

A review of the use of artificial intelligence and artificial intelligence-enhanced devices for improving health and safety practices on construction sites

Olatoyese Oni, AbdulLateef Olanrewaju and Soo-Cheen Khor
Department of Construction Management, Faculty of Engineering and Green
Technology, Universiti Tunku Abdul Rahman, Kampar Campus, Jalan Universiti
Bandar Barat, 31900, Kampar Perak, Malaysia.
olatoyese49@gmail.com

Abstract:

Despite its economic importance, the construction industry is still categorised among the leading causes of work-related injuries and illnesses in most nations. As AI-enabled technologies are implemented in the workplace, it is critical for occupational safety and health professionals to have a better knowledge of artificial intelligence (AI) approaches as well as their potential effects on work and workers. AI is a broad and diversified scientific topic that has pervaded every part of human lives and grown in significance over time. The goal of this study is to examine how AI applications may be employed in the construction industry to enhance workplace safety practices. A systematic literature analysis of existing research in the fields of AI and occupational health and safety was conducted. The study was confined to articles published between 2000 and 2022, and a total of 213 articles were chosen after screening and analysed with the aid of VOSviewer software. The findings demonstrated that research on AI enabled health and safety gained more attention in the years 2020 and 2021, having the highest publication output. China, Hong Kong, the United Kingdom, the United States, and Australia were the top countries in AI-enabled health and safety study, according to the report. The outcome of this research gives perspectives into technological innovation and application for improving health and safety practises on construction sites by identifying patterns of current research and suggesting directions for future research, which is vital for the construction industry's health and safety stakeholders to build upon in order to enhance health and safety practices.

Keywords:

Accident, algorithms, robots, remote sensing, sensor

1 Introduction

The construction industry is one of the industries that contributes significantly to the growth and advancement of many countries' economies. Construction as an industry contributes over 10% of global Gross domestic product (6–9% in wealthy nations) and employs roughly 7% of the worldwide population, totalling more than 273 million people. The global construction sector produced \$10.8 trillion worth of goods in 2017 (Word Bank, 2021).

Despite its economic importance, most countries still consider the construction industry to be one of the industries with the highest rate of work-related accidents and diseases (Vallabh and Malekian, 2018). For example, in the reporting year 2020/2021, the construction industry accounted for 27% of all labour casualties in the United Kingdom (HSE, 2021). According to HSE (2021), approximately 3% of the workforce in the UK construction sector suffers from occupational sickness each year, with additional 2% suffering from work-related accidents. According to the 2020 report by Department of Occupational Safety and Health, construction sites is responsible for 31% of all work-related accidents in Malaysia (DOSH, 2021). In the United States in 2019, construction accounted for almost 20% of all worker deaths in private businesses (HSE, 2021). Construction employs around 6% of US workers but accounts for 17% of all fatalities—the highest number of fatalities reported in any industry. The construction industry is responsible for 31% of workplace fatalities and 10% of serious workplace injuries in the UK (HSE, 2021). Through the breakdown of structures and other major operational incidents, the number of deaths, permanent disabilities, partial disabilities, and other important ecological dangers has steadily increased over time (Delabrida et al., 2015).

This unfavourable trend has led practitioners and academics searching for the fundamental determinants of poor safety practices on building sites, as well as ways to improve it for decades. The National Institute for Occupational Safety and Health (NIOSH), which founded the centre for occupational robotics research (CORR), has been at the forefront of workplace safety and robotics research in this respect. However, the related topic of AI, particularly its application in the workplace, remains shrouded in mystery. Reasoning, mathematics, cognitivism, decision theory, and neuroscience are the underpinnings of AI. AI is a vast and diversified scientific subject that has pervaded every aspect of human lives and has grown in relevance over time, with over 20,000 papers in 2019 alone (Perrault *et al.*, 2019). AI refers to a computer's ability to analyse data and provide outcomes that are similar to how a person thinks, draws judgments, as well as resolves issues in its least basic state (Howard, 2019). While AI study is still in its early stages, the concept of AI goes far to the 1940s, when Alan Turing became one of the earliest mathematicians to study the mathematical potential of AI by asking "whether a machine can think like a human or not." (Barboza *et al.*, 2017). AI has been used in academia and industry to handle variety of issues, including decision-making, environmental monitoring, lowering operational costs, and increasing productivity.

