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THE APPLICATION OF TECHNOLOGY IN ENHANCING SAFETY AND HEALTH ASPECTS ON MALAYSIAN CONSTRUCTION PROJECTS

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ABSTRACT

Construction industry is commonly known as an industry exposed to high risks in many aspects, especially related to safety and health. Despite many efforts done by all relevant parties related to the construction industry to bring awareness and enhancing the level of safety and health in construction projects, accidents keep on occurring on construction sites. Safety procedures, policies and regulations may already be implemented on-site; however, the effectiveness of its implementation is still debatable. The use of technology has proven to help in minimizing number of accidents occurrence on construction site and overall construction safety management. This paper provides an overview of various types of technology applications (3D and 4D visualisation techniques, information and communication technology, real-time tracking systems, RFIDs and remote-sensing) suitable for effective implementation and improvisation on construction jobsite that have been proposed and studied by numerous researchers worldwide based on the traditional review conducted. The information gathered can be used to determine some of the applications that can be implemented on Malaysian construction projects. The technology proposed may effectively help construction players to reduce number of accidents and thus, elevate the safety and health aspects in Malaysian construction industry to another level.

Keywords: construction safety, construction industry, safety technology.

1. INTRODUCTION

The construction industry remains one of the most dangerous industries amongst all industries. Thousands of construction workers are injured or killed in construction accidents each year around the world. Despite the stronger regulations in health and safety, no significant reduction can be noted in the number of injured or diseased workers. Regardless of many efforts done by government agencies and various sectors to enhance the level of safety and health at the workplace, statistics indicates that accidents still continues to occur at a continuous rate, especially in the construction industry. According to the Department of Occupational Safety and Health Malaysia (DOSH), the construction sector is the sector that has the highest number of death due to occupational accidents [1] compared to the other nine sectors (manufacturing, mining and quarrying, agriculture, forestry and logging, utility, transportation and storage, wholesale and retail, hotel and restaurants, finance and insurance, as well as public services and statutory bodies). The Malaysian Social Security Organization (SOCSO), in its 2013 Annual Report has stated that a total of 63,557 accident cases were reported across sectors, which is an increased of 2,005 cases or 3.26% as compared to 61,552 cases in 2012. Of these total, 56.48% accidents has reported to occur at workplaces [2]. Construction-related accidents reported and investigated by SOCSO which in the end received compensations ranging from occupational accidents causes by caught-in between objects, over-exertion and strenuous movement, means of transport and lifting equipment and working environment.

The Malaysian construction industry in nature is fragmented, and the projects have unique characteristics and independent in so many aspects. Due to the projects' nature, sometimes it is impossible to ensure all safety policies and procedures are instituted and enforced effectively. Furthermore, most of the construction workers did not view safety as an integral part of the construction process. This can be observed where most construction companies normally employ freelance safety personnel who visit the site twice a month. Based on the limited visitation time on-site, the safety personnel does not have the time to properly and effectively identify hazards and control measures ahead of time, thus resulted in an arbitrary and incomprehensive safety analysis. The dynamic nature of construction sites may pose greater risks where construction workers may be unaware of changes in the operational conditions or ignorant of newly implemented safety strategies. Since the safety personnel are not available on-site at all times, there are many cases where the practical application of the safety regulations is left up to the construction workers, which often results in an insufficient application of mitigation measures on identified hazards on-site. This paper aims to provide information from literatures on various technologies available for construction safety and health. A traditional literature review is conducted to determine the technology applications and implementations as reported by other researchers through numerous studies.

2. CONSTRUCTION SAFETY AND TECHNOLOGY

From a construction safety perspective, the number of accidents and near-misses occurred on construction sites in the last ten years has proven that further improvements are needed in all aspects related to safety and health on construction projects. The traditional practice of safety management on-site indicates that the

construction workers may not be efficiently informed of hazardous locations and safety- related issues. Communication among construction workers and project players are undeniably crucial, especially in ensuring safety information are accurately and effectively delivered and understood.

