

Rate of Occurrence of Fatal Accidents in Malaysian Construction Industry after BIM Implementation

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ABSTRACT

Construction industry impacts the health and safety of its workers tremendously. This study is aimed to determine the rate of occurrence of fatal accidents after BIM implementation in Malaysia. The data used for the research was obtained from the Department of Safety and Health (DOSH) website, and it was validated by the relevant professionals through interview. This descriptive analysis was grounded in 796 fatal accidents over the period of 2010-2018. Of those accidents, 38.16% were related to fall-related, 30.39% struck-by, 17.67% caught in-between, 9.89% drowning/asphyxiation and 3.89% others. The results indicate that the types of accidents identified are similar to that of most countries in the world. The findings also revealed that the accidents had occurred because one or combination of the following: management's failure, unsafe site conditions, workers behavior, and environmental factors. Future work will concentrate on the use of BIM-based tools for job hazard identification and safety training.

Keywords— Rate of Occurrence, Fatal Accidents, Types of Accidents, Causes of Accidents, BIM Implementation, Malaysian Construction Industry

I. INTRODUCTION

Construction industry is among the largest industries in many parts of the world [1] and was deemed the most risky sector because of the nature and complexity of the site operations [1-3]. Construction projects are also characterized as temporary and transitory [4, 5]. The workers for the job are mostly temporary employees. Workers come into contact with hazardous materials and equipment that can potentially impact their physical and safety conditions [1, 6]. It is an integral part of any nation's infrastructural development and thus results in economic growth and development that meets human needs [2, 3]. The sector is one of the main industries contributing to the Gross Domestic Product (GDP) [7]. It is known as a prominent sector that drives the Malaysian economy [8];

and typically accounts for about 3 – 5 percent of GDP a year [9]. The industry is relevant both financially and socially [10]. The industry provides jobs for around 7 percent of the world's population, but it accounts for 30 to 40 percent of the occupational fatalities [11]. It offers jobs for around 10 percent of Malaysia's total workforce [9]. While it is one of the important industries in most nations of the world in terms of GDP contribution [12]; it has long been recognized as one of the most risky sectors in many parts of the world, causing serious injuries and deaths given its importance.

Estimating construction accidents cost is very difficult because things like family's pain and suffering cannot be quantified [13]. In addition, work-related musculoskeletal conditions, which can be highly expensive in terms of cost and pain, frequently grow through months or years by repetition. Likewise, work-related diseases such as tumors or illnesses of the nervous system may not occur in the workforce for many years after exposure to asbestos, solvents or other pollutants. Construction accidents trigger numerous human casualties, lead to a lack of motivation among construction workers, interrupt construction activities, impede progress and adversely affect the industry's expense, productivity, and credibility [8]. Mason, et al. [14] discovered that the expenses of construction accidents represented 14% of the company's potential output; 8% of its tender prices in another company; and about 37% of a company's benefit in another industry. The injury rates and expense rates are higher for construction than the average for all sectors [15]. The cost of fatal accidents in US construction is estimated to be around \$5.2 billion annually [13]. On average, a construction worker's death resulted in \$4 million worth of damages. In this estimates the direct, indirect and quality of life costs are included.

Job accidents in the construction industry are common and can lead to permanent disability and high death rates [16]. This is clear from the comparable estimates of fatal and non-fatal accidents that arise in

various industries, including manufacturing. [17]. Some findings from the previous researches are briefly explained below.

In the construction sector, the risk of death is five times greater than in the manufacturing industry, while the risk of serious injury is two and a half times higher [18]. The level of debilitating accidents suffered by construction workers is approximately twice that of other industries and the death rate is nearly three times that of other industries [19]. For the construction industry, the fatal injury rate for all other sectors is higher than the national average [20]. During the last, the last 8 years around 796 construction workers in Malaysia have died or greatly injured at the workplace. That is about one construction worker's death per two working days [21]. Malaysia's construction industry reports 1.2 deaths every two working days [22]. The data was obtained from the Department of Safety and Health (DOSH), ministry of human resources, Malaysia. However, only fatal accidents were considered for the detailed

analysis in this study. The rate of deaths per 100,000 employees in the construction industry has increased at an alarming rate in Malaysia [22]. In 2014, the death rate was 7.26 for every 100,000 employees. It increased to 10.74 in 2015; it increased to 12.78 in 2016 and shot up to 14.94 per 100,000 workers in 2017. Although more attention has been given to safety management in the last decade, fatal accident rates continue to rise in the construction industry (see **Fig. 1**) compared to other industries. Accident statistics in the construction industry reveal that there is still a high rate of accidents in the construction industry in Malaysia and it gives us the idea that the industry is one of the key sectors that need a significant and fast overhaul of current site safety practices. Safety becomes very difficult when there is insufficient basic information available for mapping effective intervention, such as statistics on incidents, source of injury or death, occurrences of different types of accidents, possible causative factors and mitigation strategy.

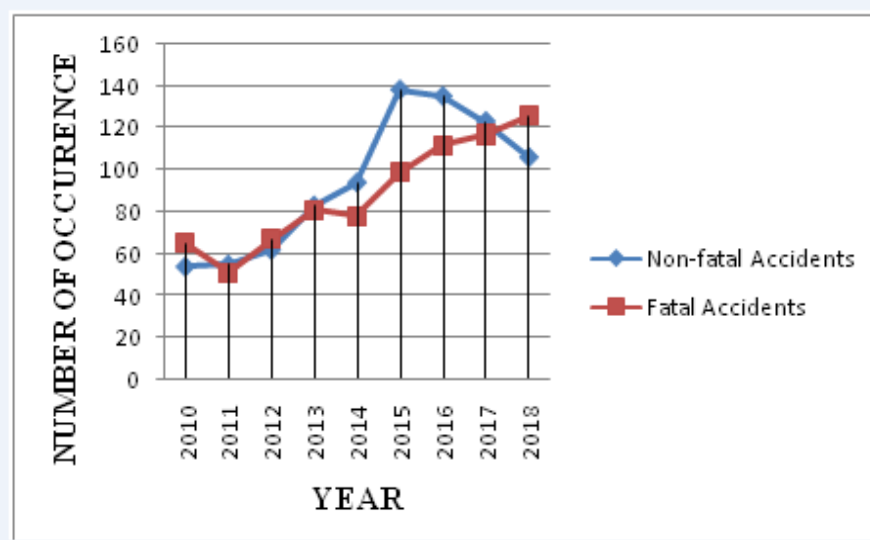


Figure 1. The reported number of fatal and non-fatal accidents in the Malaysian construction industry (2010 – 2018) [23]

Some of the reasons for the increase in fatal accidents in Malaysia are attributed to the following:

- The construction sector in Malaysia is a high-risk industry because traditional goals (cost, time and quality) are always prioritized ahead of safety [24, 25].
- Most employers don't emphasize safety because they don't know the cost of construction accidents until they happen [24].
- Lack of compliance with safety requirements has resulted in increased exposure of the workforce and the general public to a risky situation at construction sites consequently leading to a high chance of accidents [25].
- Migrant workers drive Malaysia's construction

industry [1].

- Analysis of the causes of accidents and historical data provide valuable but general information regarding safety planning [26]. These are however not sufficient to predict when and where accidents occur in unique construction projects.

Job hazard areas are generally identified by considering construction activities using two-dimensional drawings or images, project schedules, existing safety rules and experience by the relevant practitioners [27, 28]. A job hazard zone is essentially an area where potential job hazards exist and are usually caused by collisions, edges and openings, as well as temporary structures in any construction set-up [29]. This traditional method, nevertheless, lacks instinctive methodology to represent the

construction process [29, 30]. BIM-based tools are gradually replacing the traditional methods of job hazard area identification [31]. The tools can be used to imagine practical safety practices, enabling the training to be understood easily and thus improve accident prevention [30]. Visualization technology provides a visual approach to safety training, where construction operations and the environment can be clearly seen and demonstrated in a 3D manner [32, 33]. However, most of the projects undertaken using BIM technology considered only site modeling, visualization, clash analysis, asset management 4D simulation and planning in Malaysia [34-36]. The introduction and application of Building Information Modeling (BIM) technologies was seen as one of the possible solutions to the industry's ongoing problems [35, 37].

In the context of the above problems, this study is aimed to determine the rate of occurrence of fatal accidents after BIM implementation in Malaysia and those types of accidents that could have been prevented had the safety been considered in the project execution using the technology. The objective of this review and article selection was based on relevance to the research theme and area for future studies. This research was conducted by reviewing the available literature from online journals, books, and other relevant sources of data. The paper is organized as follows. The next section presents a literature review, specifically focusing on the Building Information Modeling (BIM) implementation, BIM and safety, BIM and collaboration/data sharing, main challenges of BIM implementation, and proposed solutions for the BIM challenges. The third section presents the major causes of construction accidents and their associated themes. The fourth section presents a brief description of the methodology employed for the study. And the fourth section gives a detailed analysis and explanation of the data obtained from the secondary data and interview. Finally, the last section presents the conclusion of the review and possible recommendations for future research.

II. BUILDING INFORMATION MODELING (BIM) ADOPTION AND IMPLEMENTATION

Background

BIM is a 3D model-based tool that provides data and processes for AEC experts to schedule, design, create, interact, organize, evaluate, assess, predict costs and time effectively, enhance execution processes and manage construction projects [38-43]. It can also be described as an advanced technology that can combine different varieties of construction information and players into one holistic model that can be used in all stages of a project lifecycle [44, 45]. It is also the best technology for sustainable design

and construction by reducing costs, reducing waste and errors, carbon emissions and pollution [46]. Note that BIM is not just software, it is a blend of tools and applications [47]. BIM implies utilizing 3D smart models as well as making improvements in the work and project delivery processes.

