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ADOPTION OF TECHNOLOGY FOR CONSTRUCTION SITE SAFETY MANAGEMENT: UNVEILING INSIGHT FROM PENANG CONTRACTORS

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Abstract

The construction industry has the highest fatality rate among other industries. In light of this, the pivotal role played by contractors in leveraging technology to enhance site safety cannot be ignored. Despite the emergence of various technologies, little is still known about the extent of their involvement in this regard. Thus, this research intends to explore technology adoption for safety practices among contractors, the influencing factors, and the challenges encountered when implementing this innovative approach. Survey questionnaires were distributed to G7 contractors in Penang, and 53 valid responses were obtained. The findings show that the current level of technology adoption for site safety management is still low. Key factors influencing technology adoption include the initial cost, top management commitment and contractors' awareness of the technology. Contractors' challenges involve high technology expenses, inadequate network connectivity and reduced industry profitability. This research augments the existing knowledge about technology adoption for site safety management. The outcomes further serve as useful information for contractors, policymakers and government agencies in developing initiatives to improve technology adoption among contractors and reduce the occurrence of accidents in Malaysia.

Keywords: Technology adoption, site safety management, contractors, Malaysia

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INTRODUCTION

The construction industry poses a higher risk compared to other sectors because it corresponds to 3D behaviour, which is 'dirty, dangerous and difficult' (Ahmad et al., 2018; Nik Him et. al, 2023). Massive hazardous work, particularly on construction sites, has indirectly increased the likelihood of accidents. In the United Kingdom, it is reported that the annual mortality rate per 100,000 workers is 10, whereas it is 13.44 in Malaysia (Yap et al., 2023). Fatality rate appears to be higher in developing countries such as Malaysia, Indonesia and China than in developed countries (Nnaji & Karakhan, 2020). The high frequency of mishaps in the construction industry can be attributed to various factors, including falls from heights, electrocution and environmental factors (Abdul Halim et al., 2020). To mitigate the issues, various safety measures have been implemented. The sector's prolonged poor safety performance has prompted various stakeholders to seek innovative approaches for significant improvement of site safety. According to Nnaji and Karakhan (2020), there is a clear shift towards using technology for site safety management due to the numerous benefits of integrating with traditional safety management. However, little is known about contractors' involvement in technology adoption for site safety management despite the emergence of various technologies in the sector, aligned with Malaysia's Construction 4.0. This research aims to delve further into this aspect while also investigating the factors and challenges that the contractors face. The findings would be significant in finding solutions to foster a safer construction environment.

LITERATURE REVIEW

Safety Issues in Malaysia's Construction Industry

The construction industry is widely recognised as the most perilous sector and workplace globally. Each year, approximately 60,000 individuals lose their lives on construction sites worldwide, resulting in a construction industry mortality rate that is three times higher than that of the manufacturing sector (Abu Aisheh et al., 2022). In Malaysia, Zaini et al. (2020) reported that the construction industry had a fatality rate 3.3 times higher than the overall occupational death toll in the country for the year 2020.

The elevated fatality rates can be attributed to the distinct characteristics of the construction industry. Furthermore, ensuring safety within the construction industry is challenging due to its 'transient' nature, where different teams are responsible for various projects. Moreover, the 'labour-intensive' aspect, which has led to the employment of foreign workers, is another factor that makes the construction industry a high-risk workplace. Many of these workers lack adequate training and awareness and may have had no experience in the construction work (Elsebaei et al., 2021). Jaafar et al. (2018) identified two

categories of occupational accidents: direct causes, linked to human actions and worksite conditions, and indirect causes, involving management and external factors. Data from Hamid et al. (2008) highlights that on-site accidents stem mainly from direct causes, notably 'worker carelessness and lack of knowledge,' 'reluctance in using personal protective equipment and complying with regulations,' and 'hiring unskilled labour.'

Technology adoption in Construction Site Safety Management

In the construction industry, safety management involves planning, organising, executing and evaluating the work and workforce to reduce accidents on construction sites (Thanaraj & Priya, 2019). However, according to Zhou et al. (2015), achieving perfect safety management is nearly impossible due to unexpected errors (e.g. human errors, weather conditions, later material deliveries and project modification). Traditional safety management, which relies on paper-based information, exacerbates these issues and makes it difficult to adapt to changing circumstances (Alizadehsalehi et al., 2020). To address these challenges, more advanced techniques are emerging to improve site safety, primarily focusing on utilising technology for safety management.