On one hand, advancements in robots, sensing, information processing, including computerisation, as well as powerful machine learning (ML) algorithms, have created significant opportunities for AI applications across wide range of fields. ML techniques, for example, are being employed to: enhance the efficiency of a networks of detectors designed to notice motion; choose the position of radio frequency devices utilised by cops or firemen to discover indoor personnel in the instance of a fire and similar dangers. Other notable AI applications include Law enforcement facial recognition technology, commercial or consumer support improvement, and considerable advances in digital imaging accuracy (Davenport et al., 2020). Occupational safety and health professionals must obtain a deeper grasp of AI techniques and their possible effects on work and people when AI-enabled technologies are applied in the workplace. (Maryam *et al.*, 2021). In light of this, the goal of this study is to determine how AI applications can be utilised to enhance workplace safety and health in the construction industry

through literature. To achieve this, important keywords were developed and searched for in the Scopus database. The search result was then imported to an excel spread sheet for further screening. A scientometric analysis was then carried out for the selected articles after screening with the aid of VOSviewer software. This study contributes to a growing body of knowledge suggesting that AI could be employed to identify, classify, and predict harmful behaviour within a highly dangerous workplace.

2 Literature Review

2.1 Benefits of AI application in health and safety

2.1.1 Eliminating hazardous tasks

By employing remote sensing and automation, AI can assist in the removal of workers from potentially dangerous situations by replacing the tasks of the worker with a machine. AI basically substitutes human brains' operations with computers. Stress, overwork, musculoskeletal ailments, and boredom are all hazards that can be avoided (Bin *et al.*, 2019).

2.1.2 Risk mitigation through analysis

In people analysis, machine learning is utilised to make projections regarding employees' behaviour to help managers make decisions, such as anticipating the possibility of an accident. The analytics could be based on online behaviour, communication monitoring, location tracking, and speech analytics, among other things. Sentiment analytics, for example, can be used to detect exhaustion and prevent overwork (Hasanzadeh *et al.*, 2020). Decision support systems can be used in a similar way to prevent industrial disasters or improve disaster response efficiency. Forecasting analysis as well as AI could be used to help manual material handlers avoid muscle soreness (Guo *et al.*, 2012). The use of sensing devices to analyse large volumes of data could lead to real-time, personalised occupational hazard and exhaustion control, as well as a deeper knowledge of the dangers related with particular job responsibilities. (Li *et al.*, 2018). Wearable sensors may also allow for earlier action in the event of harmful material exposure.

2.1.3 Workflows in the areas of safety and health are being streamlined.

AI could likewise be utilised for boosting the effectiveness of health and safety activities at work. For example, employees' compensation petitions are recorded using literary narration format and therefore should be allocated standardised tags individually. AI is being used to investigate how to make these quicker, cheaper, alongside minimal mistakes (Cortés-Pérez *et al.*, 2020). Near-miss detection, reporting, and analysis are critical in lowering mishap occurrences; however, they are downplayed in most cases since they are rarely noticed by humans or because workers do not report them sociocultural reasons. All of this can be improved with the use of AI (Ojelade and Paige, 2020). Other AI advantages include: increasing worker awareness of hazards; assisting in the warning of workers about workplace hazards; eliminating hazards during the design process; assisting in the visualisation of hazards; and so on. It improves safety training efficacy, improves accident investigation, improves injury reporting, isolates workers from hazards, improves safety planning, improves worker communication, improves safety inspections, and improves near-miss reporting.

3 Research Methodology

This research used a scientific mapping unit of analysis, which was carried out with the use of VOSviewer, a science mapping software. Science mapping generates pictures which depict underlying conceptual, philosophical, plus social structure of disciplines and research areas, as well as their interconnections (Cobo et al., 2011). Through scientometric or bibliometric methodologies, it shows a body of knowledge in a physical manner (Chen et al., 2015). Börner et al. (2003) defined it as a method for analysing the influence of research, interpreting the quotation procedure, and mapping the conceptual understanding and evolutions in a discipline using a huge academic information. By analysing enormous volumes of bibliometric data, scientometric methodologies helps scholars in making comprehensive literature-related findings by integrating literary themes which might be omitted in subjective reviewing investigations (Su and Lee, 2010).

