INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
Vol. 12 No. 3 (2021) 289-298

IJSCET

http://penerbit.uthm.edu.my/ojs/index.php/ijscet
ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Reinforce Technology IR 4.0 Implementation for Improving Safety Management in Construction Site

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DOI: https://doi.org/10.30880/ijscet.2021.12.03.028
Received 10 August 2021; Accepted 18 October 2021; Available online 2 December 2021

Abstract: Industrial Revolution 4.0 in recent years notorious for new advances in high technology, full automation, and digitalization. This technology has demanded by academic researchers and practitioners, on the construction industry sector in Malaysia. The construction industry is involved with complex management processes causes impossible to eliminate the potential hazards at the workplaces. Despite, the rate of accidents and deaths continue to increase year by year. The objectives of this research are to identify IR 4.0 implementation, drivers and barriers of IR 4.0 implementation for safety management in the construction industry. In approaching IR 4.0 technology, a systematic literature review has been applied. The paper is reviewed by extracting information based on topics and highlighting research directed to implement IR 4.0 for safety management. After further analyzed, 32 out of 80 journal papers were selected. Several ideas on IR 4.0 technologies with its drivers and barriers were highlighted in relation to safety management practices in the term of realize suitable practices, safety training, and planning give the benefits in implementation IR 4.0. This review provides insights into the areas that technology needs to focus on, enabling a tangible shift towards implementing IR 4.0 in the construction industry.

Keywords: Construction industry, IR 4.0, safety management, drivers, barriers

1. Introduction

Industrial Revolution 4.0 technology application for safety management has been implemented in the construction industry, globally. Industry 4.0 also founds as the promising approach based on the manufacturing and production industry (Rojko, 2017). The term IR 4.0 has gained the attention of the academic, government, and industries. The keywords of IR 4.0 in the quest of technology implementation in various nations have mostly been proposed by developing countries that realize advanced technology that provides various benefits to new skill forces, management, and safety (Zhou et al., 2013; Getuli et al., 2020). For example, the technology IR 4.0 that can be implemented such as virtual reality (VR), augmented reality (AR), Internet of Things (IoT), cloud computing, simulation and Building Information Modelling (BIM). These technologies were introduced as sophisticated information technologies that were employed concurrently to improve workspace design for safety management, as well as effective communication of planning, detection, inspection, and safety information to all applicable partners (Jiang et al., 2020; Fiorentino et al., 2014; Bello et al., 2021). Nowadays, the technology application able to create the technology can be seen through the visualization that contributed to the cyber-physical system (CPS). One of the technologies that recently gained attention

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that called as "digital twin", the system able to monitor physical processes that involved the physical world through smart decisions in real-time communication with machines, sensors, humans (Zhong et al., 2017). Contrary to other industries, the construction industry shows the low adoption of new technologies because the uniqueness of the construction sector makes up an impose for the intended adaptation of technologies that are used in many other industries (Craveiro et al., 2019). Certain problems were identifying which are ineffectiveness and low productivity of organizations, demand skills and expertise, and labour-reducing technologies (Zuhairy et al., 2015). The construction process is the most complex operation compare to other industry, which leads to great difficulty in confronting with the increasing complexity of major construction projects (Lee et al., 2020; Oesterreich & Teuteberg, 2016). Therefore, this study is to identify the drivers and barriers of IR 4.0 technologies implementation for safety management in the construction industry. The specific objectives of this research include IR 4.0 technology implementation and drivers and barriers of IR 4.0 for safety management.

2. Literature Review

This section discusses towards Industry Revolution 4.0, overview on safety management in the construction industry and Industrial Revolution 4.0 technologies.