Technology encompasses tools or equipment that address real-life issues (Khudzari et al., 2021). A notable focus has recently been on adopting technology within the construction industry. Several technologies have been introduced to improve final product quality and construction process efficiency, leading to cost savings and increased profits (Nnaji & Karakhan, 2020). Nonetheless, an expanding array of emerging technologies has been integrated into safety and health management within the construction industry over time (Zhou et al., 2013; Tung et.al, 2023).

Types of Technology Adopted for Construction Site Safety Management

In managing the safety aspect of construction sites, many safety technologies have been developed over the years, in parallel with the efforts to move towards the era of Fourth Industrial Revolution (IR 4.0). Building information modelling (BIM) is widely adopted to support construction safety management because it integrates interdisciplinary information into a unified model. This facilitates the effective identification and mitigation of hazards during construction (Muzafar, 2021). Unmanned aerial vehicles (UAVs), which are aircraft that operate without the need for a human pilot, are utilised in safety management. They can be remotely controlled from the ground, minimising potential risk exposure to workers (Melo et al., 2017). Another technology used for site safety management is robotics and automation (R&A). R&A can process numerical information and perform analytical tasks in confined and hazardous locations, reducing the risk to workers (Yap et al., 2023). Virtual reality (VR) has also been adopted, enabling

contractors to visually assess site conditions and identify potential safety issues during the planning phase (Zhou et al., 2012). Augmented reality (AR) is also employed for site safety management, integrating 3D virtual models with real-time footage to enhance the visualisation of job site conditions (Chi et al., 2013). Furthermore, radio frequency identification (RFID) technology enables precise localisation and tracking, effectively reducing potentially dangerous situations and preventing accidents (Kim et al., 2016).

Wearable safety technologies are valuable for monitoring labourers' safety on hazardous construction sites. They are user-friendly and cost-effective. Network cameras are also incorporated into site safety management. They allow contractors to collect and analyse footage of workers' actions, helping to identify factors that may have contributed to accidents. Precautionary measures can be planned and implemented accordingly (Yap et al., 2023). 3D laser scanning is another technology used in safety management, eliminating the need for human intervention in on-site monitoring and measurements in hazardous areas of the site (Schueremans & van Genechten, 2009). Finally, digital signage is implemented for site safety management, as it is more attention-grabbing than traditional safety boards. This makes it more effective in delivering important safety messages at the site (Yap et al., 2023).

Factors Affecting Technology Adoption in Site Safety Management

It is beyond important to comprehend the factors influencing technology adoption when attempting to improve the current situation (Khudzari et al., 2021). In accordance with Nnaji & Karakhan (2020), only by having a thorough understanding of the factors influencing technology adoption can effective solutions be taken to enhance technology adoption in site safety management.

i. Economic Factors

The initial cost of technology is one factor that influences its implementation. Acquiring technology for projects often involves a high initial cost, and additional expenses for maintenance and training can further increase the overall cost. Additionally, business dynamics play a significant role as an economic factor. The number of technology suppliers and cost structures can impact the decisions of construction stakeholders regarding technology adoption. Furthermore, the level of competition is another factor that affects technology adoption. High competition in the utilisation of technology for projects can lead to increased adoption by companies (Akmam et al., 2018).

ii. Management Factors

Management strategy ensures a project's completion and impacts technology adoption. To facilitate the learning and integrating of new technologies, top

management must support the contractors incorporating emerging technology into the current business (Li et al., 2022). Commitment from top management is equally vital in influencing technology adoption, as a strong commitment is essential to encourage the ongoing use of technology (Akmam et al., 2018).

iii. Behavioural Factors

Human aspects, such as understanding how to use technology, are critical factors in making decisions about its adoption (Khudzari et al., 2021). Awareness of a technology's significance is crucial in influencing decisions on technology adoption. Furthermore, the attitude towards technology adoption is an important behavioural factor. It has been observed that companies are more likely to adopt a technology when their employees have a positive attitude towards the adoption of technologies (Akmam et al., 2018).

