



A Literature-Based Framework for Analysing Fall-From-Height Accidents and Safety Preventive Measures in the Construction Industry

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ABSTRACT

Fall-from-height accidents are a significant cause of injuries and fatalities in construction industries. The occurrence of this accident may have been caused by any number of contributing factors. In addition, various preventive measures have been proposed to prevent this accident from occurring. To capture the true condition of a fall from height accident, the causes of the accident, the effects of the accident, and the preventive actions should be rendered out. Therefore, it is possible to analyse these accidents in order to determine their fundamental causes and implement effective preventative measures. This article presents a literature-based framework for analysing fall-from-height accidents. A literature review was conducted to examine existing studies and identify similar themes and patterns on fall from height accidents in the construction industry to illustrate the framework. Where the framework outlines the key factors that contribute to the accident. The framework comprises four main components: (1) fall from height accident, (2) causes of accident, (3) effect of accident, and (4) development of safety preventive measures. Along with the literature review that was carried out, an identification and outlining of the factors and subfactors of causes of accidents, effects of accidents, and preventative safety measures was taken out. The proposed framework provides a structured approach for analysing fall-from-height accidents, which can help organizations to identify the underlying causes of such accidents and implement appropriate measures to prevent them. The framework is flexible and can be adapted to suit the needs of other industries and organizations. The paper also discusses the future research directions.

1. Introduction

The construction industry is one of the primary engines of economic growth in Malaysia. Despite its significant economic impact, many occupational accidents have occurred on construction sites. According to occupational accident statistics by industry in Malaysia, there were 148 accidents that occurred at construction sites from January 2022 to November 2022, with 59 of those accidents

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resulting in fatalities [1]. As in prior years, 73 fatal accidents were recorded in 2021, 66 fatal accidents in 2020, and 144 fatal accidents in 2019.

It has been determined that there are several different types of accidents that result in fatalities in Malaysia. The construction industry has a high accident rate overall but falls from height are a substantial cause of both injuries and fatalities. In 2021, falls from a height made up 41% of all fatalities. Within the year 2020, fatalities resulting from falls from high levels accounted for 52% of all reported cases, which is an increase from the 39% reported in 2019 [2]. In the US, falls, trips, and slips from heights are the main causes of fatalities in the construction industry [3] and the most common type of construction accident in China [4]. The effects of accidents are felt negatively by many parties. Therefore, it is important to have a solid understanding of the factors that led to the fall from height accident in the first place, in addition to being aware of different types of safety preventive measures that can be taken to reduce the likelihood of a similar incident happening in the future.

2. Objective

The objective of the study is to develop a framework, which includes the causes of accidents involving falls from heights, the effect of accidents and the safety preventative measures. Previous research published and reliable resources were combed through to glean information on the factors that contributed to the incident, effect of accident, as well as the preventative safety measures which specifically on fall from height accident in construction industry. An outline of a framework was developed using the information that was gathered in order to accomplish the objective of the study. The outcomes from this study will be used to guide a future study into finding the relationships between the factors that contribute to accidents involving falls from height and the preventative measures taken in the construction industry of Malaysia.

3. Methodology

A comprehensive literature review was conducted to develop a framework on fall from height accidents in the construction industry. The literature review encompasses a comprehensive examination of prior scholarly research published in reputable academic journals. The topic's existing literature was thoroughly researched, and each study was reviewed and assessed to find its key concepts and relationships. The findings of the literature review were organized into three categories: accident causes, accident effects, and safety preventive measures. Based on the categories identified in the literature research, a framework was developed to highlight the important determinants of fall from height accidents in the construction industry. Furthermore, the literature review has provided a comprehensive compilation of data pertaining to the factors and sub-factors contributing to accidents caused by falls from heights, as well as the resultant effects of such accidents. Additionally, the review has also outlined the safety measures that have been implemented to prevent such incidents.

4. Results

4.1 Fall from Height Accident

One of the leading reasons of fatal workplace accidents and severe injuries is falling from a height [5]. An individual who falls from a higher level to the ground is known as a fall from height. According to Department of Occupational Safety and Health (DOSH), the prescribed distance of working at

height is ten feet and in the United Kingdom, the specified distance is no longer enforced [6]. Occupational Safety and Health Administration (OSHA) of the United States [7] requires that fall protection be provided at elevations of six feet in the construction industry and in Australia a construction activity with a risk of falling greater than 2 metres is considered high risk [8].