2.1 Towards Industry Revolution 4.0

Fourth Industrial Revolution is evolving an exponential globally in changing the global economy on the operation, utilization of resources, enhance quality and safety (Alaloul et al., 2020). The IR 4.0 was drawn in Malaysia on the manufacturing industry in realizing the 11th Malaysia Plan to maintain and remains a core manufacturing sector of the sustainable growth (Manokaran, 2020). Hence, Malaysia's National Policy IR4.0 has launched the "Industry Forward" (Industry4WRD) in 2018 that focus in manufacturing industry. In the policy, the Ministry of International Trade and Industry (MITI) stated the advancement and convergence of technology IR 4.0 brings a new dimension to the industrial environment, growing in a dramatic increase in industrial productivity. The transform of revolution changes the Japan which implemented IR 4.0 through the Society 5 in a strategic national political initiative (Huimin et al., 2018). In China, the State Council announced "Made in China 2025" on to revolutionize China from a manufacturing giant change into a world manufacturing power (Maria et al., 2021). Since the German federal government announced Industry Revolution 4.0 in the economic policy 2011, IR 4.0 technologies beginning to grow national with the aim toward the changing advancements in several sectors. The Construction Industry Development Board (CIDB) in Malaysia has established the Strategic Plan 4.0 (2021-2025), which aims to transform the construction sector into one that is smart, sustainable, and productive in implementing the Industrial Revolution 4.0 technologies (CIDB, 2020a). In other words, also known as Construction 4.0 revolution, in adapting the advanced technologies that can reduce reliance on low-skilled labour with low productivity in the construction industry. Construction 4.0 is primarily concerned with enhancing current and future technologies for the construction industry in order to achieve higher productivity, improved safety, and a more sustainable approach. Besides, other industries have struggle continue to shake up and compete to keep up the pace with developed countries. Hence, the IR 4.0 can be seen through the largest growth broad in manufacturing, engineering, and business (Zhou et al., 2013; Zhong et al., 2017).

2.2 Overview Safety Management in the Construction Industry

Safety and health management in the construction industry contribute to the high accident and fatality rates. National employment of the accident rate represents three developed regions (Japan, South Korea and United Kingdom) and two developing countries (Singapore and Malaysia) as shown in Table 1.

Table 1 - National employment of accident and death rate in 2019 (DOSH, 2020)

Country	Accident Rate (per 1,000 workers)	Death Rate (per 100,000 workers)
South Korea	5.36	5.09
United Kingdom	2.63	0.45
Japan	2.20	1.56
Singapore	3.96	1.10
Malaysia	2.71	3.83

The industry fatal accident rate (fatal accident/100,000 workers) in South Korea as develop country (5.09/100,000 workers) was highest than the United Kingdom, Malaysia, and Japan. In fact, there were many accidents and deaths of the workers that had serious injuries involved the construction industry sector in South Korea. Malaysia, as one of the

developing countries, has acknowledged that the accidents and deaths at the workplace in Malaysia increased yearly (Arifin et al., 2013). The collected data on 2019 revealed that the industry fatal accident rate (2.20/100,000 workers) occurred in Malaysia is lower than South Korea. In terms of its impact on employee health and safety, the construction industry is thought to be one of the most significant and remarkable contributors to long-term economic development (Chakrabortty et al., 2011; Durdyev & Ismail, 2012).

2.3 Industrial Revolution 4.0 Technologies

Industrial Revolution 4.0 or IR 4.0 is well-known with the technology development which completely automated and intelligent, capable of communicating autonomously, intelligent learning analysis, and intelligent decision-making (Jiang et al., 2020; Zhong et al., 2017). Industrial Revolution beginning to embark early 2017 in transforms upon the Digital Revolution where technology and people are connected. German government introduced Industrial Revolution 4.0 in goal to create the machinery and the automotive manufacturing industry towards the new digitalization and high technology. Rojko (2017) stated this technology is established based on the concept idea on the availability and use of the internet and IoT, integration of technical processes and business processes in the companies, digital mapping and virtualization of the real world and smart' factory including 'smart' means of industrial production and products. Adoption of information through the use of the communications technology (ICT) interface in the physical and virtual worlds, known as cyber-physical systems (CPS), which comprise online networks of social machines, linking IT with mechanical and electronic components that communicate with one another via a network. Information technologies, computers, and the internet are used to power the control operations. This system is described as a "digital twin" in the era of Industry 4.0 because it is capable of monitoring physical processes as well as the physical world and making smart decisions through real-time communication and cooperation with humans, machines, and sensors (Zhong et al., 2017). Fig.1 shows the IR 4.0 technologies used in manufacturing industry and construction industry.