iv. Technological Factors

One technological factor is the perceived usefulness of technology. Technologies that offer improved work performance while providing cost or time advantages are more likely to be adopted at a higher rate. Additionally, the perceived ease of technology use is a contributing factor. This factor involves the complexity of mastering the technology and the time and effort required for its implementation. Moreover, the perceived quality of technology also affects its adoption. High-quality technology that efficiently supports work processes tends to have a higher adoption rate (Akmam et al., 2018).

v. Regulatory Factors

Government promotion of technology is crucial in affecting technology adoption for site safety management (Akmam et al., 2018). This can be achieved through government agencies offering incentives, such as free participant training (Khudzari et al., 2021). Another regulatory factor is technology policy. As noted by Akmam et al. (2018), adopting technology for site safety management can be enhanced with a comprehensive technology policy that provides clear guidelines on technology implementation. The rules and regulations governing technology also play a significant role. This is exemplified by the study conducted by Li et al. (2022), where incomplete or unclear rules and regulations can hinder companies from adopting technology.

Based on the review, it is agreed by researchers (e.g. Nnaji and Karakhan, 2020; Yap et al., 2022a), that contractors play a pivotal role in leveraging technology to enhance site safety. Considering the emergence of various types of technologies, there is a noticeable gap in current technology adoption among Malaysian contractors, particularly in aligning with national strategic plans.

Constraints Faced in Technology Adoption for Site Safety Management

It is crucial that the constraints faced by contractors who have already adopted a technology are identified for the successful adoption of technologies in the future. This is critical for maximising the use of technology for construction site safety management.

i. Economic Constraints

According to Yap et al. (2022a), cost limitations consistently stand out as the primary constraint regarding technology implementation. These costs are primarily linked to the utilisation and maintenance of technology (Nnaji & Karakhan, 2020). Economic constraints include unprofitable worker training, which arises from the extensive training required to enhance workers' competencies in an increasingly automated industry. A low profit margin in the sector is another constraint contractors encounter when implementing technology in construction site safety management (Yap et al., 2022a).

ii. Sociocultural Constraints

The decision to use technology depends on the client, which is one of the constraints faced. This constraint often arises because employers may mandate certain technologies while prohibiting others (Nnaji & Karakhan, 2020). Additionally, the ageing workforce tends to be resistant to change. Consequently, when embracing technological changes, individuals may experience a lack of readiness and motivation to adopt new technologies due to the uncertainty surrounding new procedures and concerns about unfamiliar outcomes that could impact their business (Yap et al., 2022a).

iii. Technological Constraints

Various factors influence the implementation of safety technologies. One notable challenge is the incompatibility between technology devices, which hinders effective communication and information sharing (Gamil et al., 2020). Fast and reliable internet access is also essential to ensure technologies function at their full capacity. However, contractors often face poor network connectivity, primarily due to the limited connectivity in designated locations. In many cases, network coverage remains a concern (Yap et al., 2022a).

iv. Regulatory Constraints

The high frequency of incidents in the construction sector is often attributed to outdated government policies and inadequate enforcement. Edirisinghe (2019) noted that policies promoting or discouraging technological innovation can limit people's freedom of choice between acceptance and rejection. Additionally, a lack of regulations is common in the construction industry. Therefore, it is imperative

to establish appropriate guidelines to facilitate the effective integration of technologies in a wide range of construction operations, including safety management (Yap et al., 2022a).

v. Security Constraints

Using the Internet for technology operations poses a challenge for safeguarding connected devices, data and the Internet of Things (IoT)layers from external threats and intrusions (Gamil et al., 2020). The issue of low confidentiality regarding workers' private data is also a security-related concern. The automatic collection and recording of private data, particularly in the context of worker surveillance, monitoring and the management of recorded information, gives rise to various legal and ethical considerations (Yap et al., 2022a).

RESEARCH METHODOLOGY

For this study, a quantitative research approach was adopted. The target population consists of 360 Grade 7 contractors registered with Construction Industry Development Board (CIDB), Malaysia. Using the formula, the minimum sample size calculated for this study is 175. From the total of 200 invitations sent, 53 completed responses were received, yielding a response rate of 26.5%. The respondents were approached through a combination of two sampling methods that are frequently adopted in construction management studies: convenience sampling and snowball sampling (Bagaya & Song, 2016; Yap et al., 2019). Penang was chosen as the study's focal point because of its high real-estate market, led to large scale construction projects (San et al., 2017). In presenting the data, statistical software SPSS is being used for analysing frequency, mean score and data variability, similar to the approach taken by (Kamarudeen et. al, 2022) who also investigate similar aspects. In addition, the reliability of the collected data was analysed using Cronbach's alpha coefficient (Mohajan, 2017).