Latest technological developments have enabled the sectors of Architecture, Engineering, and Construction (AEC) to keep pace with the multidimensional real world [48]. The BIM concept was developed by Professor Charles M. Eastman in 1970 [38, 49, 50]; and AEC industries began implementing it in the mid-millennium [49-52]. In the last two decades, BIM can be found everywhere in the field of design and construction [53]. The United States of America is the first country in the world to implement BIM in the construction industry [54]. The U.S. industry became fully aware of the importance of BIM technology in the construction sector in 1997, with the first version of Industry Foundation Classes (IFC) files [50]. The idea of putting BIM into practice in Malaysia was brought in 2009 by the Director of Public Works Departments (PWD), Datuk Seri Prof. Judin Abdul Karim, who urged construction companies to adopt new technology to improve productivity and efficiency [34]. The adoption and implementation of BIM technology was seen to be the potential solutions to the problems in the industry [35, 37]. Among these problems include the safety issues usually encountered at the design and construction stage. It was also adopted to make the construction industry of the country a world-class, innovative and knowledgeable sector of global solutions [55, 56]. It can also provide an efficient, effective, flexible and innovative system while providing national productivity towards contributing to the economic growth. However, the BIM implementation in Malaysia is still at the planning and design stage; and far behind compared to the developed countries [56, 57]. Since then, it has been gaining popularity in the sector. The government of Malaysia is the biggest property holder among the country and has mandated to implement BIM for all their projects by the year 2016 [58, 59].

Looking into the previous researches, the level of BIM adoption and implementation in the construction industry is very low most especially in developing countries [34, 37, 43]; considerable attention and effort are needed to change that. In a survey conducted by Ibrahim, et al. [60], they found out that only 25.7% of the respondents were involved in BIM project while the remaining had none experience in Malaysia. The awareness of the existence of BIM technology amongst Malaysia's contractors is moderately high, but only a minority of contractors had BIM experience [61]. The pace of adoption and implementation of BIM is still slow due to legal concerns, technology capacity, user-friendliness and business structure [38, 62]. It was also found out that; the effects,

barriers, and challenges of BIM implementation in Malaysian construction projects are similar to that of other countries [37, 63]. **Table 1** below gives an overall idea of BIM implementation and adoption in Malaysia. BIM is generally adopted in the central region (i.e. Kuala Lumpur, Selangor, Negeri Sembilan, Putrajaya & Melaka) having 78%. This is due to the fast development and large scale construction projects going on in the area.

A lot of construction stakeholders in Malaysia agreed that BIM technology provides a lot of benefits such as better design, better visualization, better productivity, and better lifecycle data [61]. The first BIM project in Malaysia (UTHM multi-purpose building) have shown that

the technology improved the reliability of the roof structural connection and shortened the time frame for the installation of the roof and rework on working drawing [64]. The National Cancer Institute project demonstrated the advantages of using BIM in terms of time and cost-saving and improved work efficiency [65]. However, there are little researches to prove the advantages of BIM in the Malaysian construction industry [58]. In Malaysian circumstances, the unsettling trend prevails in which more emphasis is placed on academic research on the subject than on the real adoption of technology by the industrial players [66].

Table 1: Adoption of BIM by Region in Malaysia [61]

| S/No | Region | % of BIM Implementation and Adoption |
|------|---|--------------------------------------|
| 1 | Northern (Perlis, Kedah, Penang & Perak) | 2% |
| 2 | East Coast (Johor, Kelantan, Terengganu & Pahang) | 6% |
| 3 | Central (Selangor, Putrajaya, Melaka, N. Sembilan & KL) | 78% |
| 4 | Sabah & Sarawak | 6% |

2. BIM and Safety

Hinze and Wiegand [67] pioneered the idea of including safety within BIM technology by inspecting thirty-five design firms in the USA in order to determine whether they consider safety at the design stage or not. They found out that only one-third of those firms take safety into consideration while designing. Continuing the efforts made by those researchers, Gambatese, et al. [68] built a computer program titled, "Design for Construction Safety Toolbox." The purpose of the safety tool was to assist designers in the identification of project hazards and the implementation of design suggestions at the pre-construction stage.

A number of studies showed that BIM could be of great benefit to the AEC industry as a tool that can lead to safety by coordination, conflict prevention, progress monitoring through development, continuity in planning and simulation, data integration, cost estimates, lean building execution and increased communication between team members [34, 69]; leading to the completion of quality projects successfully [34, 43]. In addition, problems such as design conflicts, construction delays, increased construction costs, construction site incidents and disputes between construction players can be minimized through BIM implementation [34, 38, 39, 41, 51]. For example, in terms of cost reduction, data was obtained from the analysis of 32 major projects by Stanford University's Center for

Integrated Facilities Engineering and the following BIM benefits were identified: eliminating the budgeted increase by up to 40%, cost estimation precision below 3% compared to traditional methods, reducing the time required to produce a cost estimate by up to 80%, saving up to 10% of the contract value by predicting collisions, and decreasing project duration by up to 7% [70]. However, BIM experts agreed that work-specific factors such as project size and construction costs are typically less crucial than the willingness of project managers and field engineers to choose BIM projects [45]. It can also determine the virtual construction of a building or structure before its real physical development by reducing ambiguity, improving safety, identifying problems and simulating and assessing potential risks [71-74]. Moreover, BIM can be used in worker safety training, safety design, safety planning, accident investigation and safety in the facility and maintenance phase [34, 75]. Conclusively, through BIM implementation, the danger that leads to construction problems such as low productivity, low project quality can be eliminated [38, 39]. However, some of the industry practitioners perceive BIM as having little impact on safety [76].

3. BIM and Collaboration/Data Sharing

BIM technology supports the concept of incorporating project stakeholders (early collaboration), data sharing, systems, business structures, and best

practices into a single comprehensive model in order to increase productivity, efficiency, reduce waste and enhance customer-client relationships throughout the project lifecycle [34, 39, 43, 46, 64, 70, 77-82]. Based on the completed BIM projects in Malaysia; it has been found out that; application of BIM has improved collaboration and communication between construction stakeholders, minimized design changes, reduced information requests (RIRs) during construction and avoided delays in the process [35]. For BIM to be fully implemented, all parties including government institutions, agencies, consultancy firms, construction companies, and educational institutions must come and work together [41, 56, 63, 83, 84]. They must be ready to share and exchange information, expertise, and skills amongst themselves [45]. Additionally, defining the rights and responsibilities are also critical between construction players and models users [47]. According to Shang and Shen [81], project teams need to re-establish new communication channels among organizations and redefine the working pattern based on their partners' new organizational structure and function.

4. Main Challenges/Obstacles of BIM Implementation

Navendren, et al. [85] conducted a research in the UK and found out the main problems of BIM adoption and implementation from the designers' perspective to be: deployment costs, particularly for small design firms; changes to existing design methods or processes; process delays and time losses due to the creation and transfer of the BIM model to other project participants; lack of client understanding; lack of learning feedback; interoperability issues; lack of integration of the supply chain; and lack of clear national guidelines and standards. According to Criminale and Langar [86], the main obstacles for BIM implementation in the US were: time required for recruiting or training people to use BIM; cost of hiring or training people to use BIM; lack of national BIM requirements or recommendations for evaluating the use of BIM; and software interoperability [86]. Lack of BIM interest, the difficult learning curve for developing BIM skills; the current 2D drafting practices; and the lack of a pool of qualified BIM staff are the challenges faced by companies during BIM adoption and implementation in Singapore [87]. In Finland, the challenges of BIM implementation include people's resistance to change; acknowledging that BIM offers us more advantages than 2D design; managing education and training at BIM; and defining the roles and responsibilities of those involved in the construction [88]. Badrinath and Hsieh [89] identified thirty-eight Critical Success Factors (CSFs) that make BIM project successful. Out of the 38 CSFs, the most important ones were: top management support, clash detection, 3D detailing, handover and commissioning, BIM/FM integration, and energy use in Taiwan. Won, et al. [45] derived Critical Success Factors (CSFs) for implementing BIM from four

main aspects by consolidating and prioritizing scattered success factors. Of the 10 CSFs, the most important factor was the willingness to share data among project participants in an organization. And in China, the challenges for the adoption and implementation of BIM are insufficient financial resources; poor building design performance; lack of national BIM standard; and novice workers [90]. Similarly, in Malaysia according to the previous researches the obstacles are as follows: insufficient expertise and skills due to lack of technical support [37, 40, 41, 43, 56, 74, 83, 91]; training costs and the learning curve are too expensive [41, 62, 73, 92]; lack of enforcement from the client (guidance and support from government) [41, 56, 83]; organizational behaviours [41, 56, 60, 62, 65, 73, 84, 92]; technology is very expensive especially to small-medium companies [41, 62, 73, 83, 84, 92]; time taken and a lot of effort to learn and master new software [41, 60, 62, 65]; lack of knowledge or understanding what BIM can actually do within various professional disciplines [37, 40, 41, 43, 91, 92]; traditional processes [41, 65, 92]; lack of confidence among new software applications [41, 73]; absence of national standards or guidelines for BIM to evaluate the use of BIM [83]; unavailability of the parametric library are major barriers to low levels of BIM implementation [37, 40, 43, 91]; interoperability issues [43, 62]; and legal issues [60, 62]. According to Construction Industry Development Board (CIDB), Malaysia report on BIM; the findings indicate a widespread awareness of this tool across the country [61]. However, the problems that stop the immediate implementation and adoption of BIM are high cost of technology; high training cost; lack of BIM knowledge; and insufficient BIM training. It is practically impossible to identify the most important factor for the success of the BIM project [89]. A different set of these variables were shown to be critical to the success of BIM projects at various stages of the life cycle.

5. Proposed Solutions for BIM Implementation

For a company to adopt and implement BIM technology, it requires a large initial investment for software and hardware purchasing and staff training [93]. According to Ramilo, et al. [79], the largest architectural companies have fewer obstacles to implement BIM than smaller architectural firms. Similarly in Malaysia, small firms/company are not willing to use BIM technology because of lack of skills and expertise and they need a considerable amount of money to buy BIM-based tools [34, 93]. Technical challenges that occur for some organizations based on their size, as not all companies can afford to invest in new technology, especially for small and medium-sized businesses relative to larger organizations [65, 74, 86, 87, 91]. Fund from either government or other sources has been identified as one of the driving forces for the successful implementation of BIM where it can help AEC companies cover the costs of training, consultancy services, and

purchase of software and hardware [37, 40, 41, 60]. With the encouragement and support from the government and top management, the implementation of BIM in construction projects would definitely increase [37, 41, 64, 88, 89].