Fig. 1 - IR 4.0 technologies used in industries (MITI, 2018; CIDB, 2020a)

3. Methodology

This research was conducted to identify IR 4.0 technologies and drivers and barriers of IR 4.0 technologies implementation for safety management in the construction industry. The systematic literature review methodology is conducted to improve the quality of review processes of this researcher studies. This method was chosen as the research methodology which employs by Tranfield et al. (2003) applied the three main steps of planning, execution, and reporting. A series of steps articulated the analysis, allowing creating of a database containing all the characteristics of the selected papers. This step provided the information could be elaborated using various points of view based on the database. This provided a comprehensive picture of the characteristics of the literature on Industry 4.0. The search engine based on the keywords related to research studies. The keywords act as a baseline to analyze IR 4.0 technologies implementation with the drivers and barriers for the safety management in the construction industry. The research can be divided into phases as shown in Fig. 2 which are from the keywords, database, preliminary data collection phase, data analysis phase and review report.

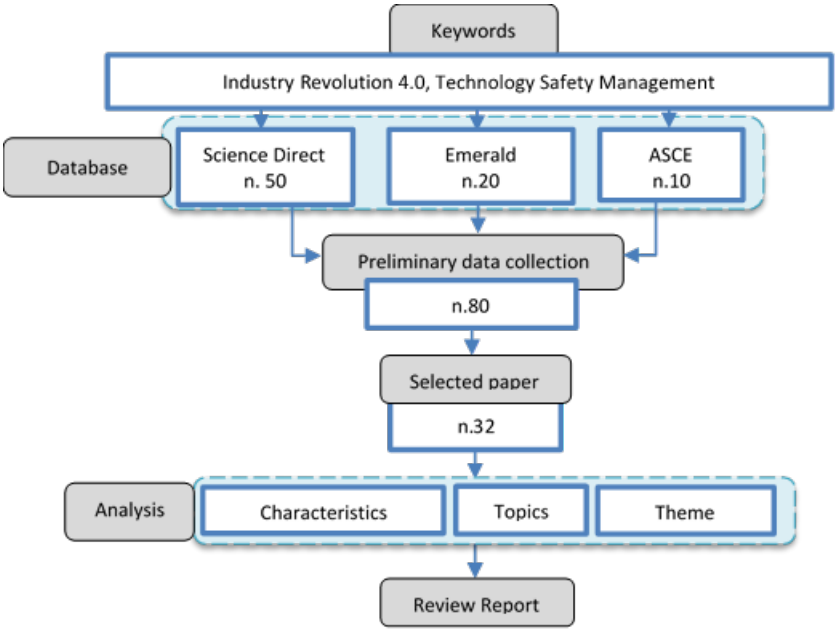

Fig. 2 - The review process

Fig. 2 shows the entire review process. Three publishing databases were focused extensively (Emerald, Science Direct, and the American Society of Civil Engineers, ASCE) to conduct this broad review, which covered related papers in engineering, manufacturing, and safety management in both academic and business sectors. This selected database is selected intents to highlight the main aspects of Industry Revolution 4.0 in implementation in the construction industry based on the good coverage of journal articles. First, searching using the keywords of "Industry Revolution 4.0" and "Technology Safety Management" (related technologies such as Internet of things, Virtual Reality, Cybersecurity, Cloud computing etc. are also used in searching the journals and articles). Based on the database, only total 80 papers were obtained as the preliminary data collection. After furthers identifying, only 32 out of 80 articles or journals were selected. Each keyword was analyses to ensure the comprehensiveness and reliability of the review process.

4. Results and Discussion

The review is based on the data gathered from the 30 articles. The findings include the paper's characteristics, such as the article's profile, the year of publication, and the countries of origin. Furthermore, the IR 4.0 technologies implementation, drivers and barriers of IR 4.0 technology implementation for safety management are highlighted.