RESULTS

The demographic information of the respondents is shown in Table 1 below.

Table 1: Respondent's Demographic Information

	Demography	Frequency	Percentage (%)
Highest Academic Qualification	High School or Equivalent	1	1.9
	Certificate / Diploma	7	13.2
	Bachelor's Degree	39	73.6
	Master's Degree	6	11.3
	Director	1	1.9
	Manager	7	13.2

	Demography	Frequency	Percentage (%)
Position in the Company	Site Manager	8	15.1
	Site Supervisor	5	9.4
	Site Engineer	21	39.6
	Safety and Health Officer	8	15.1
	Others	3	5.7
Years of Experience Working as a Contractor	Less Than or Equivalent to 5 Years	26	49.1
	6 to 10 Years	20	37.7
	11 to 15 Years	4	7.5
	More Than or Equivalent to 16 Years	3	5.7

Table 2 below presents the various types of technology that the G7 contractors used to manage safety aspects at the site. The frequency of technology usage in the management of site safety is arranged and ranked in descending order of their mean value as follows: BIM (2.49), digital signage (1.75), wearable safety technologies (1.66), network cameras (1.66), UAVs, VR and 3D laser scanning (1.32), R&A (1.25), RFID (1.19) and AR (1.13).

Table 2: Frequency of Technology Usage for Site Safety Management

Types of Technology	**N**	**Mean**	**SD**
BIM	53	2.49	1.353
Digital Signage	53	1.75	1.285
Network Camera	53	1.66	1.192
Wearable Safety Technologies	53	1.66	1.224
3D Laser Scanning	53	1.32	.872
VR	53	1.32	.754
UAV	53	1.32	1.034
R&A	53	1.25	.757
RFID	53	1.19	.590
AR	53	1.13	.394

Table 3 presents the factors affecting technology adoption for construction site safety management. Each factor affecting technology adoption for construction site safety management is presented in descending order of its mean value.

Table 3: Factors Affecting Technology Adoption for Site Safety Management

Ref.	Factors	N	Mean	SD	Rank
A1	Initial Cost of Technology	53	4.49	.724	**1**
B2	Commitment from Top Management	53	4.47	.775	**2**
C2	Awareness of the Importance of Technology	53	4.40	.600	**3**
B1	Top Management Support	53	4.34	.876	**4**
C1	Knowledge of How to Use the Technology	53	4.34	.706	**5**
D2	Perceived Ease of Use of Technology	53	4.28	.601	**6**
C3	Attitude towards the Adoption of Technology	53	4.25	.677	**7**
D1	Perceived Usefulness of Technology	53	4.21	.631	**8**
E3	Rules and Regulations of Technology	53	4.13	.833	**9**
D3	Perceived Quality of Technology	53	4.11	.670	**10**
E1	Government Promotion of Technology	53	4.04	.784	**11**
E2	Technology Policy	53	4.04	.876	**12**
A2	Business Dynamics	53	3.89	.824	**13**
A3	Level of Competition in Technology Adoption among the Companies	53	3.79	1.081	**14**

Table 4 presents contractors' constraints in adopting construction site safety management technology. The constraints here are also arranged in descending order of their mean values.

Table 4: Constraints Faced in Technology Adoption for Site Safety Management

Ref.	Constraints	N	Mean	SD	Rank
A1	Extra Costs Related to Technology	53	4.53	.668	**1**
C2	Poor Network Connectivity	53	4.13	.962	**2**
D2	Lack or No Regulations for Utilization	53	4.02	.866	**3**
A3	Low Profit in the Sector	53	4.02	1.009	**4**
B1	Scarce of Client Demand	53	4.00	.832	**5**
D1	Lack or No Government Policy for Utilization	53	3.98	.888	**6**
B2	Aging Workforce being Reluctant to Change	53	3.98	.888	**7**

Ref.	Constraints	N	Mean	SD	Rank
A2	Unprofitable Worker Training	53	3.98	1.047	**8**
E2	Low Confidentiality of Workers' Privacy Data	53	3.79	1.116	**9**
C1	Incompatibility Issues between the Technology Devices	53	3.77	.993	**10**
E1	No Assurance of Data Security	53	3.62	1.113	**11**