Field construction activities such as hazard identification and risk assessment, site inspection, progress monitoring and others require access to a wealth of project information. Currently, real-time information sharing on construction safety and health are not made available industry-wide. The only health and safety indicators that are made available industry-wide are provided by regulating bodies such as DOSH and SOCSO. The indicators include statistical data on number of accidents occurred, injuries and compensation given and other basic information. However, such data is published late in the following year. Late safety-related information limits informed decision making in active construction projects. Moreover, valuable information of one construction site, such as injuries and accidents, are seldom shared with all other interest parties. Some construction companies do not even share safety-related information among its own construction projects. This practice limits a valuable learning opportunities for the construction industry as a whole.

Based on the limitation of the safety information sharing and availability, any technology that facilitates and effectively improvise all aspects of safety and health on-site are deemed to have potential benefits in improving overall construction safety management. This is due to the fact that construction industry is known for the limited use of information and communication technologies (ICT) to improve their work processes and construction safety and health management.

Many studies have been conducted on ways to enhance construction safety in various aspects in Malaysian construction industry; however, little to none is focusing on the relevant technology that can be adapted to help improvise the construction safety management system such as autonomous data requirement analysis of near-miss accidents and technological solutions to track near-miss accidents based on real-time information on construction sites. Several researchers have proposed the use of state-of-the-art ICTs, as safety and health has become one of the key responsibilities of the project management team

3. TECHNOLOGY APPLICATION IN CONSTRUCTION SAFETY AND HEALTH

3.1. 3D and 4D visualization technology

Visualization technology has been applied in many aspects of construction, such as pre-construction process, on-site operational safety issues and improving workers' communication on construction projects. During the pre-construction process, visualization technology is utilized during the design phases to assist construction team players in identifying pre-construction problems. Currently, Building Information Modelling (BIM) is a type of 3D/4D modelling that is starting to take place in pre-construction planning process. This type of modelling is used to produce, analyze and manage design and construction information including site safety planning. Zhou [3] conducted a study on the application of BIM at the early stage of construction and found that BIM-based modelling is very useful for site safety planning. This is also has been proven through another study conducted by Rwamamara [4] in three Swedish construction projects. These projects utilize 3D and 4D visualization technology through modelling at the early stages of those projects. These studies concluded that the use of such technology, in the early stages of a project, allowed the designing and developing team to identify potential risks in the construction phase. The detection of risks at an earlier stage resulted in cost-saving and minimal design changes thus, reduced the probability of having safety issues throughout the construction process.

The application of visualization technology on on-site operational safety issues is becoming common as the technology helps greatly in safety and health during construction activities. Several researchers through their studies have found that many aspects of safety and health can benefit from visualization technology. Some examples include identifying improper construction process and procedures, developed patterns of safety risks and distinguish the safety status of each aspect of construction activities based on automated monitoring system. Talmaki [5] reported that visualization technology is applied on-site to improve the safety aspects during excavation process. This is because underground utility works, especially excavation works have recorded a number of accidents, thus increase the needs to prevent accidents related to buried utilities. Other studies include the one conducted by Malassi [6] which indicates that potential on-site safety hazards can be determined through on-site workspace detection by utilizing 4D visualization technology. Additionally, on-site safety control requirement at metro areas can be fulfilled using this technology as reported by Zhou [7]. Han [8] concluded that visualization framework for site safety management could contribute to improving safety management. Visualization framework through the proposed 4D augmented reality model combined as-planned model with safety photographs in a construction project. Visualization of safety is found to be an effective communication tool to facilitate interaction between construction workers and project managers, as well as contributes valuable as-built spatial information and cognition for construction safety education and training.