There is few or no formal framework for clear guidance on the BIM implementation [37, 94, 95] because each company develops or produces its own standard or guidelines [37]. This can cause conflict and misunderstanding between the construction players [50]. The government needs to provide comprehensive and flexible guidelines or standards for BIM implementation to suit their own project requirements [37, 40, 60]. For instance countries such as the UK, Australia, Hong Kong and Singapore have implemented the use of BIM in their construction industries through their governments [56]. Enforcement by the government would be an important approach to help to increase the interest of AEC industries towards BIM implementation in Malaysia [57]. To encourage construction players to implement BIM, it must be placed as one of the conditions in the contract tender documentation [64]. For example, it is now mandated that any government contract worth RM 100 million and above must use BIM for its execution in Malaysia [91].

Lack of training is one of the main obstacles to reaching a satisfactory level of application in BIM [93]. A large number of construction companies believe that efficiency will suffer when implementing BIM because the BIM-based tools are hard to learn and the process developed will be disturbed [95]. However, education is a critical factor in the success of implementing new technologies [96, 97]. Malaysia or any developing country can learn from successful practices (countries like UK, US, France, Germany, Switzerland, India, and Scandinavian region) to increase their knowledge about BIM implementation [98]. There is a need for better training materials and technical support, strategies for lowering BIM trainees' learning curve [94]. Organizations must also provide their workers or staff with training in order to educate them about the technology [43, 65]. Frequent seminars and workshops with affordable fees can encourage the active participation of construction professionals and awareness [60]. Moreover, the provision of trial BIM-based tools and the inclusion of BIM in higher institutions curricula could be very effective strategies to enhance its application [43]. BIM exposure to undergraduate and postgraduate students in schools can provide an excellent driving force in educating and raising awareness about the importance and its application [60]. However, the learning process requires time and training which entails additional costs for the organizations concerned [65].

The legal perspective should not be disregarded in order to minimize conflicts that may arise as a result of technological advancement in the contract document in

advance [40, 60, 62]. BIM implementation teams should be very cautious about legal risks, including information rights and associated privacy concerns and risk-sharing [70]. BIM ownership must be secured by copyright laws and other legal means in order to ensure the protection of information and the gain of the owner [77, 93, 97]. This is because poor security also decreases the effectiveness of remote interaction, information sharing and undermines stakeholder trust [42].

Organizational conduct is the analysis of success and behaviors within an organization, both collective and individual. The organizational problems include readiness of people to accept change within the organization [56, 84, 88, 99]; staff's productivity, and knowledge sharing [62]. Questions more often asked by construction players are: whether there are documented successful software application BIM cases, potential economic effects (return on investment) and whether large subcontractors or business partners are actually using the software application [45]. They also assume the contract terms are modified to implement 3D or BIM models and this will impact competitive bids [93]. Some construction players felt doubt and fear that BIM would fail in Malaysia like the failure in the construction project to fully implement the Industrial Building System (IBS) [37]. The opposite of the aforementioned problems will solve organizational issues regarding BIM implementation.

One of the factors that hinder the widespread use of BIM is the complexity of BIM software [100]. Lack of interoperability in software meant that potential project team members using different BIM-based tools might not want to work together [38, 43, 93]. Less complex technology is more favorable and easier to adopt and implement. Information cannot be transferred effectively with poor interoperability. Interoperability issues has to be solved in order for BIM implementation to progress with fewer difficulties [86].

III. MAJOR CAUSES OF CONSTRUCTION ACCIDENTS

1. Contributory Factors

Construction accidents tend to occur as a result of a combination of different factors and one or more unsafe actions and unsafe conditions [4, 24, 101-103]. Most accidents resulted from a mixture of management's failure to implement adequate safety measures to protect workers from potential workplace hazards; and the various unsafe acts committed by the workers [101, 104]. These generic factors are explained below in detail in accordance with a country's peculiarity. The literature suggests that accidents are caused by a broad range of factors, some of which include faulty machinery, conditions in the workplace,

unique nature of the industry, improper practice, the human element and management.

According to the previous researches, the root causes of construction accidents in Malaysia are as follows: workers' factors [24, 25, 103, 105, 106]; management factors [25, 103, 105, 106]; unsafe site conditions [24, 105, 106]; environmental factors [105]; and uniqueness of the industry [105]. Workers' factors and management failure are the main causes of fatal accidents in Singapore [107]. The human element is the major contributing factor causing injuries and fatal accidents in Thailand [108, 109]. In addition to that aforementioned problem, management failure; unsafe site conditions; and the unique nature of the industry are also responsible for any accidents in Thailand [109]. In the UK, the major factors responsible for occupational accidents were found to be: human elements; unsafe site conditions; nature or condition of materials used; and lack of knowledge in risk management [110]. In another research, it was found that the contributory factors are: project type; construction method; site restrictions, duration of the project; design problem, subletting work to another company; procurement method; and construction level [111]. Kartam, et al. [112] conducted a study and found out that the causes of accidents were caused by human elements; poor housekeeping; fate; use of faulty tools; management failure; and objects misplacements in Kuwait. And according to Kartam and Bouz [113], workers' factors; management issues; unsafe site conditions and uniqueness of the industry are main the contributing factors causing construction accidents. Employees' factors, management factors; unsafe site conditions; physical factors; and uniqueness of the industry are the contributing factors causing injuries and fatal accidents in the US [114, 115]. It also suggested that the shortage of fall arrest systems lack of occupational training and lack of personal protective equipment are the root causes of construction injuries in the US [116]. Lubega, et al. [117] found out that the causes of accidents were mainly due to workers factors; management failure; physical and emotional stress; lack of professionalism; chemical defects; and lawlessness in Uganda. In China the causes contributing to injuries and fatal accidents were found to be: human factors; management failure; unsafe site conditions; lack of security in material transport; lack of material storage safety; lack of spirit of teamwork; lack of innovative technology; and inadequate flow of information [118]. Poor communication and collaboration between employees and management are also the causes of construction accidents [119-121]. According to Ahmed, et al. [122] in Bangladesh, the key causes of accidents based on overall consideration were: human and management factor. The human factor is considered the main contributing cause of construction injuries and fatal accidents in Bhutan [123]. The root causes of construction injuries and fatal accidents in Taiwan are

human factor; management failure; unsafe working conditions; unsafe acts; type of project; and company size [101, 124]. Moreover, accident type; injurious contact with structures and construction facilities [101]; source of an accident; accident location; and project legal authority are also factors responsible for accidents in Taiwan [124]. The key causes of construction injuries and fatal accidents in Spain were: human and management factors [102, 125]. The frequency of injuries was correlated with variables like gender, national code, company size, length of service, incident site, day of the week, absence days, divergence, injury and climatic zones [125]. According to Dinges [126], drugs and alcohol are the root causes or contributing factors of many accidents on the job every year. The language barrier is another factor that can cause accidents in construction sites [110]. This is because most of the construction workers are often foreigners that neither speak the local language nor understand it. Jannadi and Al-Isa [127] reported that poor housekeeping causes serious impacts such as waste of time, resources and materials, and increases fire hazards and accidents.

Based on the previous studies the workers' factors include the following: rushing to complete the work [107]; unsafe action of another person(s); boisterous play among the workers; operating machines at unacceptable speed; fixing machine or equipment while in motion; work while at unsafe position or posture [114]; physical and emotional stress [117]; use of hazardous methods or procedure [101, 124]; failure to adhere with the safe use of materials, tools, vehicles, and machines [12, 24, 25, 101, 103, 105, 106, 113-115, 117, 118, 124, 128]; workers' safety mindset [12, 24, 25, 103, 105, 106, 115, 117, 128]; lack of knowledge about safety and skill for the job [24, 25, 101, 103, 105-107, 114, 117, 118, 122]; carelessness; failure to comply with work and safety procedures; [24, 25, 101, 103, 105-108, 114, 118]; and failure to wear personal protective equipment (PPE) [12, 24, 25, 101, 103, 105-108, 114, 115, 118, 122, 123, 128]. It was also reported that the factors associated with employees include the following: failure to alert and warn; operating equipment or machine without qualification or authorization [25, 103, 105, 106, 114]; individual behavior; and other countless unsafe actions [12, 114, 115, 128].

And the management issues include: lack of technical guidance; lack of competent project managers; lack of safety management manuals; inadequate of first aid measures [118]; lack of management commitment [122]; lack of stringent operating procedures; lack of safety awareness from the top management [118, 122]; financial constraints [25, 103, 105, 106, 118]; employment of unskilled personnel [25, 103, 105, 106, 117, 118, 122]; not providing the required PPE for the job; loud and excessive noise at work place; weak method for quality control; team behavior; tradition of the industry [25, 103, 105, 106]; work

overload and improper assignment distribution to personnel [25, 103, 105, 106, 114, 118]; provision of unsafe/defective/faulty tools, vehicles and machines; negligence; lack of pre-construction safety planning [12, 25, 103, 105, 106, 128]; lack of safety training [12, 25, 103, 105, 106, 117, 118, 122, 128]; lack of safety regulations and enforcement [12, 25, 103, 105, 106, 117, 118, 128]; poor management of the site [12, 25, 103, 105-107, 118, 128]; incorrect or no work procedures (unsafe methods) [12, 25, 103, 105, 106, 114, 128]; and management system inability to predict potential hazards [12, 115, 128, 129].

Also known as physical factors, unsafe site conditions are as follows: faulty tools, equipment or supplies; insufficient supports or guards; congestion in the workplace; insufficient warning systems; apparel hazard; fire and explosion hazards; bad housekeeping; dangerous atmospheric conditions; public danger; and other unsafe conditions [24, 101, 105, 106, 114, 124]. Environmental factors, such as temperature, seasonal change, environmental conditions and construction environment significantly affect the safety efficiency of construction sites by modifying the workplace environment and workers' conditions [12, 105, 128, 130].

2. Proposed Prevention Measures

The causes of injuries and the reduction of on-site hazards are extremely important considering the impact of workplace safety and health in the construction sector. A large number of the accidents could have been prevented in Malaysia if there was comprehensive safety, adequate and proper use of PPE, and regular supervision of workers while at work. Workers apply the same approach to a new project even if the project's scope is entirely different from the previous one [131]. Employees should be given appropriate and proper safety training according to the purpose of a project because of the uniqueness of the industry. Prior to starting any project, proper and detailed inspections of materials and vehicles are essential. New employees should be familiarized with the workplace because they commence any work. This is because about 50% of fatal accidents happened within a month after employment [17]. Depending on the scope of the job, the workers should be provided with the appropriate type of equipment and protective clothing to maintain effective safety standards directly on-site [132].