DISCUSSION

The results suggest that the level of technology adoption for construction site safety management in Malaysia is still considered low even though the Malaysian construction industry is making progress towards the technology adoption in managing construction site safety. The mean values can be observed in Table 2. The four most frequently used technologies for site safety management are BIM, digital signage, wearable safety technologies and network cameras. This is consistent with the literature by Yap et al. (2022b), who stated that BIM, network cameras and digital signage are among the top five most effective technologies in site safety management. BIM was ranked as the most frequently used safety technology (Yap et al., 2023). This can be attributed to the Malaysian government's active promotion of BIM usage in line with the Fourth Industrial Revolution (IR 4.0), such as making it mandatory for public works costing RM 100 million or more to implement BIM (Ibrahim et al., 2021). Digital signage was the second most frequently used technology. The increased innovative characteristics of digital signage boards, such as the ability to change colour according to weather conditions also enhance the safety management process by contractors (Karakhan et al., 2019). Network cameras and wearable safety technologies ranked equally as the third most frequently used technologies. These technologies provide various functions to manage construction site safety, such as real-time tracking of work progress at a construction site, collecting data for quality checking, and detection of potential hazards at the site (Yap et al., 2022b). The findings also showed that R&A, RFID and AR are the three least used technologies in construction site safety management. The main factor leading to the low adoption rate of these technologies in site safety management is their high cost (Yap et al., 2023). Furthermore, the limited financial capability of companies has restricted them from investing and using technologies to manage construction site safety (Nnaji & Karakhan, 2020).

Data in Table 3 demonstrates all factors affect the technology adoption by G7 contractors in construction site safety management but at different levels. The initial cost of technology was ranked as the main factor, consistent with the findings in previous research by Yap et al. (2022b). This demonstrates that the costing aspect greatly influences the adoption of safety technology, which

indirectly has implications for safety performance at a site. This is supported by Khudzari et al. (2021), who stated that cost has always been the main concern affecting stakeholder investment in technologies. Commitment from top management ranked second, which signifies that it greatly affects the technology adoption in site safety management. This is supported by Yap et al. (2022a), who stated that management factors play a crucial role in affecting technology adoption by contractors. This is mainly because the choice to use safety technology at sites depends a lot on how these leaders think and visioned on their organizational commitment (Khudzari et al., 2021).

Awareness of the importance of technology was ranked third in the factors that affect the adoption of technology. This is because stakeholders like contractor will only consider adopting safety technology as they are aware and understand the importance of using these technologies (Akmam et al., 2018). Top management support was ranked fourth. This is supported by the research findings of Li et al. (2022) and Yap et al. (2022a). Similarly, the how knowledge is equally important influencing factor. Contractors who are knowledgeable and well-trained in handling a specific technology will greatly influence firms to adopt technologies to manage site safety more effectively (Khudzari et al., 2021).

The two factors ranked last within the economic factors category were business dynamics and the level of competition in technology adoption among the companies. According to Akmam et al. (2018), the dynamics of the market to produce safety technologies, which include items like the number of suppliers of technology and its cost structure have the potential to affect their adoption by users. A higher level of competition between the contractor firms will also encourage the technology adoption for a particular project, as excellent productivity is hoped to be achieved by using these technologies for the contractors.

Data in Table 4 presents the constraints of technology usage that are significant to G7 contractors at various levels. Extra costs related to technology was ranked as the most significant constraint. This finding is consistent with the previous studies by Nnaji & Karakhan (2020) and Yap et al. (2022a), who found that high costs are often the primary concern encountered by stakeholders in implementing these technologies to manage site safety. According to Nnaji & Karakhan (2020), there are various costs incurred including the initial purchase, operation and maintenance, training costs and many more. Subsequently, poor network connectivity was ranked the second most significant constraint. This is supported by Yap et al. (2022a), who stated that technology-related challenges significantly limit the implementation of safety technologies. Without reliable broadband connectivity on the construction site, it is difficult for the safety technologies to operate at their maximum potential (Waqar et al., 2023). Low profit in the sector was ranked third. According to Yap et al. (2022a) and Yitmen