According to earlier study by Liy *et al.*, [9] and Zlatar *et al.*, [10], falls from scaffolds were among the most common fall events. Throughout the time, falls from ladders and through fragile roofs are frequent causes of accidents involving falls from height [5]. As describe by Liy *et al.*, [9], there are six types of hazards that, when triggered, will result in a fall accident. The hazards include roof falls, scaffolding falls, floor holes, ladder falls, falling from aerial hoist platforms, and falling from building girders or other structures. All the mentioned hazards are present on the construction site since the use of these tools is inevitable and essential to ensure the work process runs smoothly. The consistency of fall event that occurred in the construction industry indicates that there is possibility of accident re-occurrence and risk to the worker.

The accident may have been preventable if the hazards had not been triggered and been control. Since the study on the fall from height accident is not new and the number of publications related to the accident has increased since 2011 [11], the causes of the accident can be ascertained from earlier studies, and preventive measures may be suggested to prevent a repeat of the incident.

4.2 Causes of Fall from Height Accident

Construction workers are frequently exposed to a variety of inherent hazards linked with working conditions on construction sites. Most construction accidents occur from a combination of contributing causes and one or more unsafe acts and unsafe conditions [12]. The unsafe act also known as human element or human factor. Unsafe act can be described as any action that violates the safety procedures that have been established and has the potential to cause an accident such as removal of a safety barrier or the failure to use a safety belt [13]. While unsafe conditions are physically risky situations or circumstances where accidents or other unfortunate events may occur [14]. Inadequate site management practices, such as a lack of housekeeping [15] and failure to secure the opening area [13], can lead to hazardous conditions. Herbert William Heinrich developed the Domino theory in 1929, which is depicted in Figure 1. The theory illustrates how an accident can occur because of an unsafe act or situation, as demonstrated in a more detailed image. The following presentation illustrates the sequential arrangement of five an analogy dominos, each representing one specific phase in the process of accident causation. The domino located at the centre of a sequence leading to an accident is marked with instances of unsafe acts and unsafe conditions. They are the most important element that can result in an accident [16].

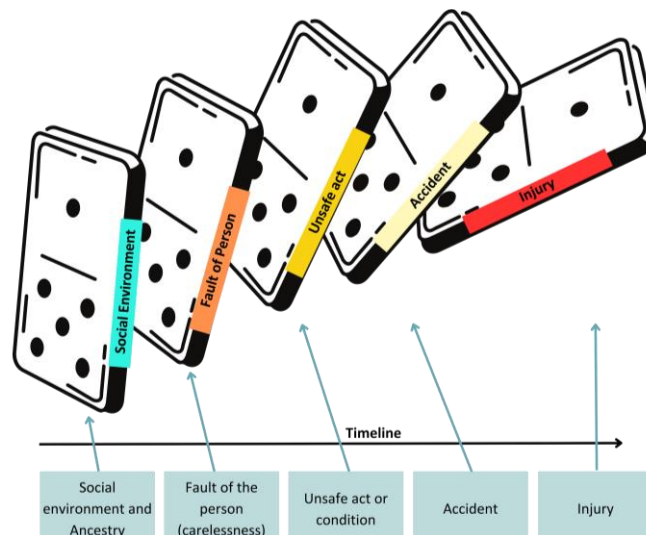


Fig. 1. The domino theory

The main factors causing of accidents in the construction industry were identified through a review of relevant literature. The factors are management factor, unsafe method, human element, job site condition, unique nature of industry, unsafe equipment, and environment factor [14]. In order to identify the factors and sub-factors that influence the occurrence of falls from heights in construction projects Vosoughi *et al.*, [17] classified the key effective factor of fall from height accident are organizational factor, individual factor, and environmental factor. While Asari and Leman [18] coded eight groups of the contributing factors, including environment, equipment, work practices, supervision, training, task error, and medical and others. Shi *et al.*, [19] used four complex systems human, machine, environment, and management to assess the risk of falling from a height. This study used these four components as the primary factors causing accidents involving falls from height.

