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FALL FROM HEIGHT ACCIDENTS IN THE CONSTRUCTION INDUSTRY IN SAUDI ARABIA

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Abstract
Falls from height (FFH) are considered the most dangerous accident in the global construction industry, especially in emerging economies like Saudi Arabia. This study investigates the causative factors responsible for FFH accidents in the construction industry in Saudi Arabia. The approach used by the study entailed a review of the extant literature to identify the main causes of FFH accidents. The identified causes were used to develop a questionnaire survey, which was administered to construction professionals in Saudi Arabia. Useable feedback from ninety-one responses was obtained and consequently analysed using the Relative Agreement Index (RAI). The results revealed that the top three causes include "lack of training", "no safety inspection", and "no safety meeting and seminar between stakeholders". The causes were also categorized into three groups including "unsafe acts", "unsafe conditions", "communication barriers", and "management commitment", where "unsafe acts" was the most influential category. The significance of this study is its potential to help control the occurrence of FFH in the construction industry through the adoption of relevant controls, safety training, and risk-based decision-making in the planning and execution of construction works.

Keywords: **Fall Accidents, Falling from Height, Construction Industry, Safety Performance, Safety Culture, Saudi Arabia.**

1. INTRODUCTION

The construction industry is regarded as one of the most hazardous workplaces in the world, which is due to the high rates of accidents, injuries and fatalities [1, 2]. According to the Occupational Safety and Health Administration (OSHA), the most common accidents in the construction industry are falls, electric shocks, struck by, and caught in between- also referred to as "the fatal four" [3]. However, the most prevalent of the four types of accidents are falls otherwise termed "fall accidents" or "falling from heights" (FFH). FFH is defined as a form of physical hazard caused by the downward movement of a victim from elevated positions such as scaffolds, roofs, ladders, or platforms during construction [4].

Numerous studies have reported that FFH during construction has become a major source of health and safety concern in many countries. According to Fang et al. [5], FFH accounts for 48% of the major injuries and 30% of fatalities reported in the construction industry worldwide. For example, the United States Department of Labour states that 21.1% of the 4.779 work-related fatalities reported in 2018 were from the construction industry. The report further indicated that the largest share of the fatalities was due to FFH [6]. Similarly, emerging countries are experiencing high rates of FFH accidents during construction. In Malaysia, it has been reported that FFH is responsible for 46.28% of the occupational injuries reported from 2013 to 2016. In China, it has been reported that FFH is responsible for 51% of all construction site

accidents, whereas it is responsible for one-third of the fatalities in Taiwan [7].

In Saudi Arabia, 46% of all reported workplace accidents are related to construction, with FFH accounting for 27% of the recorded cases in the industry [2]. The existing literature on construction safety in Saudi Arabia also confirms the menace of FFH accidents [8, 9]. Strikingly, Abukhashabah et al. [10] reported that FFH consists of 80% of the accidents in the construction sector in the city of Jeddah in Saudi Arabia. Hence, the need to understand, and consequently control the rate of FFH accidents in Saudi Arabia is obvious. This is even more emphatic considering the rapid transformation of the region with the continuous growth of mega projects. The region's construction industry is booming due to oil abundance with ambitious development plans worth billions of dollars. The GCC construction market is worth USD 3.2 trillion as of June 2021, with Saudi Arabia and the United Arab Emirates being the largest players in the region [11]. The result of such a huge development is the appearance of safety flaws in construction. Especially when considering the immature state of safety and health-related programs in emerging economies [1].

The foregoing suggests the need to investigate the causes of FFH accidents, as hazard identification is considered the first stage of mitigating and controlling construction safety risks. The research domain reveals that there are remarkable studies across the globe [5, 12, 13, 14, 15]. Despite the existence of studies on FFH from various construction climes, there is a research gap in the Saudi Arabian construction industry. In this study, the relevant research question entails "what are the causative factors of fall from height accidents in Saudi Arabia?". In that regard, the overall aim of this study is to investigate the causes of FFH accidents in the construction industry in Saudi Arabia. The potential implication of this study is to formulate an understanding of the major causes of FFH accidents, and consequently promote a risk-centric approach to planning, designing and executing construction activities in Saudi Arabia. Additionally, it could serve as a catalyst for the development of robust health and safety programs in the construction industry. The following sections present a review of previous literature on FFH, the research methodology, results and findings, discussions, and finally the conclusion sections.

