahmad Latiffi[1*]

[1] *Department of Construction Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia*

*Corresponding Author: aryani@uthm.edu.my
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Abstract

The construction industry remains one of the most risk sectors due to challenging site factors, heavy machinery operations, and insufficient real-time safety monitoring, all of contributing to an increased risk of workplace accidents. Conventional safety helmets provide only basic protection and are ineffective in detecting risks or monitoring workers' physical condition, mandating the use of more modern safety technology. This highlights the important role of adopting advanced technologies, such as smart helmets which is not only help monitor and manage potential hazards but also effectively reduce the risk of accidents, thereby improving overall safety and efficiency in construction project management. Thus, this paper discusses on the advantages of using smart helmet in construction projects in Malaysia, investigate the challenges that hinder the adoption of smart helmet in construction projects and suggest enhancement for the implementation of smart helmets in construction projects in Malaysia. The respondents involved in the interviews were construction professionals in Malaysia who have experience using smart helmets in construction project. The findings show that smart helmets improve worker safety through real-time monitoring, early hazard alerts, and systematic safety data collect, enabling for quicker and better inform decision-making. However, several barriers were observed, including workers limited digital literacy, technological limitations managing data issues, language problems during training, and inconsistent usage on-site. In order to resolve these issues, it is essential to provide continuous training, clear standard operating procedures, enhanced system reliability, and strong organizational support. In general, smart helmets have the potential to significantly improve safety performance in construction projects when implementation issues are successfully solved.

1. Introduction

The construction industry is crucial for Malaysia's national development. According to the Construction Industry Development Board (CIDB, 2023), this industry accounts for about 4% of Malaysia's Gross Domestic Product (GDP) and employs over 1.2 million workers every year. However, the construction field is dynamic and high-risk. It involves working at heights, operating heavy machinery, and dealing with hazardous materials, making it one of the most accident-prone industries in the country. Construction workers are frequently exposed to safety hazards that may lead to injuries or fatal accidents despite the enforcement of safety regulations and the use of personal protective equipment (Hinze *et al.*, 2013). The dynamic and unpredictable nature of construction sites

makes effective safety monitoring challenging, particularly when safety management relies heavily on manual supervision and traditional reporting systems (Zhou *et al*., 2015). The adoption of advanced technologies in the construction industry, particularly smart technologies, plays a crucial role in enhancing site safety by minimizing the risk of accidents among workers and improving overall project management efficiency (Zhou *et al.,* 2015; Li *et al*., 2019).

Safety helmets are basic protective equipment used to reduce the risk of head injuries among workers. Although conventional helmets provide essential physical protection, they are limited in detecting environmental hazards or monitoring workers' physiological conditions in real time (Fang *et al*., 2018). With the advancement of digital technologies, the integration of Internet of Things (IoT) systems into wearable devices has introduced smart helmet technology as an innovative solution to improve construction safety management (Lee & Kim, 2019). Smart helmets are equipped with sensors and communication features that enable real-time monitoring, hazard alerts, and systematic safety data collection to support proactive decision-making (Park *et al.,* 2020).

This study aims to address these limitations by examining the advantages of using smart helmets in construction projects, investigating challenges that hinder their adoption, and proposing strategies to enhance their implementation. Understanding both technological and human-related factors is essential to ensure effective adoption and long-term sustainability of smart safety technologies (Choi *et al*., 2017).

2. Literature Review

The construction industry is widely recognised as one of the most hazardous sectors due to challenging workplaces, heavy machinery operations, and poor real-time safety monitoring, all of which leads to high worker injury rates (International Labour Organization, 2021). As a result, researchers and industry practitioners are actively investigating the use of advanced technologies to improve safety management procedures (Zhou *et al*. 2015). Smart helmets, that combine wearable technology and IoT systems, have emerged as an innovative technology that improves traditional personal protective equipment through implementing monitoring and communication functions (Fang *et al.,* 2018).

Smart helmets can enhance construction safety through abilities including real-time location tracking, warning signs, health monitoring, and safety tracking (Lee & Kim, 2019). Smart helmet technology helps workers make quicker and more precise safety decisions, potentially lowering accident risks on construction sites (Park *et al.*, 2020). In addition, academics have examined the benefits and obstacles that influence smart helmet adoption, such as technological safety, worker acceptance, and organizational support (Choi *et al*., 2017).