In general, the factor that contribute to an accident and are directly attributable to the operator, worker, or personnel involved in the accident are known as individual factors. Work experience, not wearing personal protective equipment, and having a bad attitude are all categorised by Ramdani *et al.*, [20] as individual risk factors for construction accidents. Whilst the term equipment factors refer to the design of equipment, tools, and safety equipment [18] such as ladders and scaffolding. Tools and equipment, such as faulty or improper scaffolding or other structures and unstable scaffolding, has a high degree of agreement as an important factor of construction fall accidents [15]. While the term "management factors" refers to all the elements that have an impact on how an organisation and its members work and can result in accidents, such as poor worker supervision, budgetary constraints, and a lack of work-related and safety-related training programmes [20]. The term of "environmental factor causing accidents" refers to factors that contribute to workplace accidents that are not due to human error. Vosoughi *et al.*, [21] conducted a descriptive-analytical study in which thermal stress and work platform heights were recognized as environmental factors causing fall from height accident.

4.3 The Effect from Fall from Height Accident

Workplace accidents can result in significant financial loses for an organisation [22] and negatively affect not only the injured party but also the morale of other employees [23]. Previous study by Arunkumar and Gunasekaran [24] had conducted a cause-and-effect study for the fall from height

accident. The company's accidents were likely caused by noncompliance with safety regulations, lack of knowledge regarding personal protective equipment, overcrowded workspaces, improper utilisation of safety equipment, and unsuitable equipment. The construction industry is likely to experience various negative effects as a result of accidents, including but not limited to medical expenses, project delays, decreased productivity, reduced trust in the company, and expenses associated with training new employees. In a study conducted in Bangladesh by Ahmed [25], it was discovered that accidents at construction sites can result in various adverse consequences, including but not limited to loss of human life, decreased worker motivation and morale, workplace conflict, and delays in work progress. Where primary causes of accidents are attributed to a lack of awareness regarding safety-related issues, insufficient elimination of safety hazards during the design phase, and inadequate information and training pertaining to the equipment. Upon exploring the broader scope of the impact of accidents as gleaned from prior research, it is possible to categorise the effects of accidents into two primary factors. The factors are effect to individual and effect to organization which highly impacted in the event of an accident.

4.4 Safety Preventive Measures

The presence of hazards that are not being controlled by associated measures can lead to the occurrence of an accident. Safety preventive measures refer to the actions performed to respond to an accident or to proactively prevent accidents. In DOSH guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) the risk is being managed by controlling the presence hazard by implementing measures. At the sources of the hazard, the type of control can be classified as elimination of hazard, substitution, engineering control, administrative controls, and personal protective equipment [26]. Safety preventive measures can be implemented accordingly so far as is reasonably practicable.

In this study, four type of control measure recommended in the guideline was adopted. Elimination control by means is getting rid of a hazardous job, tool, process, machines, or material as the best way to protecting worker. According to the National Institute for Occupational Safety [27], it is recommended that a single-level building design be implemented instead of multiple floors at varying elevations, and that the use of parapet walls or permanent guard rails be considered as a means of mitigating fall hazards. The management of engineering control involves the implementation of various measures such as redesign, isolation, automation, and barrier implementation. In the occurrence of a fall from height incident, the installation of handrails, covering of holes, and appropriate design of anchor points may be suggested as engineering controls. The administrative controls by providing safe work procedures, supervision and training, job rotation, housekeeping, repair and maintenance program and hygiene. While the personal protective equipment is used when other controls are ineffective and further protection is required.

A fall from height accident framework illustrates the expected relationship between the causes of fall from height accident and the safety preventive measures.

4.5 The Literature Base Framework for Fall from Height Accident

As a result of the review of the relevant literature, Figure 2 was developed to demonstrate the framework for falls from heights accident. The framework illustrates the correlation between the causes of accidents resulting from falls from heights, the consequential effects of such accidents, and the safety measures implemented for prevention. A fall from height accident framework illustrates the expected relationship (A) between the causes of fall from height accident and the safety

preventive measures. Following an accident, safety measures are implemented as either an immediate or ongoing action plan, contingent upon the underlying causes of the incident. While, finding the causes of a fall from height accident and evaluating the extent that it impacted a person or organisation are the two components of a cause-and-effect study (B). The framework elucidates that fall from height accidents are primarily caused by four factors: individual, equipment, management, and environmental. The occurrence of accidents resulting from falls from heights has significant impacts on both individuals and organisations. The identified safety preventive measures are classified into four primary categories, including elimination control, engineering control, administrative control, and provision of personal protective equipment (PPE).