(2007), low profit margins has been a significant issue impeding the adoption of technologies by construction stakeholders. Considering the low profits that could be gained, contractors often tend to stop implementing technologies for site safety management (Yitmen, 2007). The constraint ranked fourth is the lack or absence of regulations for utilisation. This finding is consistent with study by Waqar et al. (2023), who found that regulatory-related limitations significantly affected technology adoption in construction site safety management. According to Yap et al. (2022a), there is often no updated information regarding the standards or regulations on operating the technologies. Scarcity of client demand was ranked fifth among the 11 constraints identified. This is supported by Nnaji & Karakhan (2020). This indicates that the client's intention to use technologies has certain impacts on adopting technologies in site safety management. The two constraints that ranked last were incompatibility issues between technology devices and a lack of data security assurance. In their study, Gamil et al. (2020) also found technology compatibility to be one of the least significant challenges faced by construction practitioners. However, regarding the challenges related to the 'lack of assurance of data security,' the current findings contrast with their research.

CONCLUSION

In conclusion, this research has sought to provide a comprehensive understanding of technology adoption in construction site safety management in Penang, Malaysia. The study's findings show that the current level of technology adoption for site safety management within the Malaysian construction industry remains relatively low. BIM, digital signage, wearable safety technologies and network cameras emerge as the most frequently employed safety technologies on construction sites. The technology adoption is primarily influenced by several key factors, with the initial cost, commitment from top management and an awareness of the importance of technology being the most significant among contractors. Additionally, the research findings reveal that contractors face three primary challenges: the elevated costs associated with technology adoption, a lack of reliable network connectivity and low profitability within the industry. From the contractor's perspective, this study contributes to advancing knowledge concerning technology adoption for site safety management. The insights obtained regarding influencing factors and constraints faced by contractors offer valuable information for policymakers and government agencies, aiding in the development of initiatives to enhance technology adoption among contractors. A comprehensive training program, coupled with incentivization through government grants or subsidies, would play a pivotal role in encouraging widespread technology adoption among contractors, consequently enhancing safety at construction sites in Malaysia.

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REFERENCES

Abdul Halim, N. N. A., Jaafar, M. H., Mohamad Anuar Kamaruddin, M. A., Kamaruzaman, N. A., & Jamir Singh, P. S. (2020). The Causes of Malaysian Construction Fatalities. *Journal of Sustainability Science and Management*, *15*(5), 236–256.

Abu Aisheh, Y. I., Tayeh, B. A., Alaloul, W. S., & Almalki, A. (2022). Health and safety improvement in construction projects: a lean construction approach. *International Journal of Occupational Safety and Ergonomics*, *28*(4), 1981– 1993. https://doi.org/10.1080/10803548.2021.1942648

Ahmad, N., Supaat, D., Wook, I., Tagoranao, M., & Rahman, N. (2018). Malaysians' Reluctance to Work in Local 3D Sectors: A Preliminary Review. *The Journal of Social Sciences Research*, SPI4, 220–223. https://oarep.usim.edu.my/jspui/handle/123456789/12835

Akmam, Syed Zakaria, S., Gajendran, T., Skitmore, M., & Brewer, G. (2018). Key factors influencing the decision to adopt industrialised building systems technology in the Malaysian construction industry: an inter-project perspective. *Architectural Engineering and Design Management*, *14*(1–2), 27–45. https://doi.org/10.1080/17452007.2017.1298512

Alizadehsalehi, S., Yitmen, I., Celik, T., & Arditi, D. (2020). The effectiveness of an integrated BIM/UAV model in managing safety on construction sites. *International Journal of Occupational Safety and Ergonomics*, *26*(4), 829–844. https://doi.org/10.1080/10803548.2018.1504487

Azmy, N., & Zain, A. (2016). The Application of Technology In Enhancing Safety And Health Aspects On Malaysian Construction Projects. *ARPN Journal of Engineering and Applied Sciences*, 11. URL: http://www.arpnjournals.org/jeas/research_papers/r...