2.1 Safety Smart Helmet in the Malaysian Construction Industry

Smart helmets have been introduced as an innovative option for improving worker safety on construction sites (Sireesha, 2020). Unlike traditional helmets, which only provide basic protection, smart helmets use sensors and IoT technology to monitor workers' conditions and environmental threats in real time, thereby lowering accident risks (Chim *et al.,* 2020). These helmets use numerous sensors to identify harmful conditions and relay data to monitoring systems, allowing for immediate safety response and better decision-making. Alert systems additionally enhance worker awareness and promote proactive safety management practices (Fithri *et al*., 2025). Despite these benefits, construction accident rates remain high, and the use of smart helmets in Malaysia is still limited due to a lack of knowledge and acceptance among industry stakeholders (Hamid *et al.,* 2018).

2.2 Safety Issues on Construction Projects

Common incidents include falling from heights, being struck by objects, machinery-related injuries, and exposure to hazardous materials, showing that traditional safety measures are frequently useless. Complex and unpredictable site conditions, tight project timelines that cause mental and physical strain, insufficient training, low safety awareness, failing equipment, and poor supervision all contribute to the increase of accident risk (Chua & Goh, 2017). Poor safety management may cause project delays, increase medical and severance costs, create legal obligations, and harm organisational reputation, demonstrating the need of effective safety practices for both employee safety and project performance (Ahmad & Hassan, 2019).

Despite existing regulations like the Occupational Safety and Health Act of 1994, CIDB standards, and mandatory safety training, issues occur due to inconsistent compliance and limited adoption of innovative safety technology (DOSH, 2022; Fithri *et al.,* 2025). Smart helmets allow for continuous monitoring of environmental and worker conditions, lowering accident severity and supporting Industry 4.0 safety initiatives. However, the implementation in Malaysian construction projects remains limited, emphasizing the importance of evaluating workers' understanding and acceptance (Fithri *et al*., 2025).

2.3 Cases Related to Safety in Construction

2.3.1 Malaysia

Case 1: Head Injury Due to Falling Object at Johor Bahru Construction Site (2024)

Due to falls, moving materials, and working at heights, head injuries are an increasing issue in Malaysia's construction business. These injuries are frequently made worse by insufficient supervision, poor training, and a lack of knowledge of potential hazards. A worker in Johor Bahru died in a tragic accident in 2024 after being hit by a falling metal object in an unsegregated location while not wearing a helmet that followed with safety regulations and without risk assessments (DOSH, 2024). Project delays, financial losses, and harm to one's reputation resulted from the incident. These incidents show the importance of smart helmets that offer impact detection, early warnings, and real-time monitoring in order to reduce the risk of head injuries and improve overall safety management on construction sites (Wong *et al.,* 2025).

2.3.2 United States of America (USA)

Case 2: Head Injury Caused by Collapse of Temporary Structure at a Construction Site (2023)

Head injuries continue to be a leading cause of death in the construction sector around the world, especially in affluent nations like the USA (OSHA, 2023). The fact that these incidents are frequently connected to structural failures, failure to comply to safety regulations, and poor safety management suggests that the potential of head injuries is a global concern (ILO, 2020). In 2023, workers suffered head injuries after a temporary structure collapsed due to poor planning and insufficient inspection (OSHA, 2023). In order to enhance worker safety and enable early risk detection, proactive safety measures like smart helmets combined with IoT systems are essential, as demonstrated by the event that resulted in project suspension and penalties (Wong *et al.,* 2025).

2.4 Smart Helmet

Smart helmet is a wearable device designed to ensure user safety through embedded sensors that can detect risks level wear status, and environmental conditions, often used in traffic and industrial safety systems (Chandran, Chandrasekar &, Elizabeth, 2020).

2.4.1 Purpose of using smart helmet

Smart helmet implementation in the construction industry seeks to improve worker safety and lower the risk of accidents, especially those involving head injuries in dangerous work environments (Wong *et al.,* 2025). Proactive safety solutions are essential since construction workers are exposed to risks such falling objects, working at heights, and accidents involving machinery (DOSH, 2022). In order to identify risks, bring out real-time alerts, and facilitate continuous worker and site condition monitoring, smart helmets integrate physical protection with sensors and IoT technologies (Raghunath & Ghaffar, 2025). This kind of technology promotes safer and more efficient safety management procedures, increases danger awareness, and motivates quick preventive action (CIDB, 2021).