The first move in preventing and mitigating construction accidents and their effects is to identify the main factors responsible for them [125]. Most of the occupational accidents are preventable, however, the unavoidable ones must be expected and planned to lessen their effects. Based on the reviewed literature the proposed solutions to tackle the safety management issues in the industry are extracted and explained below.

To reduce the overall rate of workplace accidents, it is important to implement effectively the necessary health

and safety practices and training to ensure that all workers recognize and comply with these requirements when working [101, 133, 134]. Safety training should be provided to the employees using the best possible ways they can understand before the commencement of the project, for instance, BIM-based tools. Workers are required to be trained before using any type of equipment or machine in the construction sites, and they should be inspected and tested by a qualified person before work commences and periodically for maintenance. Experienced workers should take care and guide the novice ones.

As for the management factors, the proffered solutions for the aforementioned factors include the following: provision of able and adequate on-site supervision will lessen the occurrence of construction accidents; giving the required holidays and occasionally organizing get together for the workers can reduce physical and emotional stress; safety rules and regulations should be enforced on the workers; provision and enforcement of workers to wear their PPE while at work; provision of warning sites at the potential hazard places on-site; provision of safe working procedures (methods) for the workers; employment of competent personnel for the job; provision of safety management manual to the workers; standard quality control should be in place; first aid measures should be provided in the working place; provision of stringent operating procedures; personnel should be assigned to the jobs they are trained to do; appointment of occupational health-and-safety personnel. Safety should be included in the planning and scheduling stage of the project by budgeting for the training and other safety management problems that may arise.

In terms of unsafe working conditions, it is still the sole responsibility of the top management to provide a safe working environment for the workers; the required PPE; and safe/usable tools, vehicles, and machines. Proper use, storage, cleanup, and disposal of the construction materials can reduce the probability of accident occurrence on the sites. The Environmental Impact Assessment (EIA) would evaluate the potential environmental consequences of a proposed project or plan, taking into account the socio-economic, cultural and human health impacts [135].

IV. METHODOLOGY EMPLOYED FOR THE STUDY

The data for this study was obtained directly from the Department of Safety and Health (DOSH) website with further clarification from some of the experienced workers. Specifically, the DOSH data from 2010 – 2018 were examined in regard to only fatal fall-related accidents. 2010 was chosen as the reference point because BIM was first adopted and implemented in Malaysia in the year 2009. Historical accident analysis can provide useful information

about the most serious accidents, their origins and their causes [136]. The current study conducted an in-depth analysis of about 796 occupational fatalities in Malaysia with the view of finding the causes, trade workers involved and other important relevant variables. The data retrieved was evaluated using univariate analysis. For each fatality report, all the available and important factors were classified into relevant categories for further analysis. To ease the comprehension of the subject matter, the findings were explained and described in tables and figures. Also, the identified and analyzed data was explained and compared with the results from the past literature.

V. DATA ANALYSIS AND DISCUSSION OF THE RESULTS OBTAINED

1. General Overview

To minimize the impact of construction incidents we need to know how the main types of accidents can be mitigated or prevented that cause the deaths and serious injuries in the industry. Any kind of accident, whatever the extent of the damage or loss, should be of concern [106]. The main types of accidents in the construction industry are: falling from a height, being struck by falling objects, electrocution and being caught-in-between [137]. Falling from height is considered the type of construction accident with the most occurrences compared with the other types followed by automobile crashes, being struck by the falling objects, caught-in-between stationary or moving objects and electric shock accident [6]. Falls, electrocutions, being struck by objects and being caught-in-between hazards are nicknamed the OSHA's "*Fatal Four*" [138]. 63.7% of all construction site deaths were caused by one of OSHA's Fatal Four in 2016. These are the types of accidents that plague most of the construction industries in the countries of the world as shown in **Table 8**.

Hinze and Russell conducted a study in the US based on the Occupational Safety and Health Administration (OSHA) fatalities data of 1980, 1985 and 1990 [139]. They found out that fall-related, struck-by, electrocution and caught-in-between are the major types of accidents in order of occurrence. Having analyzed OSHA fatality data from 1985 to 1989, similar types of accidents plaguing the US construction industry in the same order of occurrence as the aforementioned researchers were found [20]. The analyzed fatality data reported to OSHA for 1994 – 1995 had the same results as the aforementioned

researchers [140]. Falls and struck by falling objects have been the major types of accidents that cause the highest injuries and fatalities in the U.S. construction industry [141]. Ballowe [142] analyzed fatality data reported to OSHA for 2000 – 2004 and found out that the highest percentage of types of incidents was falls, followed by struck-by's, caught-in-between's, electric shocks, and others. In the UK, the types of accidents that mostly occur are fall-related hazards and being struck by a moving/falling object [110]. The common most reported types of accidents in Korea are fall from height, struck-by, caught-in-between accidents, structural collapse, and motor vehicle accidents [17]. The three most serious types of accidents in Thailand were employees who were killed by falling objects, striking against objects and falling from height [109].

In Malaysia, fatal occupational injuries are mostly caused by falling from high structures while working, being struck-by construction materials, tools, machines or vehicles [25, 143, 144], and being buried [144]. According to the Director of the State Department of Occupational Safety and Health (OSHD), the most reported cases of the types of accidents in the Malaysian construction industry are falling from height and being hit by a falling object [145]. According to Hamid, et al. [105], falls and structural failure (collapse) are the most common types contributing to fatal accidents. The most frequent types of accidents on the construction site are: falling from a height, stepping on the object and struck by falling object in Malaysia [1].

The accidents extracted were fatality and non-fatality cases for which DOSH inspections were conducted, however, emphasis was given only on the fatality cases. And according to this study, having analyzed and evaluated 796 reported fatal accidents obtained from DOSH; the most common types of accidents in Malaysian construction industry were found to be: fall-related accidents (FREDAs), struck-by accidents, caught-in-between accidents, drowning & asphyxiation, electrocution, exposure to hazardous substance and fire & explosion in order of occurrence (see to **Fig. 2**). The study offers an overview of the probable causes of Malaysia's construction accidents. Based on its outcomes, industry and government organizations in Malaysia will continue to provide the construction workers with adequate approaches and preparation. However, during the study and assessment of the reported cases, different cases were found where vital information was not provided.

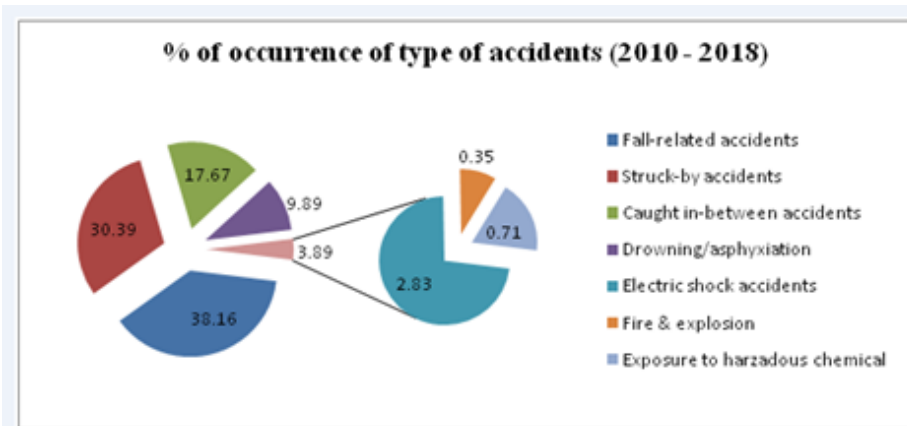


Figure 2. Percentage of occurrence of accident types in Malaysia (2010 – 2018)

Of about 303 reported fatal accidents analyzed, it was found that the highest number of fall-related accidents occurred in Johor, Penang, and Kuala Lumpur with 30.56%, 19.44%, and 18.52% respectively; while Perak has the least occurrence with 0.92% (see **Table 2**). The states that had the maximum number of struck-by accidents are Johor and Kuala Lumpur with 24.42% each followed by Penang 17.44% out of the 242 reported cases that were analyzed. In the caught-in-between accidents category, it was found out that the highest number of hazards happened in Johor, Penang, and Kuala Lumpur with 40%, 20%, and 16% respectively; while N. Sembilan, Perak, and Terengganu had the least percentage with 2% each out of the 141 cases reported to DOSH. The states in which drowning and asphyxiation occurred the most are Sabah & Sarawak with 21.43%, Johor, Pahang, and Penang with 17.86% each and Kuala Lumpur with 14.29% of the 79 cases analyzed. Of the 22 cases analyzed for electrocution occurred in Sabah & Sarawak, Johor and Kuala Lumpur with 50%, 37.5% and 12.5% respectively. Out of the whole, reported cases analyzed the exposure to chemical substance occurred only

in Johor with only 0.71%; while that of fire and explosion happened only in Johor and Kuala Lumpur with 0.35%.

The reason for the high number of accidents in Johor is because it borders Singapore directly and a lot of construction activities take place in the area. The highest number of serious injuries or fatalities in Johor was because of the emergence of high-rise buildings and the construction of new infrastructural development in the state [144]. Additionally, there are over six hundred (600) registered and active construction companies in the state. Johor is partly responsible for the stable economic development of about 12% in the construction sector. The reasons for the high number of accidents in Penang are almost similar to that of Johor. The reasons for the high occurrence of accidents in Kuala Lumpur (1) because it is the capital city (2) construction of new megastructures in the city (3) a lot of infrastructural development (4) and rural-urban migration in search of greener pasture. States like Kedah, Kelantan, Malacca, N. Sembilan, Perak, Perlis, Selangor and Terengganu had the least percentage of accidents occurrence in Malaysia because of the rate of construction activities in those places were low.