2. EXISTING RESEARCH ON FALLS FROM HEIGHT (FFH)

A critical review of 75 journal papers from a population of 297 articles, published between 1994 and 2014 by Nadhim et al. [12] suggested that there is growing interest in FFH studies mostly from the USA, Taiwan, Denmark, and other advance economies. A more recent study by Vigneshkumar and Salve, [16] reviewed 83 FFH studies from 2000 to 2018, and suggested that there is a growing interest in the application of Computer and Information Technology (CIT) tools, especially building information modelling (BIM) in FFH research. The regions where FFH research is active include South Korea, Israel, Germany, Taiwan, the United States etc. There is still a lack of interest from developing countries, despite the need for such studies. A non-exhaustive illustration of works that exist in the research domain is presented here.

Nguyen et al. [17] proposed a quantitative probabilistic risk assessment approach to assess the risk of working at heights based on a Bayesian network (BN). The causal factors leading to falls were used to develop the BN model. Sa et al. [18] utilized a questionnaire survey administered to 252 roofers in the United States to compare the safety behaviours of commercial roofers and residential roofers. The study suggested that some of the factors influencing safety behaviour include the "existence of fall protection programs", "enforcement of fall protection device use", "actual use of fall protection devices", "work type", "company size", and "race/ethnicity". Wong et al. [19] used a classification system to identify the root causes of fatal FFH accidents in Hong Kong. The study suggested that four major classes for all factors include "ill planning", "violation", "hidden hazards created by others", and "incapable staffing". Fass et al. [8] examined the accident types and frequencies of Arabian Gulf nations through 519 incident records. The study observed that the most common construction accidents in the region are fall and struck-by type of accidents. The main causes identified by the study include worker skills and training, experience, use of safety gear and risk perception, and most importantly lack of commitment to safety. Kang et al. [20] examined 20,997 construction industry accidents recorded in the Occupational Safety and Health Administration (OSHA) database to investigate fall accidents in the United States between 1997 and 2012. The study's analysis revealed that fall accidents are becoming more critical in the industry contrary to existing information, and the current state of

fall accidents requires a revision of existing policies and regulations.

Research studies seeking the adoption of Computer and Information Technology (CIT) tools have increased in recent years. Fang et al. [5] developed an automated computer vision-based method to identify workers wearing their safety harnesses while working at heights. This was based on the application of neural networks to a database consisting of photographs of people working at heights in Wuhan, China. The purpose of the system was to identify unsafe behaviour that could lead to FFH accidents. Zuluaga and Albert [21] proposed a system to select supplementary fall protection devices for bridge maintenance work based on virtual prototyping. The rationale of the study was to supplement existing bridge guardrails due to issues of inefficiency. The proposed virtual prototyping system was to cater for inefficiencies due to the trial-and-error approach adopted in selecting supplementary fall protection devices.

3. METHODOLOGY

The studies presented in section 2 of this study reveal that research methods in FFH vary widely, including questionnaire surveys, review of incident records, probabilistic risk assessment models, neural networks, and computer vision. The nature of this study as an exploratory investigation suggests the use of a questionnaire survey in line with similar construction studies [11]. Hence, the primary research method used was through a questionnaire survey of construction professionals on the causal factors of FFH accidents. Initially, a literature review was used to obtain the causes of FFH outlined from the following literature (See: [22, 23, 24, 25]). Consequently, a total list of 31 causal factors was selected and utilized to develop the questionnaire survey. These factors were further categorized into four groups including: "unsafe acts", "unsafe conditions", "communication barrier", and "management commitment" in line with the literature [24, 25].