2.4.2 Benefits of using smart helmet

Smart helmet use has a significant beneficial effect on worker safety, especially in reducing the risk of head injuries from accidents at work and from falling objects (DOSH, 2022). Smart helmets with accident sensors and automated alarm systems provide for quicker emergency response and injury detection (Wong *et al.,* 2025). Furthermore, real-time monitoring enables site managers to identify dangerous areas and evaluate safety information to enhance standard operating procedures and preventive measures (ILO, 2020). By decreasing compensation claims, project delays, and property damage, as well as improving overall safety performance and company reputation, less incidents also result in cost savings (CIDB, 2021; Raghunath & Ghaffar, 2025).

2.4.3 Challenges to increasing the use of smart helmets

The number of challenges hinder the widespread implementation of smart helmets in construction projects. Since smart helmets are more costly than traditional safety helmets, the high initial cost remains a significant

deterrent, especially for small and medium-size (SME) contractors (CIDB, 2021). Furthermore, low staff understanding and inadequate training hinder on-site adoption of modern technology (Wong *et al*., 2025). Usability is also impacted by comfort concerns, such as increased helmet weight (ILO, 2020). Moreover, despite the shown safety advantages, implementation is still being slowed by poor regulatory enforcement and technical maintenance requirements (DOSH, 2022).

3. Research Methodology

A qualitative approach was chosen to gather additional information for achieving the aims of this paper. Several semi-structure interviews were conducted with construction professionals in Malaysia who have experience using smart helmets, including projects managers, assistant project managers, and safety officers. These interviews aimed to explore the implementation of smart helmets in construction projects. The session was held via Google Meet and WhatsApp. The respondents were individuals responsible for safety management at construction sites and have utilized smart helmets to monitor ang mitigate safety issues in construction projects. The respondents were identified and selected using purposive sampling techniques, where participants were chosen based on their relevant experience and direct involvement with smart helmet technology in construction projects (Creswell, 2014). The responses gathered from participants were carefully analyzed through the content analysis method, ensuring a thorough understanding of the insights provided. This approach positively impacts the ongoing efforts to address and reduce safety concerns within the construction industry

4. Result and Findings

4.1 Respondent's Background

The purpose of the respondents' background is to identify information related to the respondents. Table 1 below shows the data analysis related to the respondents' background.

Table 1 *Respondent's Background*

Respondents (R)	Position	Type of Company	Years of Experience in the Company
R1	Project Manager	Private Agency	10 Years
R2	Assistant Project Manager	Private Agency	6 Years
R3	Safety Officer	Private Agency	5 Years
R4	Project Manager	Private Agency	11 Years

Based on Table 1 above, the respondents consist of individuals holding high-level positions such as Project Manager, Assistant Project Manager and Safety Officers at construction projects. All respondents are from private agencies and possess between 5 to 11 years of working experience, indicating that they have substantial industry exposure and practical knowledge in construction safety management. Finally, all respondents reported implementing the use of smart helmets to reduce safety issues in construction projects.

4.2 Advantages of using smart helmets in construction projects

The results of the data analysis for the stated advantages can be referred to in the following Table 2:

Table 2 Advantages of using smart helmets in construction projects

Advantages	R1	R2	R3	R4
Enhances safety	/	/		
Real time hazard detection	/	/		
Tracks worker fatigue			/	
Ensure regulatory compliance				/

Table 2 shows the benefits of employing smart helmets in construction projects. According to R1, smart helmets improve safety and offer real-time hazard detection by instantly alerting users when hazards are detected on the scene. Likewise, R2 emphasised that smart helmets contribute to a safer and more regulated workplace by assisting employees in preventing mishaps and enabling managers to track risk levels in real time. In

comparison to traditional helmets, these comments show that the technology enhances situational awareness and facilitates proactive safety management.

R1 stated, *"smart helmet is really can help to enhances safety, it can detect alert workers immediately if there have a risk or hazard in construction site"* This highlights the smart helmet's ability to mitigate accidents by quickly detecting hazards. Smart helmets use sensors and IoT technology to monitor site conditions and instantly alert workers enabling proactive safety operations, in contrast with basic helmets that only offer passive protection.