Construction project nowadays are becoming more diverse, therefore effective training of foreign construction workers is found to be a growing concern. The use of technology to aid safety training and communication on-site is significant; where visualization technology has proven to be an effective tool. The utilization of 3D visualization is found to help diverse site workers to overcome the challenges of cultural and language barriers [9]. Many applications of 3D

visualization such as interactive, non-verbal simulation helps in enhancing learning among the foreign workers and can facilitate effective safety training. As mentioned earlier, most safety information is not being shared directly with on-site workers thus, outcome from accident investigations and safety inspections are not being communicated effectively to non-English speaking workers. By utilizing visualization technology, safety information and lessons learned from on-site accidents and near-misses occurred on different construction projects may be communicated and delivered to the foreign workers. For example, the elements in 3D visualization such as visual representation in general, animation and 3D interactive viewing environment helps in minimizing the amount of verbal description required to produce common understanding among the foreign construction workers.

The traditional safety training materials, techniques and programs used by contractors to train their foreign workers are mostly monotonous and not interesting enough for the construction workers. By fully utilizing BIM in safety training and programs, workers may get more valuable safety information effectively as BIM enhances communication and understanding regardless spoken language. Additionally, BIM provides the ability to demonstrate or assess workers' understanding on a sequence of operations. An example can be seen when the foreign workers who are being trained will be asked to sequence or interactively identify certain pieces of safety equipment and/or equipment heights or dimensions.

3.2. Information and communication technology system and application

The utilization of information and communication technology (ICT) in construction safety and health is slowly taking place on many construction projects around the world, but not much can be said for Malaysian Construction Industry. A communication system for construction safety has been developed by a group of researchers from The University of British Columbia as means to monitor safety on construction projects [10]. The system developed real-time safety indicators with the data transmitted from diverse construction projects. The data transmitted are stored in a centralized database which can be accessed and analyzed by on-site managers on the project or from different construction sectors. The real-time information obtained from this system is use for informed decisions in work sites. This is an alternative source to the construction industry's safety and health information platform, where all this while is only accessible from reports and statistics published by regulatory bodies.

Other applications related to the utilization of databases in construction safety include the development of web-based communication framework as proposed by Cheung [11] to manage health and safety issues in construction projects. The developed system allowed different safety stakeholders of a project to upload and download information wherever Internet access was available. Valuable information can be obtained by understanding how safety indicators vary from one project to another and from one construction type to another, in order to improve construction industry safety and health.

Many aspects of construction safety, such as on-site safety monitoring, safety training, on-site hazard identification, and safety inspections have been using the ICT application as means to improve safety management and reducing number of on-site accidents and near-misses. Lee [12] has conducted a study that developed a safety monitoring system based on ultrasonic, infrared sensors and a wireless telecommunication system at an on-site location where fall accidents often occur. This system is developed to help minimize the rate of fatal accidents on the construction site. It operates by double-checking with existing preventive measures to reduce dead zones of safety management where fatal accidents occur. Another use of ICT in construction safety is through the use of wireless internet for safety management. According to Nuntasunti [13], live videos can be used to identify potential safety hazards in a project. Several cameras are installed on the roof of adjacent buildings to better obtained images to better identify potential safety hazards. Stored images from the camera installed would permit a contractor to document the efforts made to prevent accidents and further use it to understand what did lead to an accident, should one happen.

An example of ICT application for innovative and proactive safety and health management system is studied by Riaz [14]. The system use a combination of Global Positioning Systems (GPS), smart sensors and wireless networks to track site operatives and plant, notify workers of pending danger on-site and eventually contribute to reducing accident rates at construction sites. The system helps construction personnel to learn from any experiences acquired, or mistakes made, during the construction of a project. Moreover, reports on dangerous occurrences can be generated from the system.

Improvement in safety inspections can be observed through the use of mobile ICT tools as the construction industry is now moving towards a proactive rather than a reactive approach by conducting regular health and safety audits and inspections. Besides, mobile technologies could offer a method that enables workers to report near-misses conveniently at the point of activity, which in return would amplify the number of near-misses reported. The data recorded could be automatically analyzed and the outcome may address the construction areas that are in need of improvement. According to Bowden [15], Skanska in Finland utilizes a SMS/WAP and MMS-based system to the solutions to on-site safety-related problems. The system sends problem notifications to the subcontractors who can respond via SMS when the problem is solved. This system provides fast solutions, where corrective actions that previously took several days to complete are now done in a few hours.