4.1 Publication Interest and Origin

Fig. 3(a) shows the general view on the paper published from 2013 to 2021. The topic of Industrial Revolution 4.0 on safety management has just lately acquired notice, and scholars' interest in its various aspects has expanded significantly in recent years. The most number of paper publishers suggested in 2020, indicating that the research community is beginning to explore ways to realize IR 4.0 in the construction industry. Because the research is still on-going in 2021, a lesser number of publications than in prior years does not appear to be as important. The geographical origin of publication as shown in Fig. 3(b), there is a strong contribution of United States authors with 10 articles publication from 2013 to 2021. Hence, it indicated the higher than other origins. The second authors are from China with 9 articles followed by the United Kingdom, Australia, Italy, Canada, and South Korea (Korea).

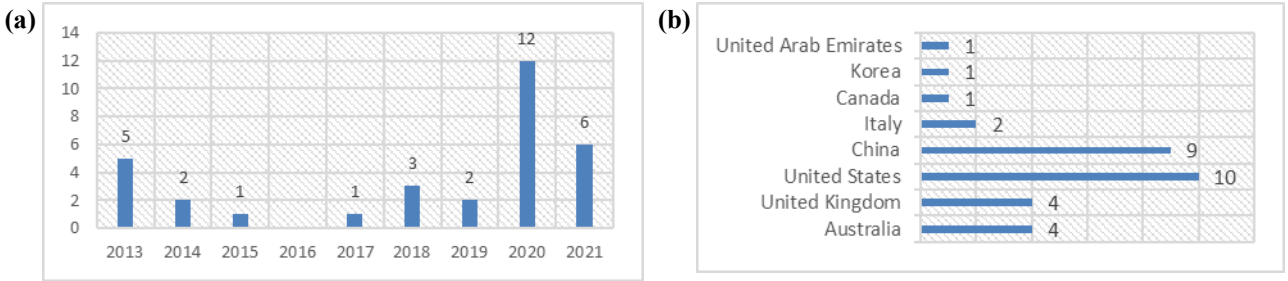

Fig. 3 - (a) The publications interest of scholar; (b) The origin of publications

Fig. 4 shows the entire journal list hosting of the selected articles. Most of the journal were published on Automation in Construction. Looking at the journals in which papers were published, there are many of them, and only a few of them published over one article.

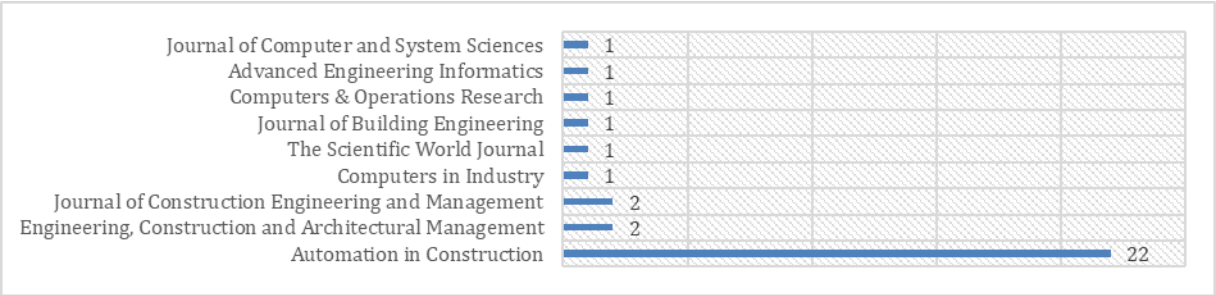

Fig. 4 - Journal list hosting of the selected articles

4.2 Industrial Revolution 4.0 Technologies Implementation in Construction Industry

The application of the technology in Malaysia utilisation is revealed to have a significant influence on the business performance of construction organisation as it intentionally reducing construction accidents (Zuhairy et al., 2015). Fig.5 shows the technology that used for safety management.