The questionnaire survey was designed to contain two parts. The first part was to seek information on the demographic characteristics of the respondents. The second part included the identified 31 causal factors of FFH and was designed based on a Likert scale of agreement from 1 to 4, as follows (1) strongly disagree, (2) disagree, (3) agree, and (4) strongly agree. The questionnaire was also reviewed by five experts in a pilot study to ensure clarity, inclusiveness and relevance of the causal factors of FFH. Subsequently, the questionnaire was administered in a web-based format to a wide range of construction professionals in Saudi Arabia. Web-based surveys have the advantage of being flexible and can reach a wide audience, while saving costs in terms of paper and postage [26]. The large number of construction professionals in Saudi Arabia suggests an equally large sample size, however, this study managed to obtain 91 responses due to the lack of cooperation from many professionals. Manu et al. [27] noted that the response rate to questionnaires in safety studies is usually low due to potential legal issues. The data collected were analysed using the Relative Agreement Index (RAI) equation, which is an adaptation of the Relative Importance Index (RII), and is considered an efficient way to analyse Likert scale questionnaire surveys [28]. The formula is provided as follows:

$$\text{Relative Agree Index (RAI)} = \frac{\Sigma w}{A*N} = \frac{4n_4 + 3n_3 + 2n_2 + 1n_1}{4*N}$$

Where:

w = the weightage given to each indicator by the participant, ranging from 1– 4.

n_1 = a number of participants for "strongly disagree".

n_2 = a number of respondents for "disagree".

n_3 = a number of respondents for "agree".

n_4 = a number of respondents for "strongly agree".

A= The highest weight, which in this study is 4.

4. RESULTS AND DISCUSSIONS

4.1. Demographic characteristics of the respondents

The demographic characteristics of the respondents in this study are illustrated in Figures 1–3. As observed in Figure 1, participants provided information about their gender, where 72% were male, whereas 28% were female. These findings are to be expected since the majority of construction site workers are typically male. The observed gender imbalance is corroborated by various reports in the literature that show that over 70% of all construction workers are male [29, 30, 31, 32]. This observation is typically attributed to the long working hours, as well as the stressful, laborious and hazardous nature of the workplace tasks in the construction industry [32]. Other studies have attributed the male-dominated nature of the profession to the lack of family responsive work practices [31], hence women are more likely to quit and leave their jobs in the