Bagaya, O., & Song, J. (2016). Empirical Study of Factors Influencing Schedule Delays of Public Construction Projects in Burkina Faso. *Journal of Management in Engineering*, *32*(5). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000443

Chi, H.-L., Kang, S.-C., & Wang, X. (2013). Research trends and opportunities of augmented reality applications in architecture, engineering, and construction. *Automation in Construction*, 33, 116–122. https://doi.org/10.1016/j.autcon.2012.12.017

Edirisinghe, R. (2019). Digital skin of the construction site: Smart sensor technologies towards the future smart construction site. Engineering, Construction and Architectural Management, *26*(2), 184-223. https://doi.org/10.1108/ECAM-04-2017-0066

Elsebaei, M. A., Elnawawy, O., Othman, A. A. E., & Badawy, M. (2021). A framework to activate the health and safety regulations in the Egyptian construction industry. *Journal of Engineering, Design and Technology*, *19*(5), 1158–1191. https://doi.org/10.1108/JEDT-05-2020-0194

Gamil, Y., A. Abdullah, M., Abd Rahman, I., & Asad, M. M. (2020). Internet of things in construction industry revolution 4.0. *Journal of Engineering, Design and Technology*, *18*(5), 1091–1102. https://doi.org/10.1108/JEDT-06-2019-0164

Hamid, A., Majid, M., & Singh, B. (2008). Causes Of Accidents at Construction Sites. *Malaysian Journal of Civil Engineering*, 20, 242– 259. DOI: https://doi.org/10.11113/mjce.v20.15769

Ibrahim, F. S., Esa, M., & A. Rahman, R. (2021). The Adoption of IOT in the Malaysian Construction Industry: Towards Construction 4.0. *International Journal of Sustainable Construction Engineering and Technology*, *12*(1). Retrieved from https://publisher.uthm.edu.my/ojs/index.php/IJSCET/article/view/6299

Jaafar, M. H., Arifin, K., Aiyub, K., Razman, M. R., & Kamaruddin, M. A. (2018). *Human Element as the Contributing Factor Towards Construction Accidents from the Perspective of Malaysian Residential Construction Industry* (pp. 296– 308). https://doi.org/10.1007/978-3-319-60525-8_31

Kamaruddeen, A.M., Rui, L.S., Lee, K.L., Alzoubi, H.M., & Alshurideh, M.T. (2022). Determinants of Emerging Technology Adoption for Safety Among Construction Businesses. *Academy of Strategic Management Journal, 21*(S4), 1-19.

Karakhan, A., Xu, Y., Nnaji, C., & Alsaffar, O. (2019). Technology Alternatives for Workplace Safety Risk Mitigation in Construction: Exploratory Study. In *Advances in Informatics and Computing in Civil and Construction Engineering* (pp. 823–829). Springer International Publishing. https://doi.org/10.1007/978-3-030-00220-6_99

Kasim, N., Sarpin, N., Mohd Noh, H., Zainal, R., Mohamed, S., Manap, N., & Yahya, M. Y. (2019). Automatic Materials Tracking Practices Through RFID Implementation in Construction Projects. *MATEC Web of Conferences*, 266, 05001. https://doi.org/10.1051/matecconf/201926605001

Khudzari, F., Rahman, R., & Ayer, S. (2021). Factors Affecting the Adoption of Emerging Technologies in the Malaysian Construction Industry. *IOP Conference Series: Earth and Environmental Science*, *641*(1), 012006.

Kim, H., Lee, H.-S., Park, M., Chung, B., & Hwang, S. (2016). Automated hazardous area identification using laborers' actual and optimal routes. *Automation in Construction*, 65, 21–32.

Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement*, *30*(3), 607–610.

Li, C., Zhang, Y., & Xu, Y. (2022). Factors Influencing the Adoption of Blockchain in the Construction Industry: A Hybrid Approach Using PLS-SEM and fsQCA. *Buildings, 12*(9), 1349.

Melo, R. R. S. de, Costa, D. B., Álvares, J. S., & Irizarry, J. (2017). Applicability of unmanned aerial system (UAS) for safety inspection on construction sites. *Safety Science*, 98, 174–185.

Mohajan, H. (2017). Two Criteria for Good Measurements in Research: Validity and Reliability. *Annals of Spiru Haret University*, *17*(3), 58–82

Muzafar, M. (2021). Building information modelling to mitigate the health and safety risks associated with the construction industry: a review. *International Journal of Occupational Safety and Ergonomics*, *27*(4), 1087–1095.