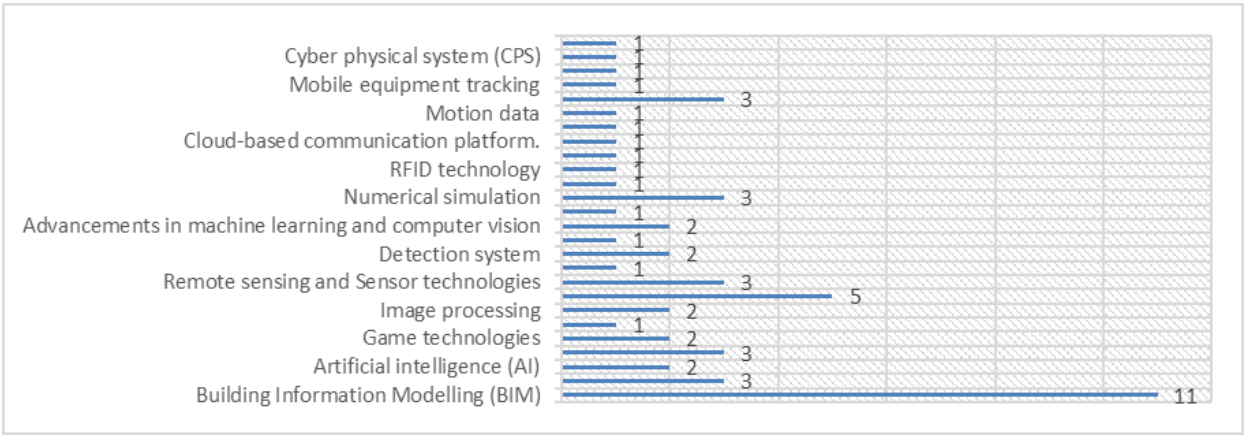

Fig. 5 - Technologies implementation for safety management

Based on Fig.5, most academic researchers have focused on Building Information Modelling (BIM) as the primary application in safety and health research around the world in the construction industry to reduce potential risks on construction sites. According to Alaloul et al. (2020), there are largely utilization of BIM in the digital simulation and modelling of the project, which is generated earlier from the first task in the project to become a reality that can significantly improve the construction industry's workability among the construction practitioners. Therefore, BIM with IR 4.0 technologies were mainly applied by academic researcher as the main technology used to speed up the technology advancement for digital information and reducing construction accidents. Second technologies are visualization technologies that consists of 3D and 4D model commonly used for the simulation and BIM application.

Besides, there are several technologies such as the virtual reality, cloud-computing, Internet of Things, and artificial intelligent that also been utilize for the safety management purpose among the researchers. IoT-enabled construction presents the real-time data collection and sharing among many resources such as machines, workers, materials, and jobs (Zhong et al., 2017). VR and AR possible to allow the worker to evaluate the virtual workspace configuration in correspondence with the real site objects (Alaloul et al., 2020). Cohen et al. (2019) stated cloud computing provides with resource sharing, dynamic allocation, flexible extension and numerous other advantages. Furthermore, the developed AI which the ability of robots, along with elimination of safety issues, open new opportunities for cobot utilization in assembly lines which can be used smartly to assist manual assembly work (Cohen et al., 2019).

In 2019, the academic researcher has started the interest on the advance technologies (Cyber-physical Systems and Digital Twins) that used in construction industry for the safety management. Matana et al. (2020) stated CPS is the assimilation of physical processes with computational processes. The physical system is a system that people can understand with their five sensory organs. Cybernetics is a scientific discipline study on control and communication of living things and machines. The control processes are based on information technologies, computers, and internet. According to Zhao et al. (2021), the digital twin serves as a bridge between the physical and cyber worlds. Massive

amounts of data are collected directly from smart products and distribution networks via the Internet of Things and then communicated in real time. The previous researchers discover that CPS technologies, presenting as fully capable of operating in the IR 4.0 environment.

4.3 Industrial Revolution 4.0 Technologies Implementation in Construction Industry

Industrial Revolution 4.0 implementation has emerged as an important in assist the health and safety in the workplace to reduce various factors such as environmental, human, equipment and management towards the new digital industrial revolution. In order, to overcome the safety issues, the systematic literature review is conducted to identify the drivers and barriers of IR 4.0 in safety construction industry as shown in Table 2.