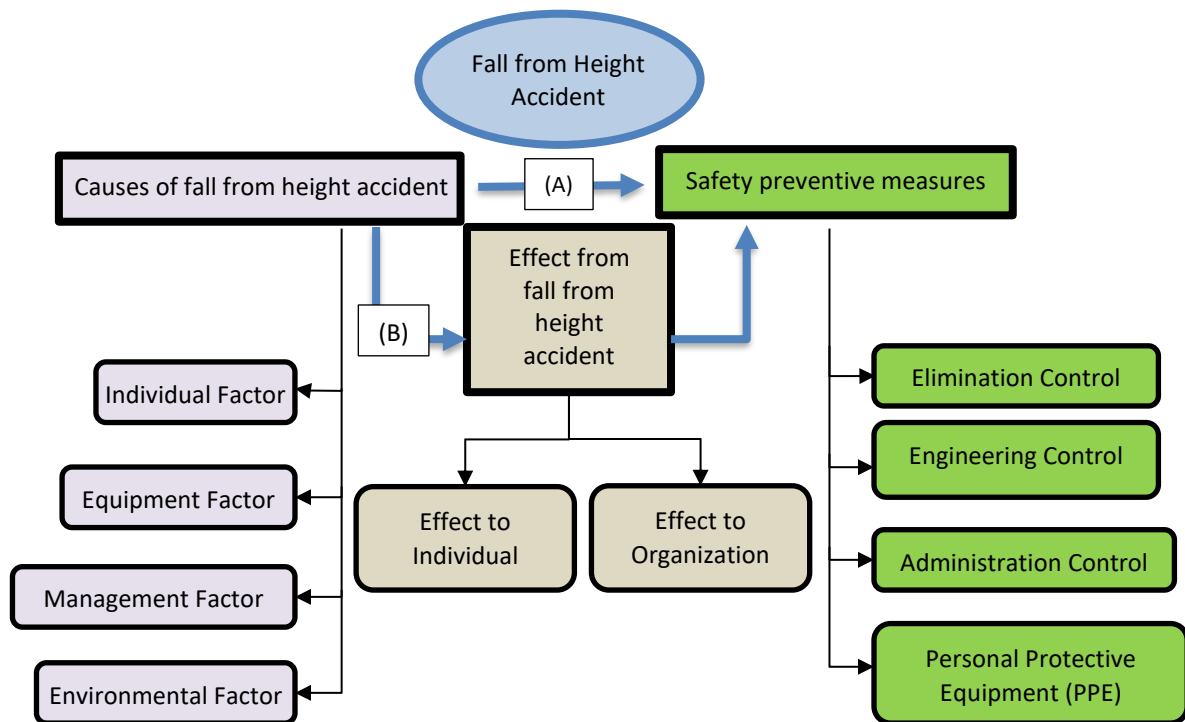


Fig. 2. Causes of fall from height accident and safety preventive measures framework

4.6 The Fall from Height Accident Framework for Malaysia Construction Industry

As previously mentioned, the fall from height accident framework depicted in Figure 2 includes various elements, and the factors identified therein are further subdivided into sub-factors. All of the elements within the sub-factors have been gathered from the findings of the literature review. In order to tailor the identified sub-factor to align with the practises of the Malaysian construction industry, validation was sought from experts in the field who possess a minimum of five years of work experience in the Malaysian construction industry. The Malaysian construction industry's framework for falls from height accidents and the contributing factors and sub-factors illustrated are shown in Figure 3.