A search strategy was devised for the purpose of this study in order to find relevant material. The literature search was conducted using the Scopus database. This choice of Scopus is because it covers a wide range of subjects, such as science, technology, social sciences, the arts, as well as humanity (Hong and Chan, 2014). The most important search terms or phrases are ("occupational safety and health", "risk", "accident", "artificial intelligence", "robot", "automation", "construction industry" and "construction site"). The search yielded a total of 428 results. Articles published between 2000 and 2022 were considered. Only open-access papers were considered. Engineering, computer science, earth and planetary science, material science, environmental science, and decision science were the selected subject area and the document type was restricted to articles, conference papers, and conference reviews.

Paper source was likewise restricted to conference proceedings, journals, and book reviews. Only papers that had reached the final publication stage were included, while papers published in languages other than English were excluded. At this point, 97 articles were eliminated and reports that could not be retrieved were deleted, with the remaining 325 papers being exported to an excel sheet for eligibility screening. All duplications were examined in order to maintain the review quality. All studies that were not within the study scope, had repetitive publishing, or had an improper sample size were therefore eliminated. Abstracts of the retrieved articles were also inspected to ensure the quality and relevance of the papers to the current study. At this point, 112 papers had been discarded, leaving 213 publications that had passed the screening to be included in this study. Fig. 1 represents the PRISMA diagram for the publication selection process.

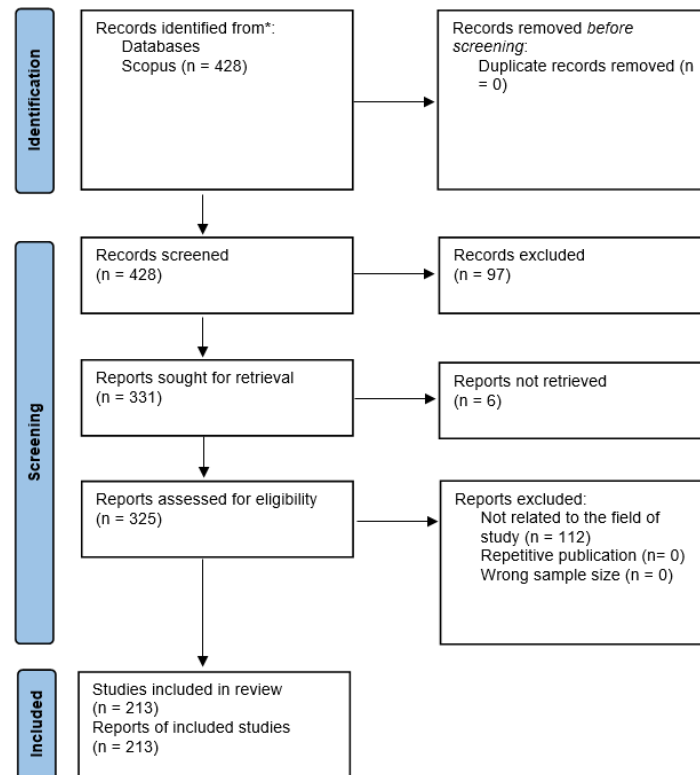


Figure 1: Prisma framework adopted

4 Findings and Discussion

4.1 Analysis of publication year

The distribution of the 213 articles providing insight into AI research interest over years 2000–2022 is shown in Fig. 2. It can be deduced that even though research into the subject area started way back in the year 2000, it gained more attention in the years 2020 and 2021, showing the pick period for this research. This may be due to the increase in casualty rates on construction sites, which has shown no sign of abating. This supposedly has been the motivation for research into solving the problem especially with the aid of artificial intelligence, which has been extensively used in other industries.