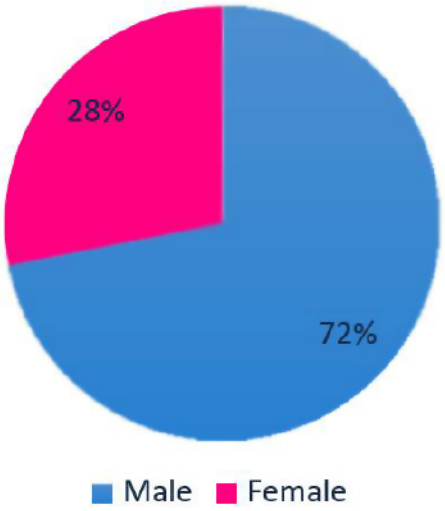


Figure 1.
Gender distribution of respondents

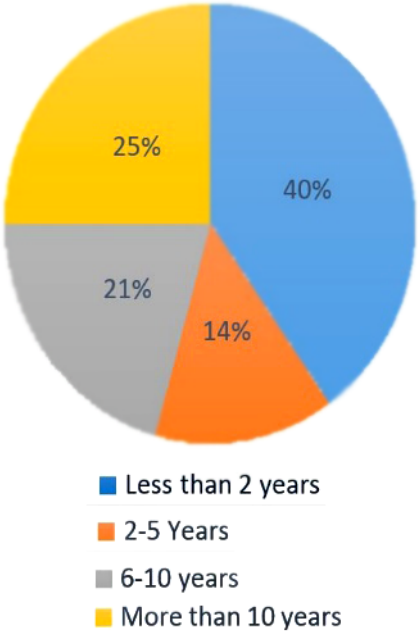


Figure 2.
Distribution of respondents based on years of experience

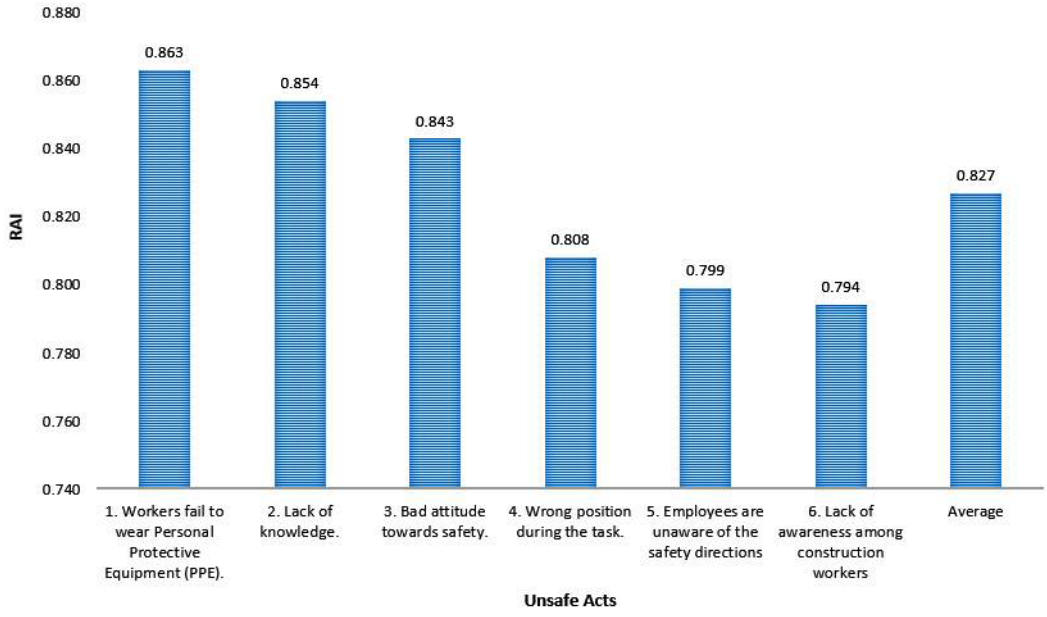


Figure 3.
Unsafe acts and corresponding RAI

construction industry [29, 30]. Other researchers have reported that the current structure of the workers is due to the traditional employment practices of the industry, which favours engaging males who naturally have brute strength, good tolerance for inclement weather, outdoor conditions, and foul language [29].

Similarly, Figure 2 presents the distribution of the study respondents in terms of work experience in the construction industry. As observed, 40% of the respondents have less than two years of experience in the industry, whereas 25% have over ten years of experience. It was also observed that 21% and 14% of the respondents have 6–10 and 2–5 years of experience in the industry, respectively. It is assumed that respondents with longer years of experience in the construction industry are likely to provide more reliable feedback.

Table 1.
RAI of causative factors related to fall from height accidents

FFH Causative Factors	RAI	Rank
Lack of training	0.885	1
No safety inspection	0.879	2
No safety meeting and seminar between stakeholders	0.868	3
No safety officer or supervisor	0.863	4
Workers fail to wear PPE	0.863	4
Poor housekeeping	0.857	5
Lack of knowledge	0.854	6
No safety programs	0.849	7
Bad attitude towards safety	0.843	8
Poor warning signs	0.841	9
Failure to provide PPE	0.821	10
Lack of PPE	0.821	10
Wrong position during the task	0.808	11
Working at a high level	0.808	11
Employees are unaware of the safety directions	0.799	12
Bad delivery of safety message	0.799	12
Lack of awareness among construction workers	0.794	13
Bad safety policies	0.794	13
Unstable scaffolding	0.791	14
Poor understanding of safety signs	0.772	15
Working in a crowded space	0.758	16
Unclear safety information	0.739	17
Bad weather during the work	0.728	18
Floor opening in the site	0.725	19
Defect of machinery	0.725	19
Inadequate communication between workers	0.723	20
The environment is not suitable for work	0.714	21
A language barrier between staff	0.662	22
Fall protection provided (e.g., safety harness)	0.659	23
Stakeholders are giving priority and value to safety practices	0.618	24
Periodic medical examination for workers	0.615	25