Table 2 - Drivers and barriers of technology IR 4.0 implementation

Technology	Drivers	Barriers
Augmented reality (AR)	▪ Data up to date, time and cost saving, knowledge, level user's skills (Fiorentino et al., 2014), Increase recognition, effective workflows (Garbett et al, 2021)	▪ Details of setups, user interface integration with data, camera calibration (Fiorentino et al., 2014), training (Garbett et al, 2021)
Virtual reality (VR)	▪ Real-time observe (Cheng & Teizer, 2013), support high-risk training and cost-effective and training (Chen et al., 2021)	▪ Impact on existing work and training practices (Cheng & Teizer, 2013)
Internet of Things (IoT)	▪ The efficiency and effectiveness in checking tools (low-cost, portable), ability to identify failures and notify users (Yang et al., 2020), improve location estimation accuracy (Zhao et al., 2021)	▪ Not energy-saving solution for wireless communication (Yang et al., 2020), privacy issues (Zhao et al., 2021)
Artificial Intelligence (AI)	▪ Opinion-based judgments, perceptions, and risk assessments (Baker et al., 2020)	▪ Costly and larger dataset needs (Baker et al., 2020)
Cloud computing	▪ Effectively monitored, improved safety with location information and provide decision support tools (Bello et al., 2021)	▪ Costing and low of security (Bello et al., 2021)
Simulation	▪ Formulate better strategies (Sun & Turkan, 2020)	▪ Data interoperability and technical limitations, unable simultaneously model (Sun & Turkan, 2020)
Cyber- Physical System (CPS)	▪ The management benefits system (Jiang et al., 2020)	▪ Limitations smart construction (Jiang et al., 2020)
Digital Twin	▪ Improve productivity, enhanced human capabilities, vision, communication, and strength (Zhao et al., 2021)	▪ Support on the virtualization of equipment (Zhao et al., 2021)

The previous researchers found that safety practices are in a positive direction and provide better knowledge of technology application in the aspect of implementing suitable practices in the construction industry. There are numerous advantages of implementing IR 4.0, which can be used for smart and advanced technology. Clearly stated that advancement technology influences the safety management performance Hence, this cannot be denied as the previous researcher founds that Industry 4.0 technology able to reduce costs, production time, productivity, and improve decision making. The barriers were determined by the components of each technology employed in this research. Implementation of IR 4.0 was a challenge to embrace and implement for both employer and employees, in particular those related to the smart safety system, the shortage of financial resources demanded implementing sustainable practices, especially those related to the purchase of machinery and equipment. On training and the awareness, the construction players need to re-train on an environmental change. Implementation IR 4.0 requires the skills and expertise of workers in checking and

maintaining the system. IR 4.0 involvement in the IoT's utilization, which the privacy issues are a threat towards the employee's personal.

4.4 Industrial Revolution 4.0 Technologies Implementation in Construction Industry

Industry development focuses on the Industrial Revolution 4.0, as the technologies are being advanced and their application potentials are being increased. Fig.6 shows the reinforcement of safety management with IR 4.0 technologies. Recently there has been a growing interest in the adoption of the smart system that applied in the construction industry sector, which is cyber-physical system and digital twin in a safety management system. Other's technologies were also mentioned in Fig.6 as the technology IR 4.0 that commonly used for the construction purpose. Mostly, the combinations of technology with IR 4.0 were widely recommended by previous researcher such as IoT and digital twin enabled smart tracking for safety management, cloud-enabled BIM and BLE Mobile Tracking Sensors (Park et al., 2016; Zhao et al., 2021). This collaboration of the technologies, results in assist by reducing, eliminate errors, and maximize safety management to a greater interval of construction industry modernization (Cohen et al., 2019). Besides, the advanced information technologies can be simultaneously used to improve workspace planning for safety management and the effective communication of the planning and safety information to all relevant partners (Oesterreich & Teuteberg, 2016). The several drivers and barriers were listed based on the technology application. This driver acts as the benchmarks in this research studies in realizing the IR 4.0 technologies. The barriers help in identifying the challenges that encounter the problem by utilizing the technology.