As the construction industry moving forward and starting to embrace the application of ICT in safety and health aspects, there is a possibility of utilizing automation

on construction site by eliminating the need of construction personnel to be in the danger area. All construction equipment and machineries can be operated autonomously without on-board drivers or personnel, with the aid of GPS.

3.3. Real-Time tracking system, rfids, automation and remote sensing technology

The development of promising information technologies, such as radio frequency identification (RFID) and wireless sensor networks has driven researchers to study their application to construction. Wu [16] proposed a real-time tracking system to monitor near-miss accidents that might have caused potential death. The system consist of ultrasonic signals for indoor and outdoor location tracking, sensors for environment surveillance such as light, noise, temperature and humidity, and RFIDs for recording on-site safety data. Besides monitoring near-misses on-site, real-time tracking system may also predict potential risk situations and possess the ability to react when the level of risk increases [17]. This system utilizes advanced communication equipment, vast sensor deployment and considerably high computational resources. Collision avoidance on-site can be prevented through the implementation of proactive, anticipatory approaches for risk identification and mitigation such as the usage of GPS and sensor technologies to monitor and record real-time positioning, vehicle tracking and collision detection during the construction process.

Worker's safety on-site is considered as an important aspect in construction safety and health. Abderrahim [18] designed a mechatronic system for the safety of construction workers, where the workers are tracked through the tags placed on the compulsory hard hat and every piece of construction equipment on-site. The information obtained from the tags is processed by a centralized server to avoid danger on construction sites. Another study that looked into workers' safety on-site was conducted by Lee [12]. This study developed a mobile sensing device for detecting workers approaching potentially dangerous areas by sending warning signals to the workers at risk. It is proposed as means of minimizing the number of possible fall-related accidents and thus, increases the efficiency of overall site safety management. Additionally, a similar system is proposed by Carbonari [19] which purpose is implementing a safety policy that triggers warning alerts as preventive measures for workers in hazardous positions. Navon [20] developed an automated model to monitor fall hazards where the model identifies and manages fall hazards among scheduled construction activities. It also determines the harmful areas associated with dangerous construction activities and presents them graphically on the project's drawings.

4. CONCLUSIONS

Technology in general has become a part of various industries worldwide, including the construction sector. This has been proven through numerous studies conducted by researchers on technology applications in various safety and health aspects, such as on-site operation and processes, safety training, safety information communication, site monitoring and control, and others. The developments of different safety systems have substantially increased the effectiveness of safety and health implementation on-site. Additionally, it is expected to enhance standard safety policies and assist inspectors and coordinators in executing their tasks. The best case scenario would be a construction company utilizes a given system in all its projects, and shares safety performance indicators of each project, with the managerial teams of all the projects.

Application of 3D/4D visualization can be an effective tool in pre-project planning by the use of BIM at the earlier stage of the project. Site safety plan can be better developed using BIM as a tool to assist in identifying potential safety problems. Moreover, the application of BIM extends to safety training, where it helps to train a diverse population if guidelines are followed to ensure that the approach in language is culturally appropriate. This approach helps construction companies increase their workers' safety awareness and reduce the number of accidents in their jobsites by using 3D/4D models to provide better safety and construction processes training.

Safety systems developed using the ICT applications and real-time information provides many benefits as well. A safety manager or project manager can be expected to understand the location of unsafe activities and practices more quickly and can inform workers of safety guidelines more effectively. It can also help project managers as well as clients and owners, who may not have specific information and knowledge about a project, with decision-making processes.

Even though the use of technology deemed to have great advantages to the construction safety and health aspects in general, not everyone agreed that these technological improvements were viable even though some companies were already looking at implementing some of the proposed systems. As with other IT applications, there will be some barriers and challengers; therefore, it is important for construction companies to identify the most suitable application that can help them to effectively implement on-site safety management and thus, reducing the number of accidents occurred. Advanced technology applications in construction safety, whilst not the total solutions, may provide construction personnel and safety practitioners with a useful means with which to monitor, record and learn from the interaction that exists between the developed model or system and the construction workers and personnel on a construction site.

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