4.2. Causative factors of FFH accidents

The investigation on the causative factors responsible for FFH accidents in the construction industry in Saudi Arabia was examined based on four groups mentioned in section 3. This includes: "unsafe acts", "unsafe conditions", "communication barrier", and "management commitment". Table 1 presents the overall RAI of the causative factors ranked accordingly. It is observed that the RAI ranged from 0.615 to 0.885 with an average value of 0.781. The top five causative factors are "lack of training", "no safety inspection", "no safety meeting and seminar between stakeholders", "no safety officer or supervisor", and "workers fail to wear PPE". On the other hand, the least five factors are "periodic medical examination for workers", "stakeholders are giving priority and value to safety practices", "fall protection provided (e.g., safety harness)", "a language barrier between staff", and "the environment is not suitable for work". The results are described in more detail in the ensuing sections:

4.2.1. Unsafe acts

Unsafe acts are considered a critical factor in the occurrence of FFH in the construction industry. For example, the refusal of workers to wear PPE on site is considered a major reason for FFH. Figure 3 presents the RAI of factors under the category of unsafe acts that could result in FFH in the construction industry. As observed "workers fail to wear PPE" was ranked the highest based on the RAI of 0.863 (86.26%), which is in good agreement with the findings of Liy et al. [24] for construction sites in Malaysia. On the other hand, "lack of knowledge" was ranked the second most unsafe act based on the RAI of 0.854 (85.44%). According to the study by Al Haadir and Panuwatwanich [33], lack of knowledge is a crucial factor in influencing safety performance in Saudi Arabia. The findings also revealed that a "bad attitude towards safety" was also ranked high with an RAI of 0.843 (84.34%). The RAI for "unsafe acts" computed from the RAI of all causative factors in this category is 82.7%. The study by Liy et al. [24] revealed that staff that exhibit poor or nonchalant attitudes towards health and safety programs or protocols are more prone to FFH, which according to the authors could be addressed through training. However, "lack of awareness among construction workers" was ranked the lowest based on an RAI of 0.794 (79.4%).

4.2.2. Unsafe conditions

An illustration of the various unsafe conditions that could result in FFH and their corresponding RAI values are presented in Figure 4. It was that "poor housekeeping" is ranked the highest with an RAI value of 0.857 (85.7%). This indicates that this factor is the primary unsafe condition that causes FFH accidents. Similar findings have been reported by Liy et al. [24], where poor housekeeping has been observed to result in untidy and unorganized worksites, which increases the risks of falls [24]. Likewise, Mosly [23] reported that poor housekeeping practices are common at construction sites in Saudi Arabia, particularly in small to medium-sized companies. The study