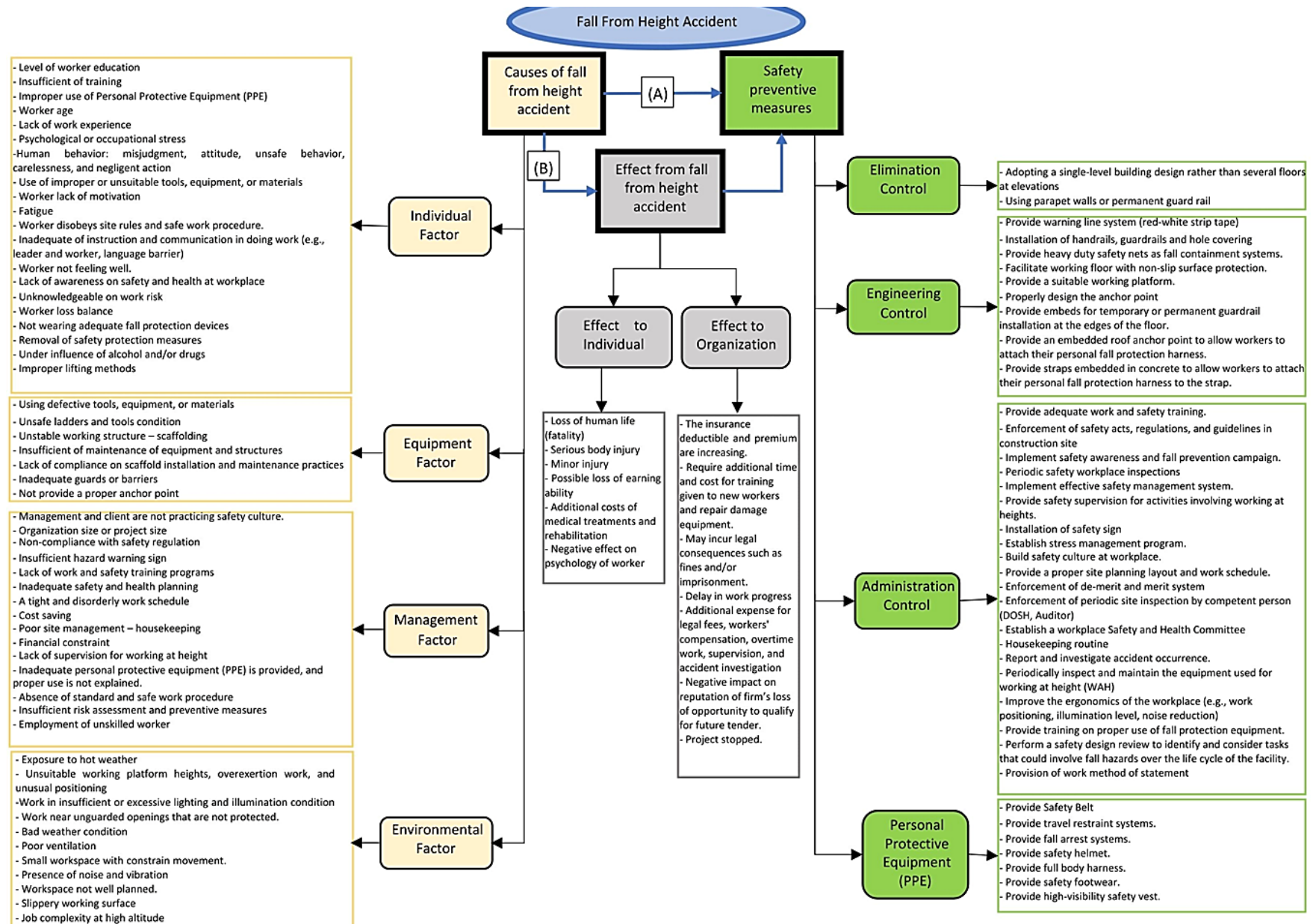


Fig. 3. Causes of fall from height accident and safety preventive measures framework and its factors

5. Conclusions

Since 2015 Department of Safety and Health (DOSH) have the track record of the occurrence of fall from height accident. The accident significantly impacts to the worker and organisation. There are numerous preventive steps available that can be used to lessen the likelihood of the accident. The suggested framework provides a structured approach for analysing fall-from-height accidents, which can help organisations identify the underlying causes of such accidents and implement appropriate measures to prevent them. This can help reduce the number of fatalities and serious injuries that occur because of such accidents. The framework is adaptable, so it can be modified to meet the requirements of a variety of different fields and types of organisations. The framework illustrated can serve as a guide for future research in determining the relationship of causes fall from height accident and safety preventive measures in Malaysia construction industry.

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