Table 2: Percentage of occurrence of accident types across Malaysian states and federal territories (2010 – 2018)

| States & Federal Territories | % of occurrence of accident type | | | | | | |
|------------------------------|----------------------------------|---------------------|-----------------------------|-----------------------|----------------|--------------------------------|------------------|
| | Fall-related accidents | Struck-by accidents | Caught in-between accidents | Drowning/asphyxiation | Electric shock | Exposure to chemical substance | Fire & explosion |
| Johor | 30.56 | 24.42 | 40 | 17.86 | 37.5 | 100 | 50 |
| Kedah | 3.70 | 1.16 | 4 | | | | |
| Kelantan | | 1.16 | | 3.57 | | | |
| Pahang | 6.48 | 8.14 | 6 | 17.86 | | | |
| Malacca | 1.85 | 6.98 | 6 | | | | |
| N. Sembilan | | 1.16 | 2 | | | | |
| Perak | 0.92 | 2.33 | 2 | 3.57 | | | |
| Perlis | 2.78 | | 2 | 3.57 | | | |
| Penang | 19.44 | 17.44 | 20 | 17.86 | | | |

| | | | | | | | |
|-------------------------|------------|------------|------------|------------|------------|------------|------------|
| Sabah & Sarawak | 11.11 | 5.81 | 12 | 21.43 | 50 | | |
| Selangor | 3.70 | 5.81 | 8 | | | | |
| Terengganu | 0.93 | 1.16 | 2 | | | | |
| Kuala Lumpur, Putrajaya | 18.52 | 24.42 | 16 | 14.29 | 12.5 | | 50 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

2. Fall-Related Accidents (FREDA)

Fall-related accidents (FREDAs) are the most common type of fatal accidents in many countries worldwide, such as the United States [139-142, 146], China [118], the United Kingdom [110], Spain [102], Korea [17], Singapore [107], Taiwan [101, 124, 147], and Malaysia [1, 25, 105, 143] is not exempted (see **Table 8**). FREDA is the major cause of several severe injuries and deaths in the construction sector [17, 22, 128, 148-151]. It is also considered the most occurring type of construction accident compared to the other types [6, 95, 141]. Falls from structures are the most hazardous forms of construction injuries attributable to wind speed structural height, risky activities and the actions of the workers [4, 152]. Rozenfeld, et al. [153] analyzed about 700 accidents in construction and found that the most persistent type of incident is FREDA. Out of the total, about 10,400 (40 percent) construction workers who died in the US between 1993 and 2013 were FREDAs [154]. More than 3120 of the cases reported were attributed to insufficient, disabled or unsuitable use of fall protection equipment [141]. Most of the reported cases happened not far from the ground, as employees often ignore safety precautions when operating at low levels because they feel it is less likely to slip from that height [16, 95, 141]. Haron [95] found that 75% of the roofing falls occurred at elevations below 9.15 meters and 45% at 6.10 meters. The mean height at which the fall originated and fall distances are 10.8 and 10.64 meters respectively [141]. Therefore low-level jobs should not be overlooked for safety precautions and be given the same gravity for all other cases as other works at height.

The most common injuries caused by FREDA include fractures, trauma, contusions, concussions, bruises and abrasions [137, 141]. After a physical injury which in some situations has had a direct influence on a worker's body, a psychiatric illness can also occur due to the loss of a job opportunity or permanent disability [155]. Head injuries account for approximately one-fourth of all incidents and multiple injuries [141].

New and advanced safety training approaches should be considered, as traditional methods may not be sufficient to enable employees to recognize and eliminate all risks associated with falling [95]. For instance, some studies have shown that BIM-based tools can be used to minimize accidents in the case of a fall. Zhang, et al. [156]

created a tool that can identify unprotected edges of slabs and openings, and install the guardrail system automatically. However, the limitation of this study is lack of robust BIM-modeled fall hazard control and limited only to guardrail systems and scaffolding. Qi, et al. [157] have also built a framework where developers can use it for automatic accident-related safety checks utilizing BIM-based software and a knowledge base based on best practices.

A. Causes of FREDA

The contributing factors for FREDAs include lack of safety training [16, 95, 141], human error, and inappropriate use of controls [141]. Insufficient use of PPE fall protection and inoperable safety equipment contributed to FREDA [16, 95, 101, 134, 158, 159]. There are several factors that cause FREDA, namely: risky activities, individual characteristics, place, management and environmental conditions [137]. They are also due to a lack of awareness about potentially hazardous conditions [101, 134, 160]; worker unfamiliarity with the work environment; insufficient employer monitoring; and unsafe acts [101, 134]. In addition, they occur as a result of workers working at a high elevation without adequate safety management measures in place [22, 101, 134, 160]; falling objects, accidents caused by lifting or using mobile or tower cranes, failures in scaffolding and failures in the work platform [22]. Worker misjudgment might account for roughly one-third of construction workers' falls [95]. Inadequate lighting on the night shifts can also impact the visibility of the surrounding area and ultimately trigger falls to a site that runs 24/7 [161]. Pressure on the workers from their site supervisors to speed up work on site, especially in the afternoon, causes FREDA [162]. The job complexity which distracts workers' attention while working at significant heights could also be a major cause of FREDAs [163].

Furthermore, off the roof, collapse of the scaffolding, scaffolding, collapse of the structure, opening of the floor, off the ladder, opening of the roof, off the edge of the open floor and off the beam support are the most common causes of falls [139]. 45% (about 229 fatalities) occurred as a result of the first five aforementioned causes while about 345 fatalities happened because of all causes. According to Chi, et al. [12], a lack of compliance with the scaffolds and unguarded openings are the main causes of catastrophic fall. Problems with scaffolding are lack of

work platform, lack of suitable scaffolding for the job and lack of fixed barrier for the scaffold. Scaffolds can be very hazardous when used or improperly installed [6, 164]. Ladders, scaffolds are the primary agents for fatal fall accidents [16, 148-150, 165-168]; and falls off the structure [148, 149]. It has also been discovered that extensive work on defective scaffolds or ladders is one of the sources of FREDAs [167]. Falls can also occur as a result of breakdown of a support system, slipping through an unknown or exposed opening, and being struck by an object [139].

It was discovered that about 65.74 percent of the fall-related accidents occurred due to slip / trip due to lack of PPE / unsafe work environment while the 34.26 percent are attributed to scaffold / platform / landslide / structural collapse. The causes that triggered FREDA in Malaysia were found to be: natural cause; no safe site and maintenance job procedures; no guardrails and warning signs for most of the cases reported by FREDA; inability to use and improper use of PPE, dangerous working platforms when operating at high altitude; no monitoring of work at height; structural collapse; inability to carry out risk analysis of the scaffolding dismantling procedure; fencing not mounted on the scaffold to avoid falling; communication gap between workers; lack of safety training; and scaffolding installations were not according to standard.

B. Trade Workers

It can be seen in **Table 3** that construction

Table 3: Trade work for FREDA in Malaysia (2010 – 2018)

| Trade work name | % of occurrence |
|---|-----------------|
| Helper | 28.70 |
| Carpentry works | 25.93 |
| Mason/bricklaying | 11.10 |
| Scaffolding | 9.26 |
| Housekeeping/maintenance works | 9.26 |
| Non-construction worker or civilian | 5.56 |
| Electrician | 4.63 |
| Other (painting, drilling works for installing explosive, tiling, welding & iron bending) | 5.56 |
| Total | 100 |

C. Monthly Distribution for FREDA

The months (see **Fig. 3**) in which FREDA happened more were 12.9 and 13 per cent respectively in March and November. And May with 3.7 percent is the month with the least incidence. This could be because there

laborers, were the most endangered trade workers affected by FREDA with the highest percentage with 28.7%; followed by carpenters with 25.93%; followed by Mason with 11.1%, and scaffolders with 9.26%. These findings are backed by the following previous researches. It has been found that laborers, scaffolders, and electricians are the most endangered professions of the dead employees for FREDA [16]. Falls are often connected to employees on the roofs, scaffolds, ladders and opening floors [95]. According to Im, et al. [17], the trade workers most affected by falls are painters, scaffolders and plasterers. The occupations of most injured workers by FREDA are construction laborers, roofers, carpenters, structural metal workers, painters, brick masons and stonemasons, electricians, supervisors, drywall installers, plumbers, and pipefitters [141]. It was clear that falls were a primary cause of serious injuries or deaths for carpenters, welders, drywall installers, elevators repair workers, masons, sheet metal workers, painters, roofers, and steelworkers [96]. Workers with no experience and those that work for small companies have been identified to be at the highest risk of fall-related accidents [12]. Most of the reported FREDAs happened at the edge with 82.41 percent, while the remaining portion occurred at the openings. These could be as a result of operating on dangerous walkways; near the edges or openings of an unsuitable guardrail structure; unguarded stairs; uneven or sloping surfaces; and skylights [128, 137, 152]. Falls can also occur in ground level holes, such as trenches or service pits [151].

were less construction activities during festival celebrations. There was, however, no detailed information to provide the explanations for the higher frequency in the months described above.

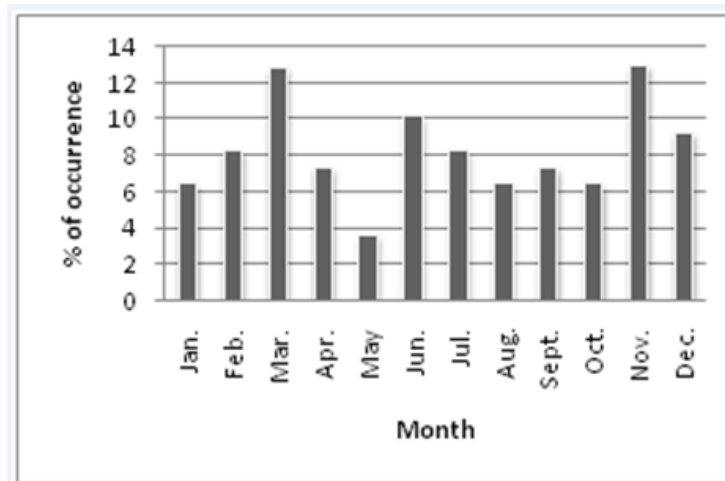


Figure 3. Percentage of occurrence of FREDAs by month in Malaysia (2010 – 2018)

3. Struck-by Accidents

Of the fatal four hazards, struck-by hazards are the second highest cause of fatalities among construction workers after FREDA [138, 169] (see **Table 8**). This corresponds to this research finding. It accounted for 30.39% of the analyzed data in this research. Struck-by accidents occur when a worker encounters a moving, dropping, spinning or rolling object or material forcibly [24, 138]. Struck-by accidents also mainly include construction workers or civilians being hit by equipment, vehicles other than construction machines, falling materials, vertically lifted materials, materials transported at 180 degrees and trench cave-ins [146]. Struck-by-equipment and struck-by-falling-object account respectively for 58% and 42% [169]. Struck-by-falling-object accidents are not given adequate consideration [170]. Efforts to curb struck-by accidents should be based on equipment-related activities, whereas in other cases the initiative should be aimed at preventing falling objects [96].