R2, "*With smart helmets, workers can avoid accidents which is can ensure the safety about themselves to more careful at construction site especially the risk of site place"* This shows that smart helmets offer safety protection and real-time hazard detection, enabling employees and managers to adopt preventative action. IoT-enabled smart helmets with motion sensors, for example, can monitor factors like gas leaks, heat stress, or unexpected falls and offer early notifications to avoid on-site accidents.

R3, meanwhile, concentrated on how smart helmets can monitor employee fatigue, describing how the system may identify fatigue symptoms and alert employees before problems arise. Assuring regulatory compliance is another significant benefit that R4 emphasised. Smart helmets help organisations adhere to safety standards and keep accurate data for inspection purposes. Overall, every respondent listed distinct but complimentary advantages, indicating that smart helmets help with compliance management, health monitoring, and safety enhancement in building projects.

4.2.1 Purposes of using smart helmet in construction projects

The results of the data analysis for the stated purpose of using smart helmet can be referred to in the following Table 3:

Table 3 *Purposes of using smart helmets in construction projects*

Purpose	R1	R2	R3	R4
Reduce workplace accidents	/	/	/	
Strengthen safety culture on site project	/	/		/
Promote adoption of modern safety practices	/		/	/

Table 3 lists the primary objectives of using smart helmets in construction projects. As indicated by R1, R2, and R3, the results show that lowering workplace accidents is a primary goal. They underlined that early hazard detection, real-time notifications, and ongoing site condition monitoring are all ways that smart helmets are utilized to avoid injuries. This illustrates how smart helmets promote accident prevention and enhance overall site safety performance by acting as proactive safety tools rather than just traditional protective equipment.

Furthermore, R1, R2, and R4 concurred that smart helmets contribute to a stronger safety culture on construction sites. The use of this technology enhances employee awareness, motivates compliance to safety protocols, and supports responsible action. Employees are more likely to take safety rules seriously and contribute to a more orderly and safety-conscious workplace when they are aware that site conditions are regularly assessed.

R1 highlighted, "*Using smart helmets makes workers more aware of safety on site."* This opinion emphasizes how smart helmets actively promote a stronger safety culture among workers, reaching beyond basic protective equipment. Wearable technology that provides real-time monitoring and alerts. This makes employees more aware of any risks, promoting proactive and safe behaviour.

R2 added, *"When smart helmets are implemented, workers take safety more seriously."* The statement shows how smart helmets enhance safety culture on construction projects by reminding workers to keep the guidelines and always aware of potential dangers. Based on R2's findings, the helmets in Malaysian projects promote proactive, disciplined behaviour, making safety a daily practice rather than simply a rule.

R4 supported this perspective by stating, *"Smart helmets help create a better safety culture among workers at the construction site."* This response show that smart helmets help shape safety behaviour and culture on construction sites. Beyond protecting individuals, they encourage workers to make safety part of their routine, follow protocols, and hold peers accountable. By providing continuous feedback on site conditions, smart helmets promote a proactive approach to identifying and avoiding risks.

Additionally, R1, R2, and R4 agreed that smart helmets encourage the use in modern safety procedures. The construction industry's transformation to technology-driven safety management is shown in the integration of

IoT and digital monitoring systems. The implementation of smart helmets serves a variety of purposes, with a particular emphasis on modernizing safety management in building projects, reducing accidents, and improving culture.

4.3 Challenges Hindering Adoption of Smart Helmet in Construction Projects

Table 4 below shows the data analysis related to the challenges hindering adoption of smart helmet.

Table 4 *Challenges hindering adoption of smart helmet in construction projects*

Challenges	R1	R2	R3	R4
High initial costs	/	/	/	/
Lack of training		/	/	
Worker resistance			/	/
Limited regulatory support	/			/

Based on Table 4 presents the main challenges hindering the use of smart helmets based on responses from R1, R2, R3, and R4. All respondents agreed that high initial cost is the most significant barrier, as the purchase price, maintenance, and technical requirements require high financial investment. This discourages many contractors, especially SME sized companies, from adopting the technology despite its safety benefits.