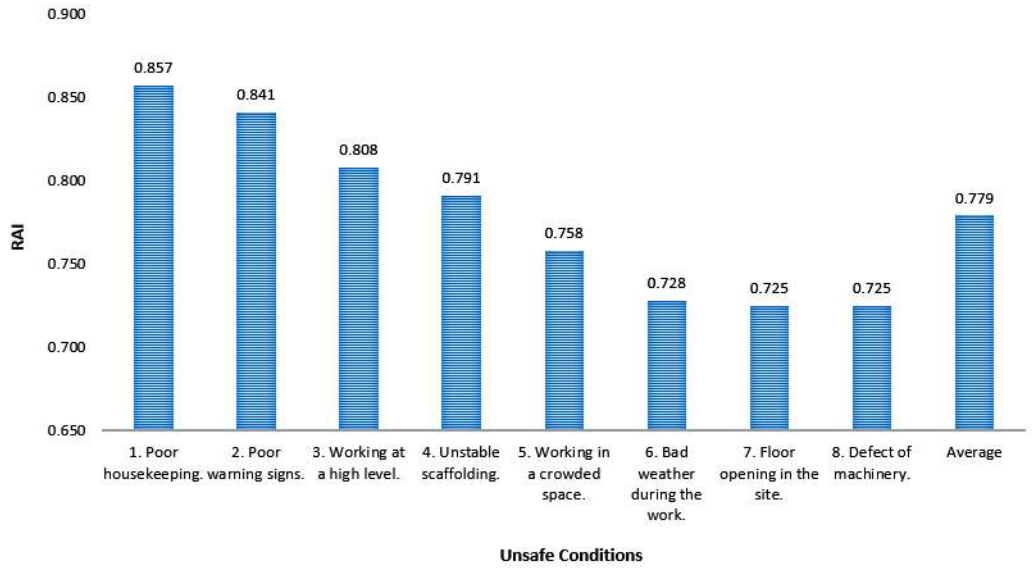


Figure 4.
Unsafe conditions and corresponding RAI

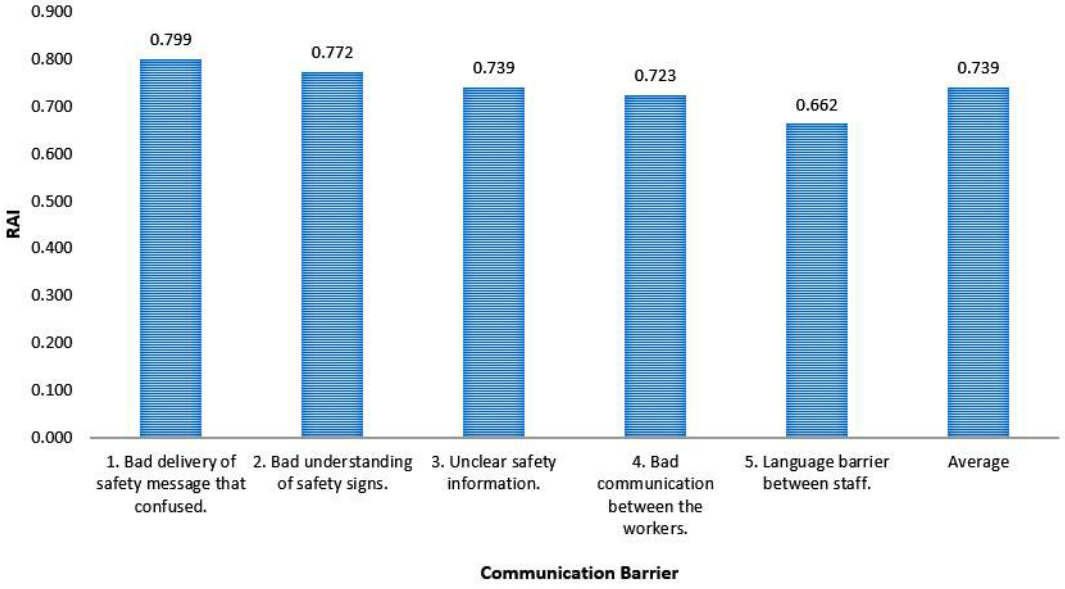


Figure 5.
Communication barriers and corresponding RAI

notes that poor housekeeping leads to other unsafe conditions such as open electric wiring, murky doorways, unsafely stored materials, and objects placed in the street or sidewalks. Another FFH causative factor related to unsafe conditions is "poor warning signs", which is characterised by an RAI value of 0.841 (84.1%). The RAI for "unsafe conditions" computed from the RAI of all causative factors in this category is 77.9%. According to Mosly [23], many construction sites in Saudi Arabia lack proper warning or safety signs which should constantly remind workers of safety measures. FFH accidents is also caused by "working at a high level" or heights as shown by the RAI of 0.808 (80.8%). Typically, working at heights exposes workers to fall hazards [24].