Previous researches have demonstrated that BIM-based tools can be used to minimize the effect of struck-by accidents on construction sites. Wu, et al. [170] built an innovative approach for the preventive avoidance of struck-by-falling-object accidents on construction sites. The model was designed in such a way that all the system components are unified in ZigBee RFID sensor network architecture in order to know the real-time location information of both workers and materials or objects in the workplace. This research would provide a possible approach to monitoring struck-by-falling-object injuries on the basis of constructive avoidance in real-time information which could serve as a basis for further analysis.

A. Causes of Struck-by Accidents

This type of incident may be due to lack of scaffolding toe boards, lack of workers' tool belts, poor storage and stacking, and poor housekeeping [24]. Misjudgment of a dangerous situation was the most common human factor contributing to struck-by accidents, responsible for 35.8% of all incidents [146]. The risky operation in which struck-by accidents occurred the most was hoisting [146, 170]. The main three agents of struck-by accidents include structural elements, large mechanical machinery, and pipe [170]. Struck-by equipment accidents were classified as those in which the equipment moved at least 8 km / h (5 mph) [96]. Nevertheless, if the machinery was rolled over a person, it was decided that the sort of incident would be a caught-in-between accident, regardless of speed. The most common types of equipment involved in struck-by accidents are: truck (39.4%), private vehicle (11.5%), backhoe/excavator (12.5%), crane (9.5%) and loader (6%) [146].

Struck-by construction materials/objects and machines are the most frequent causes of serious injuries or deaths with 55.81 and 36.05% respectively in Malaysia (see **Table 4**). Some of the causes to have geared the struck-by accidents in Malaysia were identified as follows: lack of PPE for the workers, lack of engineering controls, machines not well inspected before usage, no safe working procedure for lifting works, failure of the crane's operator to read load chart, failure to comply with mobile crane standard procedure for lifting works, no safety procedures for that are susceptible to collapse (failure of structure), no fence or barrier to prevent the general public from entering the premises of the construction sites, drunken personnel, and environmental factors.

Table 4: Cause of death/serious injury for struck-by accidents (2010 – 2018)

| Trade work name | % of occurrence |
|--|-----------------|
| Struck-by construction material/object/permanent & temporary structure | 55.81 |
| Struck-by a construction machine/truck/lorry | 36.05 |
| Struck by private vehicle | 5.81 |
| Natural cause (i.e. struck by lightning) | 2.33 |
| Total | 100 |

B. Trade Workers

Crafts linked to the operations of heavy equipment are more commonly involved in accidents of being struck [108]. Most non-qualified operators are sustaining injuries due to inadequate equipment handling [110]. This is because they cannot evaluate a situation and react accordingly. Trade workers most affected by struck-by

accidents include concrete placers, finishers, plumbers, and construction machinery fitters, operators and mechanics [17]. It was found that construction laborers are the most common trade workers exposed to this type of incident with 45.35%, followed by machine operators with 11.63% and mason with 9.30% (see **Table 5**).

Table 5: Trade work for struck-by accidents (2010 – 2018)

| Trade work name | % of occurrence |
|---|-----------------|
| Helper | 45.35 |
| Machine operator | 11.63 |
| Mason/bricklaying | 9.30 |
| Carpentry works | 6.97 |
| Housekeeping/ maintenance works | 6.97 |
| Non-construction worker or civilian | 5.8.1 |
| Scaffolding | 3.48 |
| Other (painting, drilling works for installing explosive, tiling, welding & iron bending) | 10.47 |
| Total | 100 |

C. Monthly Distribution of Struck-By Accidents

The months (see to **Fig. 4**) in which struck-by accidents had occurred the most are June and July with 12 and 14% respectively. And the month with the least

occurrence is January with 4%. However, there was no detail information to provide the reasons for the higher occurrence in the above-stated months.

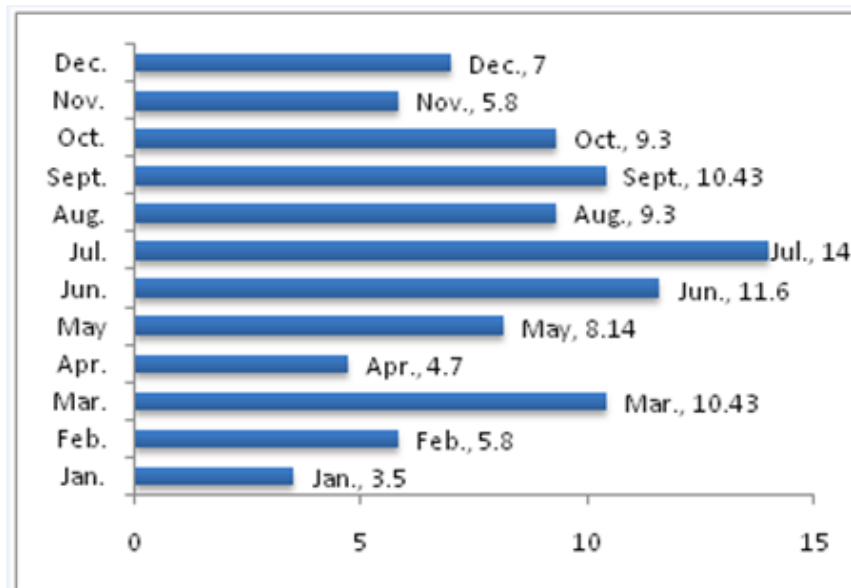


Figure 4. Percentage of occurrence of struck-by accidents by month in Malaysia (2010 – 2018)

4. Caught-In-Between Accidents

This type of accident is characterized as being caught between the moving and stationary objects or sections of the machine or between the moving part of the machine and the material [105, 143]. They have been categorized more accurately as being associated primarily with equipment trench cave-ins accidents [140]. Most of the caught-in-between accidents occurred due to infringement of OSHA laws [139]. These include training and education in safety; cranes, lifts and elevators; scaffolding design; floor openings and platforms; general scaffolding; and cave-ins excavation protection. They are triggered by being trapped in a pit or trench [143]. The soil collapsed and buried workers in most situations. In order of occurrence caught-in-between are the third most frequent accidents in Malaysia with 17.67%. However, in some countries, it is the fourth most frequent type of accident after electrocution (see **Table 8**).

A. Causes of Caught-In-Between Accidents

Caught in-between working platform and permanent or temporary structure by collapse or failure, caught in the middle of construction machine or equipment, and trench cave-in were the causes of serious injuries or deaths with 46%, 42%, and 12% respectively in Malaysia from 2010 to 2018. Approximately 69.5% of the caught-in-between deaths were triggered by dangerous behavior [171]. They were commonly related with working at a running machine (about 21.2%), tool or machine activated unintentionally (about 14%), taking unsafe posture (about 13.3%), operating errors (about 6.1%), and failure to secure (about 5.2%). Fatalities of construction workers are directly attributed to the operation of earth moving machines [172]. Lack of work-specific training is the primary cause of

caught-in-between accidents [116]. Trench cave-ins accounted for a significant number of the caught-in-between fatalities in the US [139]. In most instances, trench workers were not properly protected by sloping edges, trench boxes or shoring [140]. The causes of fatalities as a result of caught-in-between accidents are trench cave-in, heavy equipment, overturning heavy equipment machinery, moving part of heavy equipment, and construction materials [139, 140].

Some of the causes to have geared the caught-in-between accidents in Malaysia were identified to be as follows: lack safe work procedure, machine not well checked and inspected before usage, no safe working procedure for lifting works, lifting of excessive load, failure of the crane's operator to read load chart, failure to comply with mobile crane standard procedure for lifting works, failure to comply with safe operating procedure, environmental factors, and lack of safety training.

Using 4D simulations, site personnel can visually identify the sequence of activities and requirements for materials and equipment before starting work [173].

B. Trade Workers

The three trade workers to have died mostly due to this type of accident are construction laborers as a result of trench cave-ins; machine operators as a result of failure to comply with the safe operating procedure; and mason, mostly because of structural collapse (see **Table 6**). According to Im, et al. [17], the most trade workers to have died as a result of caught-in-between are heavy truck drivers, construction operators; construction machinery fitters, operators and mechanics; and plumbers and pipefitters in order of occurrence in Korea. Crafts linked to the operations of heavy equipment are more commonly

involved in accidents of caught-in-between [108].

Table 6: Trade work for caught in-between accidents (2010 – 2018)

| Trade work name | % of occurrence |
|---|-----------------|
| Helper | 28 |
| Machine operator | 22 |
| Mason/bricklaying | 16 |
| Trench excavator | 14 |
| Scaffolding | 6 |
| Carpenter | 4 |
| Non-construction worker or civilian | 4 |
| Other (housekeeping, site security, welder) | 6 |
| Total | 100 |

C. Monthly Distribution for Caught-in-Between Accidents

The months (see **Fig. 5**) in which caught-in-between accidents had occurred the most are June and September with 14% each. And the months with the least

occurrence is February and April with 2% each. However, there was no detail information to provide the reasons for the higher occurrence in the aforementioned months.