R2 added*, "Cost is the main reason to adoption a new advanced technology in construction site, that's why some sites do not adopt it."* This statement highlights that one of the main barriers to the adoption of smart helmets in the construction industry is cost. Despite the obvious safety and productivity benefits, some contractors are hesitant to invest because of high purchase costs, maintenance, and technical support requirements. Cost is an important challenge to implementing IoT enabled safety technologies, according to research, particularly in emerging markets with low budgets.

Moreover, as R3 and R4 point out, insufficient instruction restricts worker's ability to use smart helmets correctly, which lowers their productivity on the construction site. However, worker opposition, as indicated by R3 and R4, shows that some employees prefer traditional helmets because they are used to them and are reluctant to adopt new technologies.

R3 stated, *"Even though it improves safety, the initial investment for smart helmet or new technology is difficult to justify for smaller projects,"*. This statement show how pricey smart helmets are, which is a significant challenge for small contractors with a tight budget despite their safety advantages. R3's decision is consistent with studies that indicate the implementation of IoT-enabled safety technologies in construction is slowed by high upfront costs.

Furthermore, the adoption process is hindered by the lack of strong incentives or necessary standards to encourage contractors to use smart helmets, as highlighted by R1 and R4. R1 explained, *"No regulation forces for contractors and firms whether to adopt the technology, the progress is very slow and take time".* This highlights that contractors might put off implementing new technologies in favour of cost-saving strategies in the lack of clear regulations or enforcement. Therefore, to promote acceptance, strengthen security protocols, and ensure broader industrial use of smart helmets, stronger laws and policies are essential. In general, the use of smart helmet technology in construction projects is influenced by a combination of financial, technical, behavioural, and regulatory considerations.

4.4 Suggestion enhancement for the implementation of smart helmets in construction projects in Malaysia.

Table 5 below shows the data analysis related to the suggestion enhancement for the implementation of smart helmet.

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Table 5 *Suggestion enhancement for the implementation of smart helmets in construction projects in Malaysia*

Suggestion to enhance smart helmet implementation	R1	R2	R3	R4
Provide comprehensive training	/		/	/
Government incentives and subsidies		/		/
Awareness programmes		/	/	

The suggestions provided by R1, R3, and R4 to improve the use of smart helmets in construction project are shown in Table 5. The results demonstrate that all respondents agreed that personnel need thorough training in order to understand safety helmet operations, assess alarms, and use the technology appropriately. Comprehensive training guarantees that smart helmets can function efficiently and provide the greatest possible safety advantages on construction sites.

Furthermore, government subsidies and incentives highlighted by R2 and R4 that were recommended for reducing contractors' financial burdens. Companies, particularly SME contractors, can be encouraged to adopt smart helmet technology and get past cost-related barriers by receiving financial help in the form of tax benefits or subsidies.

R2 stated, *"from now government tax incentives would be high encourage adoption to adoption a new technology in construction projects,"*. This demonstrates how financial support lowers expenses, particularly for SME contractors. As a result, these incentives are important for encouraging adoption of smart helmets and enhancing worker safety in the construction industry.

In addition, R2 and R3's suggested awareness programmes were shown to be essential in enhancing employees' comprehension and acceptance of smart helmets. In order to enable successful long-term adoption, awareness campaigns and workshops can lower resistance to new technology, raise safety knowledge, and foster favourable attitudes toward contemporary safety procedures.

R3 added, *"Awareness programs can reduce resistance if we take or adoption new technology especially smart helmets, it's helps save duration time and reduce accidents in construction site for sure...".* This highlights the importance that employee acceptance is because adoption can be slowed by a lack of knowledge or fear of new technology. In order to improve safety and lower the rate of accidents on construction sites, awareness campaigns like safety seminars and demonstrations are important for developing understanding, establishing confidence, and encouraging the usage of smart helmets.

5. Conclusion

The findings of this study demonstrate that the implementation of smart helmets can help reduce accident rates and safety issues in construction projects, particularly in Malaysia. The various approaches discussed in this study are able to assist professional project management teams on construction sites in implementing smart helmet usage to address safety issues and overcome the identified research problems.

Indirectly, this implementation also supports management efforts in reducing risks within the construction sector, especially those involving life-threatening hazards at construction sites. Therefore, relevant stakeholders play an important role in fulfilling this responsibility to ensure that the construction industry can reduce accident and fatality rates on site.

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Conflict of Interest

Authors declare that is no conflict of interest regarding the publication of the paper.