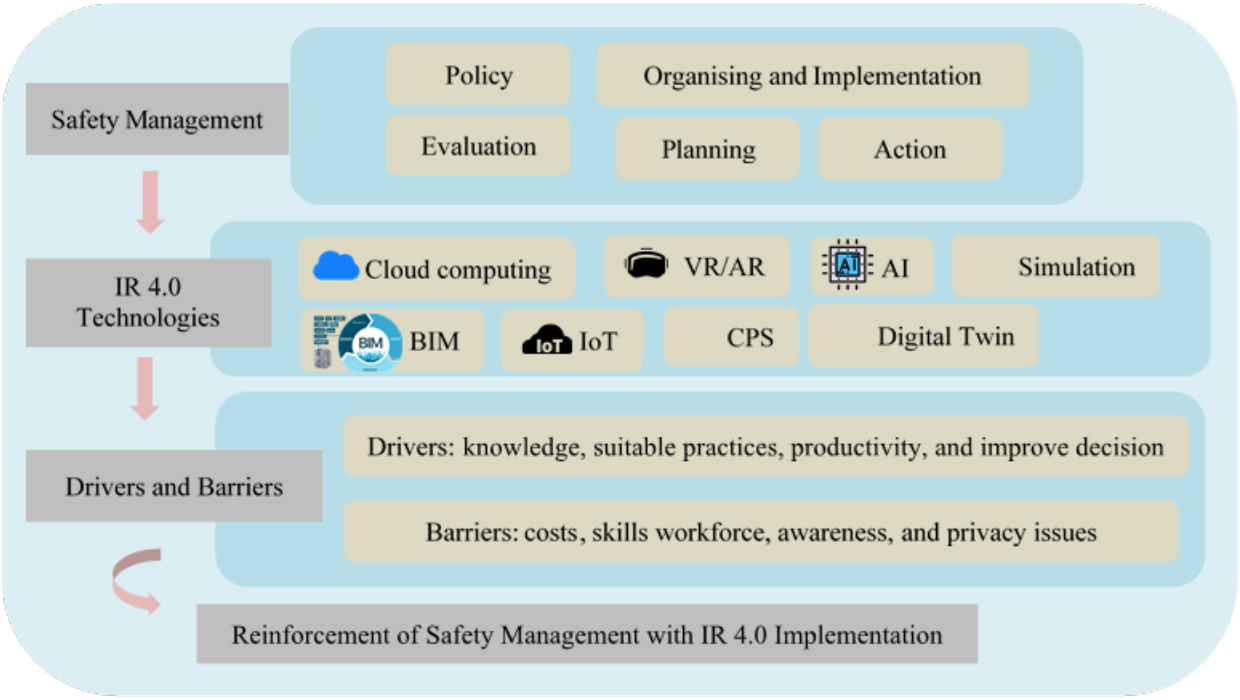

Fig. 6 - Reinforcement of safety management with IR 4.0 technologies

The safety management cover five categories that helps in improving the safety performance at the construction site. The policy "Industry Forward" (Industry4WRD) and Strategic Plan 4.0 (2021-2025) had been introduced in Malaysia towards the IR 4.0 technologies. The ability of the technology approach potentially increases construction safety by implementing IR 4.0. In addition, the require of proper planning, organizing and action needs to be as the reinforcement of the safety management. Therefore, maximizing the level of the technologies in health and safety can enhance the safety performance based on drivers that discovers on potential of IR 4.0. These studies only discover the IR 4.0 technology, driver and barriers in implementing IR 4.0. However, in presence of a considerable amount of review presented in relation to an implementation, it's reasonable to envision the development and implementation of IR 4.0 technologies in transform the construction industry towards Construction 4.0.

5. Conclusion

The literature review is carried out on specific studies to uncover the drivers and barriers of IR 4.0 technologies implementation for safety management in the construction industry. The previous researchers had highlighted the IR 4.0 technologies are needed in order to prove that further enhancement of the implementation able to enhance safety management performance. The next phases will be focused on the key elements and the requirements of IR 4.0 technologies.

Acknowledgement

This research was supported by Ministry of Higher Education (MOHE) through Fundamental Research Grant Scheme (FRGS/1/2020/TK01/UTHM/02/1).

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