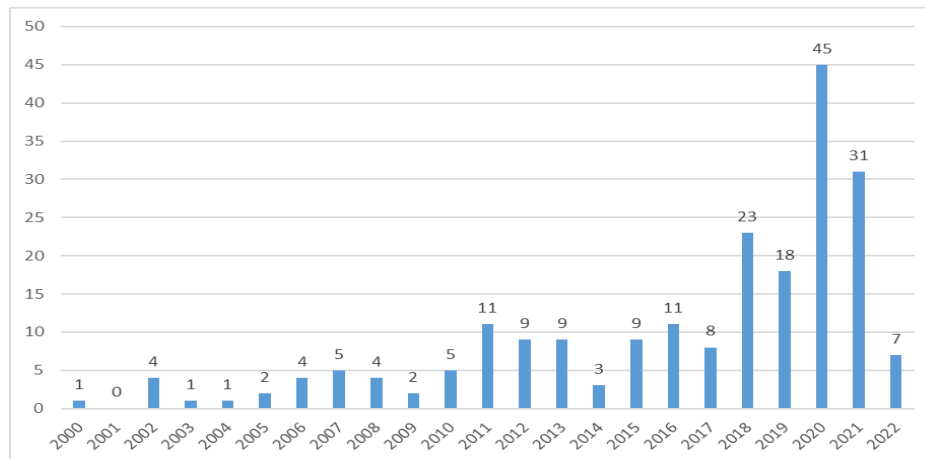


Figure 2: Publication year

4.2 Country co-authorship network

Figure 3 shows the network of co-authorship by countries with a minimum of 3 documents. A total of 21 countries meet this threshold, but only 16 have links with other countries. The figure shows that there are a total of 26 links with 43 total link strengths. With 25 papers, 5 links, and 12 total link strength, China leads, followed by Hong Kong with 10 papers, 5 links, and 10 total link strength, the UK with 16 papers, 5 links, and 10 total link strength, the United States with 37 papers, 6 links, and 10 total link strength, Australia with 14 papers, 4 links, and 7 total link strength, and Singapore with 11 papers, 3 links, and 6 total link strength. Followed by Germany with 13 papers, 3 links, and 5 total link strength, Canada with 13 papers, 2 links, and 4 total link strength, Russian Federation with 7 papers, 2 links, and 4 total link strength, France with 3 papers, 3 links, and 3 total link strength, Japan with 9 papers, 3 links, and 3 total link strength, Malaysia with 11 papers, 3 links, and 3 total link strength, and South Korea with 11 papers, 3 links, and 3 total link strength. Spain with 3 papers, 3 links, and 3 total link strength, followed by Taiwan with 7 papers, 2 links, and 2 total link strength, and Saudi Arabia with 3 documents, 1 link, and 1 total link strength.

Even though the number of documents was reduced to 3, only a few countries were able to meet the threshold. It can therefore be said that many countries are still missing on the list of countries using artificial intelligence research to solve health and safety problems. A wide gap still exists in co-authorship across other countries, especially African countries. In order to have a full knowledge of the effectiveness of artificial intelligence in solving health and safety problems, similar research has to be conducted in and co-authored across various countries.