Author's Contribution

The author confirms the contributions to this paper as follows: **study conception and design**: Nur Ilham Binti Abdul Aziz and Aryani Binti Ahmad Latiffi; **data collection**: Nur Ilham Binti Abdul Aziz; **data analysis and interpretation of results**: Nur Ilham Binti Abdul Aziz; **manuscript draft preparation**: Nur Ilham Binti Abdul Aziz and Aryani Binti Ahmad Latiffi. All authors have reviewed the results and approved the final version of the manuscript.

References

Ahmad, A., Omar, R., & Abdul Hamid, M. (2020). Smart helmet for construction site safety monitoring: A review. *Journal of Physics: Conference Series, 1529*(5), 052026.

Ahmed, H. F., Mohamed, M., & Rahman, M. M. (2021). IoT-based smart helmet for construction workers safety. *IOP Conference Series: Materials Science and Engineering, 1091*(1), 012015.

Ahn, C. R., Lee, S., & Sun, C. (2020). Wearable sensing technology applications in construction safety. *Journal of Construction Engineering and Management, 146*(4), 04020030.

Ali, M. A., Wahab, A. F., & Rahmat, I. (2023). Smart safety wearables and policy frameworks in Malaysian construction sites. *International Journal of Occupational Safety and Health, 19*(1), 14–25.

Asenahabi, B. M. (2019). Basics of research design: A guide to selecting appropriate research design. *International Journal of Contemporary Applied Research, 6*(5), 76–89.

Azhar, S., Shafiq, N., & Abdullah, A. (2020). Safety management in Malaysian construction industry: Challenges and recommendations. *International Journal of Construction Management, 20*(3), 205–218.

Azmi, A. H., Mohamad, A. M., & Arshad, S. (2022). Smart helmet for real-time monitoring and safety management in construction industry. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 96*(1), 93–104.

Behm, M. (2019). Wearable technologies for construction safety management. *Journal of Construction Engineering and Management, 145*(6), 04019034.

CIDB. (2020). *Construction Industry Transformation Programme (CITP) 2016–2020*. Construction Industry Development Board Malaysia.

CIDB. (2021). *Construction Safety Performance Report 2021*. Construction Industry Development Board Malaysia.

CIDB. (2023). *Construction Industry Development Board Annual Report 2022*. Construction Industry Development Board Malaysia.

Chandran, N., Chandrasekar, V., & Elizabeth, L. (2020). Smart helmet for industrial safety. *International Journal of Engineering Research & Technology, 9*(4), 211–214.

Cheng, T., & Teizer, J. (2017). Real-time construction safety monitoring using wearable sensing technologies. *Automation in Construction, 72*, 41–52.

Cheng, T., & Teizer, J. (2017). Real-time safety risk monitoring and visualization system for construction sites. *Automation in Construction, 72*, 55–66.

Chua, D., & Goh, C. (2017). *Safety management in Malaysian construction sites*. Construction Research Institute Malaysia.

DOSH. (2022). *Guidelines on occupational safety and health in the construction industry*. Department of Occupational Safety and Health Malaysia.

DOSH. (2023). *Occupational accident statistics 2023*. Department of Occupational Safety and Health Malaysia. https://www.dosh.gov.my

DOSM. (2023). *Occupational injury statistics Malaysia 2023*. Department of Statistics Malaysia. https://www.dosm.gov.my

Fithri, P., Sireesha, V., & Anusha, S. (2025). Smart helmet warning systems in industrial safety. *Journal of Safety Research, 84*, 102–110.

Hamid, A. R. A., Singh, B., Yusof, A. M., & Abdullah, N. A. C. (2018). The causes of accidents at construction sites in Malaysia. *Malaysian Journal of Civil Engineering, 30*(1), 1–15.

Hashim, A. E., Yusof, N. M., & Abdul-Aziz, A. R. (2022). Challenges of adopting construction technologies among Malaysian SMEs. *Journal of Construction in Developing Countries, 27*(1), 45–60.

ILO. (2020). *Safety and health in construction: Global estimates of accidents and diseases*. International Labour Organization.

Ismail, M. A., Razak, A. H. A., & Rahim, A. H. A. (2022). Challenges and opportunities of smart helmet adoption in Malaysian construction industry. *Journal of Engineering Science and Technology, 17*(2), 1089–1102.