Nik Him, N. F., -, N. A. A., Tun Ismail, W. N. A., & Tuan Abdullah, T. N. Z. (2023). Assessment of Safety Management Attitude Practices toward the safety culture of the Construction Sector. *PLANNING MALAYSIA, 21*(25). https://doi.org/10.21837/pm.v21i25.1220

Nnaji, C., & Karakhan, A. A. (2020). Technologies for safety and health management in construction: Current use, implementation benefits and limitations, and adoption barriers. *Journal of Building Engineering*, 29, 101212. https://doi.org/10.1016/j.jobe.2020.101212

San, K., Riazi, S., Nawi, M., & Esa, M. (2017). The Roles, Challenges & Improvement of Project Manager in Project Financial Management in Building Development in Penang, Malaysia. *Int. J Sup. Chain. Mgt*, *6*(1), 238–245. ISSN 2050-7399

Schueremans, L., & van Genechten, B. (2009). The use of 3D-laser scanning in assessing the safety of masonry vaults—A case study on the church of Saint-Jacobs. *Optics and Lasers in Engineering*, *47*(3–4), 329–335. https://doi.org/10.1016/j.optlaseng.2008.06.009

Thanaraj, M., & Priya, M. (2019). Effective Safety Management in Construction. *ISO 9001:2008 Certified Journal*, 6(4), 832–836. e-ISSN: 2395-0056

Tung, Y.-H., Chia, F.-C., & Yong, F. Y.-Y. (2021). Exploring The Usage of Digital Technologies for Construction Project Management, PLANNING MALAYSIA, 19(17). https://doi.org/10.21837/pm.v19i17.983

Waqar, A., Khan, M. B., Shafiq, N., Skrzypkowski, K., Zagórski, K., & Zagórska, A. (2023). Assessment of Challenges to the Adoption of IOT for the Safety Management of Small Construction Projects in Malaysia: Structural Equation Modeling Approach. *Applied Sciences*, 13(5), 3340. https://doi.org/10.3390/app13053340

Yap, J. B. H., Chow, I. N., & Shavarebi, K. (2019). Criticality of Construction Industry Problems in Developing Countries: Analyzing Malaysian Projects. *Journal of Management in Engineering*, *35*(5). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000709

Yap, J. B. H., Lam, C. G. Y., Skitmore, M., & Talebian, N. (2022a). Barriers To the Adoption of New Safety Technologies in Construction: A Developing Country Context. *Journal Of Civil Engineering and Management*, *28*(2), 120–133. https://doi.org/10.3846/jcem.2022.16014

Yap, J. B. H., Lee, K. P. H., & Wang, C. (2023). Safety enablers using emerging technologies in construction projects: empirical study in Malaysia. *Journal of Engineering, Design and Technology. https://doi.org/10.1108/JEDT-07-2021-0379*

Yap, J. B. H., Skitmore, M., Lam, C. G. Y., Lee, W. P., & Lew, Y. L. (2022b). Advanced technologies for enhanced construction safety management: investigating Malaysian perspectives. *International Journal of Construction Management*, 1–10. https://doi.org/10.1080/15623599.2022.2135951

Yitmen, İ. (2007). The challenge of change for innovation in construction: A North Cyprus perspective. *Building and Environment*, *42*(3), 1319–1328. https://doi.org/10.1016/j.buildenv.2005.10.032

Zaini, M., Bakri, M., Razak, N., Sabar, M., & Hasan, B. (2022, March). Analysis Of Occupational Accidents in The Malaysian Construction Sector. Department of

Statistics Malaysia (DOSM). https://www.dosm.gov.my/v1/uploads/files/6_Newsletter/Newsletter%202022/DOSM_ILMIA_3_2022_SERIES%2051.pdf

Zhou, W., Whyte, J., & Sacks, R. (2012). Construction safety and digital design: A review. *Automation in Construction*, 22, 102–111. https://doi.org/10.1016/j.autcon.2011.07.005

Zhou, Z., Goh, Y. M., & Li, Q. (2015). Overview and analysis of safety management studies in the construction industry. *Safety Science*, 72, 337–350. https://doi.org/10.1016/j.ssci.2014.10.006

Zhou, Z., Irizarry, J., & Li, Q. (2013). Applying advanced technology to improve safety management in the construction industry: a literature review. *Construction Management and Economics*, *31*(6), 606–622. https://doi.org/10.1080/01446193.2013.798423

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