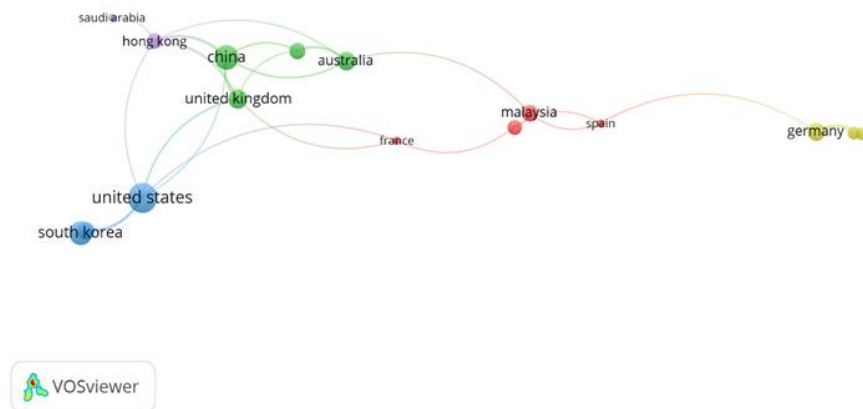


Figure 3: Country co-authorship network

4.3 Co-occurring network of keywords

Figure 4 shows a networking depiction mapping of the five co-occurring keywords groups, illustrating the evolution of study focus based on co-occurring keywords during a 22-year timeframe (2000–2022). Keywords are succinct and representative summaries of the information of published papers. The trending subjects in the subject domain can indeed be discovered within a certain period using a keyword co-occurrence network. An evolutionary connectivity can show how a study field has evolved over time. Using the VOSviewer package, a co-occurrence connectivity was generated comprising a collection of 2205 keywords. 94 keywords fulfilled the criterion of 5 co-occurrence keywords, and 5 important keyword groups were determined with 1953 links and 4850 total link strengths. According to Liang et al. (2018), The extent of co-occurrence is measured by the proximity of terms to one another plus the resemblance of terms. The top 10 frequently used keywords were: construction industry with 121 occurrences and 747 total link strength; artificial intelligence with 70 occurrences and 458 total link strength; accident prevention with 60 occurrences and 414 total link strength; construction sites with 54 occurrences and 326 total link strength; occupational risk with 39 occurrences and 315 total link strength; robotics with 48 occurrences and 296 total link strength; construction safety with 37 occurrences and 289 total link strength; risk assessment with 32 occurrences and 257 total link strength; automation with 45 occurrences and 242 total link strength; accidents with 30 occurrences and 242 total link strength. The five clusters were also summarised as follows:

Cluster one, labelled in red, had 26 keywords, such as accident prevention, agricultural robots, antenna, camera, computer vision, construction accidents, construction equipment, construction process, construction sites, construction workers, construction work, convolutional neural network, cranes, deep learning, industrial robots, intelligent robots, internet of things, machinery, object detection, object recognition, occupational safety, productivity, risk perception, robot programming, robotics, and robots.

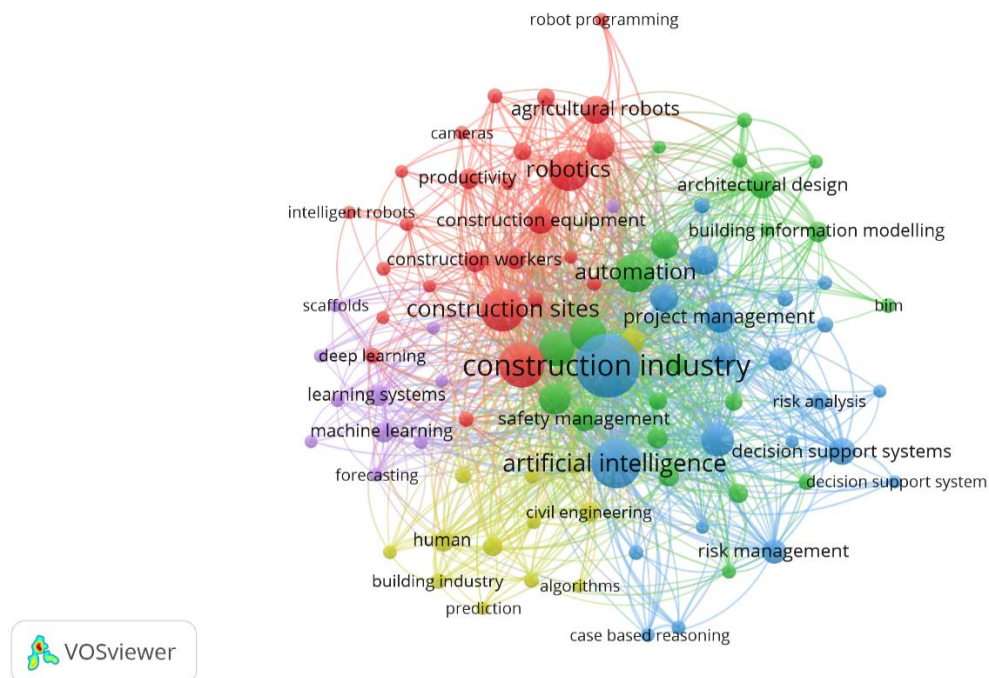


Figure 4: Co-occurring network of keywords

Cluster two, labelled in green, had 22 keywords. These included accidents, architectural design, automation, BIM, building information modelling, construction safety, hazard identification, hazards, health, health and safety, health hazards, health risks, human resource management, industrial hygiene, information management, information theory, occupational health and safety, occupational risk, process control and safety management.