Jesudoss, A. V., Vybhavi, V. S., & Anusha, S. R. (2019). Smart construction helmet for accident reduction. *International Journal of Recent Technology and Engineering, 8*(2S), 406–409.

JKKP. (2021). *Occupational accidents statistics 2021*. Department of Occupational Safety and Health Malaysia.

JKKP. (2022). *Occupational accidents statistics 2022*. Department of Occupational Safety and Health Malaysia.

JKKP. (2023). *Occupational accidents statistics 2023*. Department of Occupational Safety and Health Malaysia.

JKKP. (2024). *Ops tapak bina report 2024*. Department of Occupational Safety and Health Malaysia.

Kamarudin, M. H., Mokhtar, N., & Ahmad, A. (2021). Smart helmet for construction safety monitoring: A review. *International Journal of Engineering and Advanced Technology, 10*(4), 183–188.

Khairul, M., Rasli, A. M., Madzhi, A. W., & Johari, A. S. (2013). Smart helmet for construction safety. *International Journal of Engineering and Technology, 5*(1), 12–16.

Kumar, A., & Prasad, K. (2020). IoT-based smart helmet for construction worker safety. *International Journal of Engineering Research & Technology, 9*(4), 211–214.

Lee, J., & Yu, J. (2019). A study on smart safety helmet development for construction sites. *Journal of Construction Engineering and Management, 145*(6), 04019036.

Li, H., Wang, J., & Fang, D. (2022). Enhancing safety wearable technology through sensor calibration and system optimization. *Safety Science, 150*, 105743.

Li, X., Fang, Y., & Teizer, J. (2022). Wearable technology adoption for construction site safety: A systematic review. *Sustainability, 15*(14), 11165.

Liu, F., Zhang, Z., & Yang, Y. (2020). Assessing implementation barriers of smart safety devices in Chinese construction projects. *Safety Science, 130*, 104892.

Mohd Yusof, M. H., Ismail, Z., & Rahman, M. A. (2022). Readiness and training gaps in IoT adoption for construction safety. *Malaysian Journal of Civil Engineering, 34*(2), 123–138.

Mohd Yusof, N. Z., Othman, S. K., & Ariffin, M. A. M. (2023). Smart helmet for construction safety: A review. *IOP Conference Series: Earth and Environmental Science, 1184*(1), 012005.

Muhammad, N., Teizer, J., & Pradhananga, N. (2019). Adoption of wearable safety technology in construction. *Journal of Construction Engineering and Management, 145*(7), 04019044.

NST. (2024). Worker killed by falling object at Johor Bahru construction site. *New Straits Times Online*. https://www.nst.com.my

Norazmi, N., Mansor, M. A., & Zulkifli, S. (2023). Smart helmet for construction safety: Implementation and challenges. *Journal of Construction Management and Engineering, 1*(1), 23–35.

OSHA. (2023). *Construction safety technology adoption report: Wearables and smart devices*. U.S. Department of Labor.

Patel, M., Gupta, V., & Singh, J. (2021). A comprehensive review on smart helmets: Current trends and future directions. *Journal of Ambient Intelligence and Humanized Computing, 12*(4), 4529–4545.

Raghunath, R., & Ghaffar, A. (2025). Real-time wearable sensing for proactive construction safety management. *Safety Science, 160*, 106041.

SOCSO. (2023). *Annual report 2023*. Social Security Organisation Malaysia. https://www.perkeso.gov.my

Teizer, J., Cheng, T., & Fang, Y. (2020). Wearable sensing for construction safety: A systematic review. *Automation in Construction, 114*, 103155.

Wang, J., Li, H., & Fang,D. (2020). Smart wearable technology for real-time construction safety monitoring. *Safety Science, 124*, 104587.

Wong, K. H., Rahman, M., & Teizer, J. (2025). IoT-enabled smart helmets for hazard detection in construction. *Automation in Construction, 156*, 105015.

Zhang, Z., Liu, F., & Yang, Y. (2019). Implementation of smart safety devices in construction projects. *Safety Science, 118*, 284–295.

Zhang, S., Teizer, J., Lee, J. K., Eastman, C. M., & Venugopal, M. (2019). Automated safety monitoring in construction using sensing technologies. Automation in Construction, 98, 184–195.