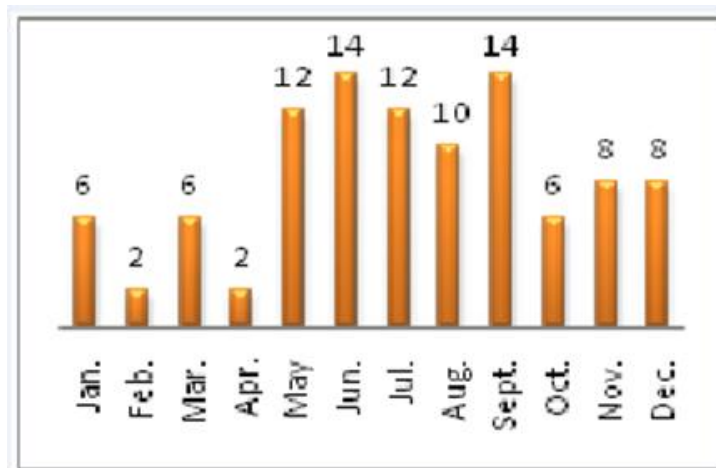


Figure 5. Percentage of occurrence of caught in-between accidents by month in Malaysia (2010 – 2018)

5. Drowning/Asphyxiation

Drowning is death due to suffocation when a liquid prevents the intake of oxygen into the body from the air resulting in asphyxia [174, 175]. And the primary cause of death is generally hypoxia and acidosis which leads to cardiac arrest. Drowning is the world's third leading cause of unintended injury or death, accounting for 7% of all injury-related deaths [174]. For every person who dies from drowning, about four people receive treatment for non-fatal drowning in the emergency department [176]. Asphyxiation is a state of insufficient oxygen supply to the body arising

from an abnormal breathing that can occur as a result of drowning or working in a confined space [142, 177]. Watanabe and Morita [178] acknowledged that suffocation, strangulation and chemical exposure could be part of asphyxiation.

In order of occurrence drowning/asphyxiation are the fourth most frequent accidents in Malaysia with 9.89%. However, most of the countries in the world categorized it as others because of its least occurrence. 25% of the analyzed accidents occurred in the water while the remaining 75% occurred in confine space for drowning and

asphyxiation in Malaysia. Of the 110 incidents, 36.36 percent revealed that the events occurred in manholes or utility vaults [142].

It is reported that proper supervision, swimming training, technology legislation, and public education will eliminate more than 85% of cases of drowning [179]. Preventing asphyxiation-related deaths may require greater transparency in safety programs and better education programs. Emphasis should be given on the importance of safety training on occupational hazards in or near water and in confined spaces. With more thorough investigations of these types of incidents and better collection of data, more thorough programs can be devised to prevent accidents. BIM-based tools will surely give a clear view and simulations of the construction sites for proper and more advance safety training.

A. Causes of Drowning/Asphyxiation

The causes of drowning/asphyxiation were found to be: lack of safe working procedures in water and confined space, lack of PPE while working in or near a water body and lack proper and adequate supervision [142]. From the narrative descriptions it was found that the main causes of this type of accident were as follows: lack of safe

working procedure in water and confined space, lack safe work procedure for piling works, lack or insufficient PPE for work in water, failure to conduct hazard identification, risk assessment, and risk control (HIRARAC) for water treatment plant tank cleaning works, and lack of safety training. It was also found out that the cause of death as a result of the drowning was due to suffocation or lack of oxygen for all the cases analyzed under this type of accident in this research.

B. Trade Workers

The workers that died the most due to suffocation or lack of oxygen were construction laborers with 28.57%. This was followed by trench excavators with 17.86% (see **Table 7**). From the narrative descriptions, all the laborers died while working in a confined space while the trench excavators died as a result of earth landslide while working. The non-construction workers died because they entered unfenced construction sites thereby falling into unmarked manhole or utility vault accounted for 14.29%. The machine operators died while operating their machines accidentally fell into water with 14.29% also. And the remaining trade workers died while carrying out their usual job accounted for 17.85%.

Table 7: Trade work for drowning/ asphyxiation (2010 – 2018)

| Trade work name | % of occurrence |
|-------------------------------------|-----------------|
| Helper | 28.57 |
| Trench excavation | 17.86 |
| Non-construction worker or civilian | 14.29 |
| Machine operator | 14.29 |
| Plumbing works | 7.14 |
| Housekeeping/ maintenance works | 7.14 |
| Gantry pipe installation & welding | 7.14 |
| Electrician | 3.57 |
| Total | 100 |

C. Monthly Distribution for Drowning/Asphyxiation

The monthly distribution of drowning incidents ranged from 0% in August to the highest percentage in June with 31.25% (see **Fig. 6**). March, May, September, and November accounted for 25% with 6.25% each and

February, April and December accounted for 75% of the drowning/asphyxiation incident. Monthly variations may be related to weather phenomenon, however, that did not explain the reasons for the occurrence.

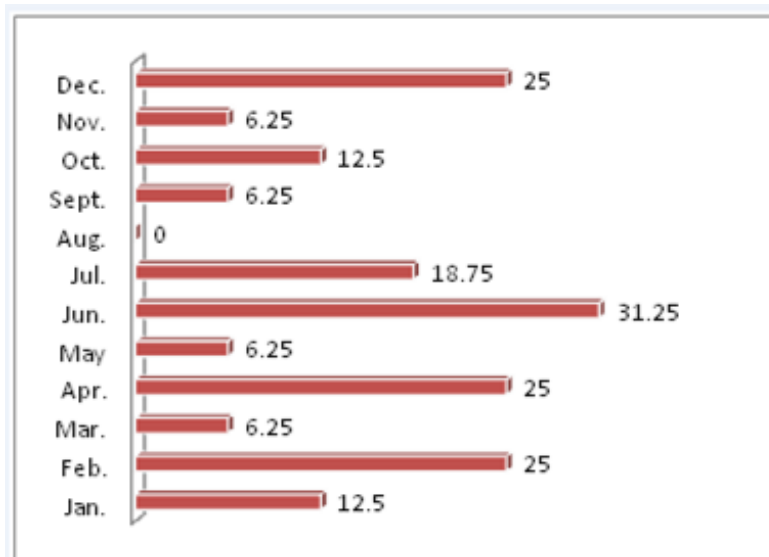


Figure 6. Percentage of occurrence of drowning/asphyxiation by month in Malaysia (2010 – 2018)

6. Other Type of Accidents

Electric shock, exposure to chemical substance and fire explosion accounted for only 3.89% of all analyzed data. In this research, they are classified as other because of the little percentage they have.

A. Electric Shock Accidents

Electrical accidents are nearly five times more likely to have severe consequences than the industry's typical incident [180]. According to Hinze and Russell [139], the causes of deaths as a result of electric shock are direct contact with live wire, crane boom with a power line, materials hit with the power line and ladder contact with a power line. It is clear that a vast majority of the electrical shock accidents occurred from contact with overhead electrical power lines and it was all due to human mistakes [139, 140]. Contact with overhead power lines occurred with younger workers more frequently, whereas contact with electrical wiring, transformers, and other related equipment occurred more frequently with older workers [181]. Outdoor activities containing power lines, boomed trucks and support equipment, such as ladders and scaffolds, are prone to comparatively greater electrical risks and therefore require extra safety training and countermeasures [182]. Electrical work-related fatal accidents occurred during the installation, maintenance and repair of electrical, HVAC and cooling equipment [183]. The causes of accidents in Malaysia were attributed to direct contact with live wire (60%), lorry loader boom in contact with power line and natural cause (i.e. struck by lightning) with 20% each. All the reported cases were as a result of lack of technical expertise in the related field, defective existing wiring, and use of faulty construction tool.

According to the report, electricians, laborers, and

welders were the trade workers that were most exposed to this type of accident with 62.5%, 25% and 12.5% respectively in Malaysia from 2010 to 2018. Electricians, building laborers and brick-layers experience about two-third of all-electric accidents in the construction sector [180]. Electricians (47%), construction laborers (23%), painters (6%), roofers (6%) and carpenters (6%) were recognized to be the construction trade workers with the most fatal electrical injuries from 2003 to 2007 in the US [183]. The trade workers most exposed to electric shock are electrical equipment mechanics [17]. Line installers and repairer, laborer, electrician and construction machine operator are particularly susceptible to electrocution [182]. In addition, the proportions of electrocution accidents were found to be significantly higher for younger workers compared with all other industries [181, 182]. Younger and older employees are more prone to electric accidents [180].

The monthly distribution of electric shock incident ranged from 0% in January, February, March, April, July, August, September and November to the highest percentage in December with 37.5%. May and July accounted for 50% with 25% each while October accounted for only 12.5%. Monthly variations may be related to weather phenomenon, however, that did not explain the reasons for the occurrence.

B. Exposure to Hazardous Chemical

Chemical hazards are often in the air and can appear as dusts, fumes, mist, vapors or gasses; and exposure usually occurs by inhalation, though some airborne hazards can settle on and be soaked up through skin [184]. They can also occur in liquid or semi-liquid state or powders. The cause of death in Malaysia (2010 – 2018) as a result of chemical exposure was due to the inhalation of harmful chemical substance while working for all the analyzed

cases. The trade workers to have died as a result of chemical exposure were air-conditioner maintenance employees. Most of the victims of chemical exposure are males and younger employees are more exposed than the older ones [185]. Employees in the construction industry had the longest average exposure of more than six hours per week, followed by employees in the mining manufacturing and agricultural, forestry and fisheries sectors, where the mean exposure time in each case reached four hours.

Pacheco-Torgal and Labrincha [186] claimed that Architects, Engineers, and Designers have limited knowledge of the nature and impact of construction materials on health and the environment. The impacts of exposure to building materials on health and the environment are not given adequate consideration [187]. Another problem is that small numbers of construction workers know the kind of chemicals they are exposed to in the workplace [185]. The information needs to be understood by laymen by simplifying it using simple, not scientific language [188]. The diseases or illness usually encountered by trade workers as a result of exposure to chemical substance are as follows [184]: sandblasters, tunnel builders and rock drill operators suffer from silicosis; asbestosis among asbestos insulation employees, steam pipefitters, and construction workers for demolition; bronchitis amongst welders; allergies to skin among masons and others involved in cement work; and neurological problems involving painters and others which are subjected to organic solvents and lead. The most commonly reported control measures for chemical exposure were the provision of washing facilities, training on the safe handling of chemicals and supply of gloves [185].