Cluster three, labelled in blue, also had 22 keywords, which included artificial intelligence, case-based reasoning, construction, construction companies, construction industries, construction management, construction projects, choice making, choice support tools, experience and understanding systems, optimisation, project management, quality control, remote sensing, threat evaluation, risk evaluation, hazard assessment, safe work technology, safety factor, and virtual reality

Cluster four, labelled in yellow, had 13 keywords, which included algorithms, articles, building industry, civil engineering, construction site, construction site safety, construction work, human, neural network, occupational accident, prediction, and safety.

Cluster five, labelled in purple, had 11 keywords, which included classification of information, construction activities, data mining, decision trees, forecasting, learning algorithms, learning systems, machine learning, safety inspection, scaffolds, and wearable technology.

The co-occurrence of terms revealed that health and safety research has developed through time, moving away from traditional approaches and toward digital technologies such as remote sensing and video surveillance, among other things. For example, the National Institute for Occupational Safety and Health (NIOSH) established the Centre

for Occupational Robotics Research (CORR) to research the impact of robotics and artificial intelligence in the workplace on worker safety, health, and well-being. Similarly, the European Agency for Workplace Health and Safety investigated the use of Artificial intelligence-enhanced devices as well as software at work, examining where they are used, how they are used, and the implications for occupational health and safety (Ding et al., 2011). Utilizing footage from close circuit television (CCTV), smart carpets, plus wireless sensors designed to be used in the living area, support vector machine algorithms have been created to identify accidents and determine divergent movement patterns as indicators of prospective accidents (Vallabh and Malekian, 2018). Based on experimental and training datasets, these models obtained fall detection accuracies of up to 100%. Nevertheless, their usefulness and applicability in real-world contexts require more investigation.

5 Conclusion and Further Research

This study has successfully conducted a comprehensive review using a scientific mapping approach to analyse articles related to the use of AI in occupational health and safety on building sites. 213 articles from the years 2000–2022 were retrieved from the Scopus database for this study. According to the findings, the year 2021 had the most publications, with China, Hong Kong, UK, USA, and Austria leading the way in terms of research production as well as co-authorship. In the construction industry, artificial intelligence, accident prevention, construction sites, occupational risk, robotics, construction safety, risk assessment, automation, and accidents were the top keywords in terms of co-occurrence.

However, future research needs to look into predicting construction sites accidents using different machine learning algorithms so as to know the best algorithms with the highest prediction accuracy. Also, there is a need for future research to look into the cost implications of introducing AI into occupational health and safety on construction sites in order to determine its economic viability. Finally, there is a need to carry out more research on the challenges and disadvantages of AI enabled health and safety on construction sites.

The outcome of this research gives perspectives into technological innovation and application for improving health and safety practises on construction sites by identifying patterns of current research and suggesting directions for future research, which is vital for the construction industry's health and safety stakeholders to build upon in order to enhance health and safety practices.

6 References

- Barboza, F.; Kimura, H. and Altman, E. (2017) Machine learning models and bankruptcy prediction. *Expert Syst. Appl.*, 83, 405–417.
- Bin, F.; Xi, Z.; Yi, C. and Ping, W.G. (2019) Construction safety education system based on virtual reality. *IOP Conf. Ser. Mater. Sci. Eng.*, 563.
- Börner, K., Chen, C and Boyack, K.W (2003) Visualizing knowledge domains. *Annu. Rev. Inf. Sci. Technol.* 37 (1) pp179–255,

- Chen, C., Dubin, R. and Schultz, T. (2015), “*Science mapping*”, in Mehdi Khosrow-Pour, D.B.A. (Ed.), *Encyclopedia of Information Science and Technology*, 3rd ed., IGI Global, Hershey, PA, pp. 4171-4184.
- Choi, M.; Ahn, S. and Seo, J.O. (2020) VR-Based investigation of forklift operator situation awareness for preventing collision accidents. *Accid. Anal. Prev.*, 136, 105404.
- Cobo, M.J., López-Herrera, A.G., Herrera-Viedma, E. and Herrera, F. (2011), “Science mapping software tools: review, analysis, and cooperative study among tools”, *Journal of the American Society for Information Science and Technology*, Vol. 62 No. 7, pp. 1382-1402.
- Cortés-Pérez, J.P.; Cortés-Pérez, A. and Prieto-Muriel, P. (2020) BIM-integrated management of occupational hazards in building construction and maintenance. *Autom. Constr.*, 113, 103115.
- Davenport, T.; Guha, A.; Grewal, D.; Bressgott, T. (2020) How artificial intelligence will change the future of marketing. *J. Acad. Mark. Sci.*, 48, 24–42.
- Delabrida, S.E.; Angelo, T.D.; Oliveira, R.A.R. and Loureiro, A.A.F. (2015) Towards a Wearable Device for Monitoring Ecological Environments. In *Proceedings of the 2015 Brazilian Symposium on Computing Systems Engineering (SBESC)*, Foz do Iguaçu, PR, Brazil, 3–6 November 2015; pp. 148–153.
- Department of Occupational Safety and Health DOSH (2021) “Laman Web Rasmi Jabatan Keselamatan dan Kesihatan Pekerjaan Malaysia - Utama,” 2021. [Online]. Available: <http://www.dosh.gov.my/index.php/ms/>. [Accessed: 12-Feb-2022].
- Ding, J.; Wang, J.; Yuan, N. and Pan, Q. (2011) The monitoring system of leakage accidents in crude oil pipeline based on ZigBee technology. In *Proceedings of the 2011 Second International Conference on Mechanic Automation and Control Engineering*, Inner Mongolia, China, 15–17 July 2011; pp. 1774–1777.
- Guo, H.; Li, H.; Chan, G. and Skitmore, M. (2012) Using game technologies to improve the safety of construction plant operations. *Accid. Anal. Prev.*, 48, 204–213.
- Hasanzadeh, S.; de la Garza, J.M. and Geller, E.S. (2020) How Sensation-Seeking Propensity Determines Individuals’ Risk-Taking Behaviors: Implication of Risk Compensation in a Simulated Roofing Task. *J. Manag. Eng.*, 36, 04020047.
- Hong, Y. and Chan, D.W. (2014). Research trend of joint ventures in construction: a two-decade taxonomic review. *J. Facil. Manag.* 12 (2), 118–141.
- Howard, J. (2019) Artificial intelligence: Implications for the future of work. *Am. J. Ind. Med.*, 62, 917–926.
- Health and Safety Executive (2021). Health and safety statistics available at <https://www.hse.gov.uk/statistics/>
- Li, X.; Yi, W.; Chi, H.L.; Wang, X. and Chan, A.P.C. (2018) A critical review of virtual and augmented reality (VR/AR) applications in construction safety. *Autom. Constr.*, 86, 150–162.
- Maryam, P, Salah, F.I., Margaret, S., Preethi, P and Houshang, D. (2021) REDECA: A Novel Framework to Review Artificial Intelligence and Its Applications in Occupational Safety and Health. *Int. J. Environ. Res. Public Health*, 18, 6705.
- NIOSH. (2021) Available online: <https://www.cdc.gov/niosh/topics/robotics/default.html> (accessed on 15 September 2021). Ojelade, A.; Paige, F. (2020) Virtual Reality Postural Training for Construction. In *Proceedings of the Construction Research Congress 2020*, Tempe, AZ, USA, 8–10 March 2020; pp. 268–277.

- Perrault, R.; Shoham, Y.; Brynjolfsson, E.; Clark, J.; Etchemendy, J.; Grosz, B.; Lyons, T.; Manyika, J.; Mishra, S. and Niebles, J.C. (2019) *The AI Index 2019 Annual Report*; AI Index Steering Committee, Human-Centered AI Institute; Stanford University: Stanford, CA, USA, 2019.
- Su, H.N and Lee, P.C (2010) Mapping knowledge structure by keyword co-occurrence: a first look at journal papers in technology foresight, *Scientometrics* 85 (1) pp65–79,
- Vallabh, P and Malekian, R. (2018) Fall detection monitoring systems: A comprehensive review. *J. Ambient. Intell. Humaniz. Comput.*, 9, 1809–1833.
- World Bank (2021). Annual report available at <https://www.worldbank.org/en/about/annual-report/world-bank-group-downloads>