C. Fire and Explosion

Even though explosions and fires are not the most common cause of construction site injuries, these incidents can have devastating effects on the health and safety of workers. The cause of fatality as a result of fire and explosion in Malaysia from 2010 to 2018 was due to inadequate supervision and lack of safety training. The victims died as a result of smoke inhalation or blast for the

reported cases. The trade workers to have died as a result of fire and explosion incidents were construction laborers in Malaysia. Construction laborers, welders or cutters, electrical workers, heavy equipment operators, carpenters, supervisors, mechanics, painters, plumbers, managers, and other unidentified trade workers are the construction employees to have been died by fire and explosion in the US from 1992 – 2007 [189]. Customized programs enable sprinkler designers to develop systems in 3D models and automatically prepare hydraulic calculations, print system component listings and even put hangers and bracing on pipe sizes and dimensions on drawings [190]. For instance, if a user picks a fire pump in the program, a strong, well-established BIM file can provide all relevant information to the user.

Welding, electronic flares, heavy equipment hitting underwater pipes, open flames, motor vehicle crashes, and cutting or drilling are the most common causes of catastrophic fire and explosions accidents in construction sites [191]. The factors responsible for the fire incident were found to be lack of supervising, breach of safety regulations and insufficient fire management [192]. It has also been found that secondary accidents such as collapses, explosions, and suffocation occurred when fires erupted. According to Holt and Lampl [129], there are two ways of dealing with fire; stopping it from occurring and managing the effects in case it happens.

However, emphasis was given only to the major types of accidents. According to some of the researchers mentioned in **Table 8**, other include motor vehicle crash, collision, amputation, burst, excessive motion, contact with unusual temperature, or atmospheric pressure and mine disaster [17]. They also include cardiovascular / respiratory system failure, inhalation, rubbing / abrading, bite / sting / scratch, repeated movement / pressure and ingestion [141, 146]. According to Hinze, et al. [140], others include explosion, fire, asphyxiation, drowning, and natural causes. López, et al. [102] identified putting too much pressure on one's self as another type of accident in Spain which accounted for about 1% of the reported and analyzed cases.

Table 8: Types of construction accidents from different countries (%)

| Incident type | Author(s) | | | | | | | | | | | | | | | | | | | | |
|-------------------------------------|--------------|--------------|--------------|--------------------|--------------------|------------------|-----------------------|-------------------|---------------------|----------------------|---------------------|---------------|-----------------|--------------------|---------------------|---------------------|------------------------|---------------------|---------------------|-------------------|---------------|
| | OSHA (1980)* | OSHA (1985)* | OSHA (1990)* | OSHA (1985 - 1989) | OSHA (1994 - 1995) | Chi and Wu [146] | Huang and Hinze [140] | Tam, et al. [117] | Hinze, et al. [145] | Haslam, et al. [109] | López, et al. [101] | Ballowe [141] | Im, et al. [17] | Ling, et al. [106] | Cheng, et al. [100] | Cheng, et al. [123] | Mohammed and Ishak [1] | Chong and Low [142] | Hamid, et al. [104] | Ayob, et al. [24] | Present study |
| Falls | 34.8 | 36.6 | 39.6 | 33 | 34 | 41.7 | 36.3 | 48 | 36 | 57 | 36.6 | 39 | 54.1 | 36.9 | 54 | 47 | 41.97 | 27.1 | 43.41 | 46.28 | 38.16 |
| Struck by | 18.8 | 27.9 | 29.5 | 22 | 18 | 6.5 | 24.3 | 22 | 26.7 | 33 | 30.3 | 23 | 8.6 | 20.9 | 5 | 10 | 25.92 | 46.9 | 25.58 | 33.1 | 30.39 |
| Struck against | 2.5 | - | - | - | - | - | 2.3 | - | - | 3 | 1.7 | - | - | - | - | - | - | - | - | - | - |
| Electrical shock | 19.7 | 17.1 | 16.9 | 17 | 20 | 14.6 | 13.4 | 11 | 12.9 | 2 | 5.9 | 13 | 9.6 | 9.9 | 9 | 8 | 6.17 | - | 5.43 | 5.79 | 2.83 |
| Caught in/between | 16 | 13.3 | 9.3 | 18 | 15 | 7.9 | 11.6 | - | 11.9 | 1 | 8.8 | 15 | 2.8 | - | - | 3 | 11.11 | 9.7 | 19.37 | 4.96 | 17.67 |
| Drowning & Asphyxiation | - | - | - | - | 3.12 | 2.4 | - | - | - | - | - | - | 1.2 | - | - | - | - | - | 4.66 | 2.48 | 9.89 |
| Fire and/or explosion | - | - | - | - | 2.99 | 4.3 | - | 2 | - | - | 0.7 | - | 2.7 | - | - | - | - | - | - | 1.65 | 0.35 |
| collapse | - | - | - | - | - | 11.3 | - | 13 | - | - | - | - | 9.6 | - | 14 | 19 | - | - | - | - | - |
| Chemical Exposure/Harmful substance | - | - | - | - | - | 2.2 | - | 3 | - | - | 0.8 | - | - | - | - | - | - | - | - | 0.83 | 0.71 |
| Other | 8.2 | 5.1 | 4.7 | 10 | 1.17 | 9.1 | 12.1 | 1 | 12.5 | 4 | 15.2 | 10 | 11.4 | 32.3 | 18 | 13 | 14.83 | 16.3 | 1.55 | 4.91 | 3.81 |
| Country | USA | USA | USA | USA | USA | Taiwan | USA | China | USA | UK | Spain | USA | Korea | Singapore | Taiwan | Taiwan | Malaysia | Malaysia | Malaysia | Malaysia | Malaysia |

Note: column 2,3,4 were adopted from [138] and 5,6 from [139]

7. Non-Construction Workers

A lot of workers come to Malaysia from neighboring countries (e.g. Indonesia, Thailand, Vietnam, Taiwan, Cambodia, Pakistan, India, Bangladesh, etc.) in search of greener pasture. The management employs them easily because of the cheap labor. The problems that normally arise are: (1) the foreigners usually receive zero or little safety training prior to the commencement of the project (2) another issue is the language barrier, some of the workers might speak similar language to that of indigenous people but to the rest is a different story. When it comes to construction is a thing of trust, teamwork, and collaboration, anything short of that can lead to a catastrophic accident in any construction site. For example, imagine workers working at height without clearly understanding one another, the end product will definitely lead to disaster. Inappropriate or lack of warning signs lead to accidents related to non-construction worker or civilian in a construction site.

Non-construction workers and foreigners are victims of some of the reported accidents but their specific number was not provided. It was reported that some of the construction sites did not have a fence or barrier to prevent

the **non-construction worker or civilian** from entering the premises.

VI. CONCLUSION

This study was subjected to 796 fatal occupational accidents (as reported by DOSH over the period of 2010 - 2018) to statistical analysis. Of those fatalities 38.16% involved incidents were related to fall-related accidents, 30.39% struck-by accidents, 17.67% caught in-between accidents, 9.89% drowning/asphyxiation, 2.83% electric shock, 0.71% exposure to hazardous chemical and 0.35% fire and explosion. The results indicate that the types of accidents plaguing Malaysian construction industry are similar to that of most countries in the world. It also be concluded that the rate of occurrence of accident in the industry is increasing at an alarming rate. The findings also revealed that majority of the accidents had occurred because one of the following or combination: management's failure to implement adequate measures to protect workers from potential workplace hazards, many unsafe acts on the part of the workers themselves and lack of safety training. The results from this study could help to improve the

working environment and productivity of the construction industry. They can also help raise awareness of safety and provide valuable guides for potential appropriate safety precautions and management plans.

This paper is not without limitations. More than 90% of the reported cases from the DOSH database does not provide the gender, age, employment period, experience, time of the accidents and company size in which the accident occurred (number of workers) of the victims of accidents in the report. However, we believed the victims to be mostly male; this is because of the religious and cultural background of the country. In addition, the injuries sustained by the victims were not properly documented for all the types of accidents. In the future, these are the areas DOSH and other responsible agencies need to improve in order to make their records up to date and international standard. Moreover, the numbers of foreign workers need to be clearly indicated in the reports' abstracts so as to fully understand the trend or pattern of what might be the causes of accidents in the in-depth data analysis. Additionally, in the case of FREDA the heights at which the accidents occurred were not provided in the report. The depths of the excavation where caught-in-between accidents occurred were not also provided in the report. The materials or tools that caused the struck-by accidents were not stated in the report provided. Reports should include the number of hours of work performed in or around water bodies to assess the potential risk of drowning for the construction workers.

Difficulties in evaluating research emerge not only from the different data sources but also from the way incident forms are named. Nonetheless, there was no clear set of types used regularly to track the occurrence of accidents through government agencies or empirical study and some previous research covered irrelevant incidents [142]. Classifications of accidents need to be standard and consistent for easy recording, reporting, and cataloging of the types of incidents that occur appropriately and accordingly. The DOSH and other relevant government agencies are responsible for establishing the rules, standards and the legal requirements for the safety and health of all workers at the workplace in Malaysia [145]. A complete database of occupational accidents should be established to optimize safety procedures at every workplace in the industry.

To reduce the overall risk of workplace accidents, it is vital to enforce efficiently the required health and safety procedures and training to insure that all employees understand and comply with these standards while working [101, 133, 134]. Safety training should be provided to the employees using the best possible ways they can understand before the commencement of the project, for instance, BIM-based tools. Had the BIM-based tools been utilized appropriately for safety improvement, the rate of accident

occurrence might decrease. However, the problems that stop the immediate implementation of BIM were found to be high cost of technology; high training cost; lack of BIM knowledge; and insufficient BIM training. Workers are required to be trained before using any type of equipment or machine in the construction sites, and they should be inspected and tested by a qualified person before work commences and periodically for maintenance. Sophisticated tools and equipment should be operated by the qualified personnel on the construction site [110]. Experienced workers should take care and guide the novice ones.

Hence, the main conclusion of this analysis is that workplace accidents are preventable because the bulk of occupational accidents are triggered by management negligence, lack of adequate and proper supervision and lack of safety training. Future work will concentrate on the use of BIM-based tools for job hazard identification and safety training. BIM's ultimate limitation is the amount of information available in the model, and the user's input [190].

SUPPORTING FUND ORGANIZATION

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ACKNOWLEDGMENT

The authors would like to express their utmost gratitude to Universiti Teknologi PETRONAS (UTP).

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