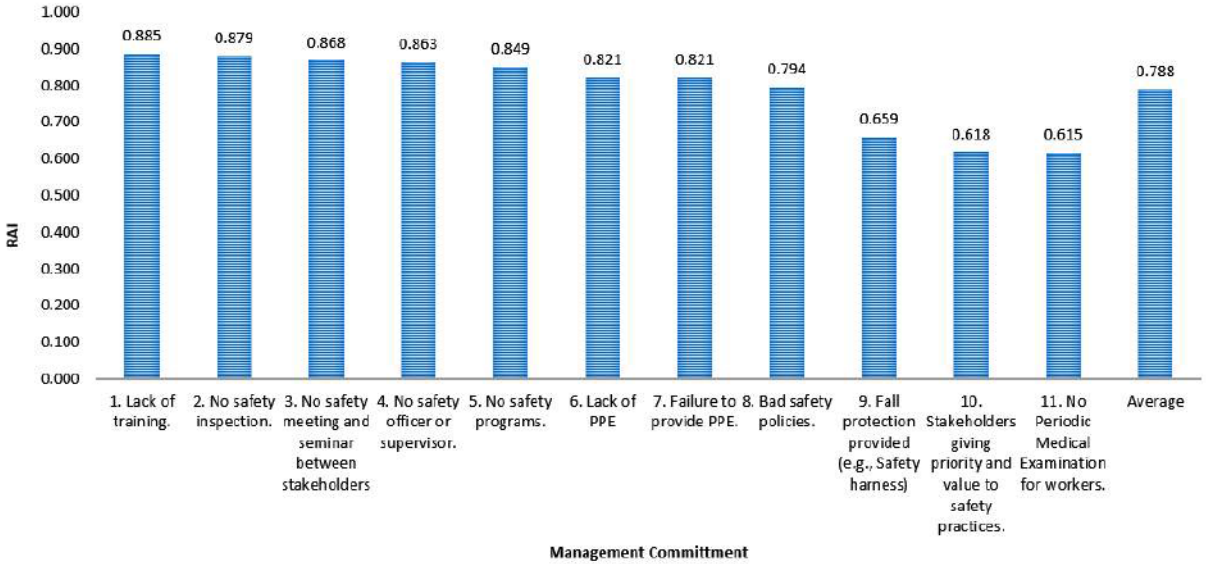


Figure 6.
Management commitment and corresponding RAI

4.2.3. Communication barrier

There are five causes responsible for FFH accidents which are related to communication barriers as shown in Figure 5, as the "bad delivery of safety message" was perceived to have an RAI of 0.799 (79.95%). Similarly, "bad understanding of safety signs" had an RAI of 0.772 (77.2%). The third most influential causative factor is "unclear safety information" with an RAI value of 0.739 (73.9%). The RAI for the "communication barrier" computed from the RAI of all causative factors in this category is 73.9%. If the employer's safety information, catalogue, or warning sign is unclear to the workers, then it is futile. Hence, safety information must be understandable by all workers to ensure adherence to the safety directions. It may be inferred that construction professionals consider poor communication of safety-related information and instructions as a major cause of FFH accidents. Thus, construction workers must receive and understand safety instructions in a comprehensible format. Misunderstanding of safety signs, and instructions could lead to more FFH accidents on the site. Conversely, the proper delivery of safety messages could reduce fall hazards at construction sites [24].

4.2.4. Management commitment

There are eleven causative factors of FFH accidents in construction related to management commitment as shown in Figure 6. As observed, the "lack of training" is the primary factor that causes FFH due to an RAI of 0.885 (88.5%). Through management's commitment, training programs on health and safety can be developed and implemented at construction worksites. This will be of potential benefit to reducing the incidence of FFH accidents onsite. According to Liy et al. [24], the implementation of health and safety programmes and their resultant effect of reduced accidents could also help to motivate workers. Motivation will encourage workers to share their opinions and partake in the health, safety, and professional training programs proposed by the management. However, a lack of training could lead to severe accidents and injuries [25]. The second most influential causative factor is "no safety inspection" with an RAI of 0.879 (87.9%). Respondents strongly agree that lack of safety inspection is a significant cause of FFH accidents. Awad [34] notes that one of the critical elements of safety duties is having regular inspections on site. Additionally, regulations to enhance on-site health and safety management can prevent falling injuries during work [12]. The respondents also strongly agree that "no safety meeting and seminar between stakeholders" is a major cause of FFH accidents as evident in its RAI value of 0.868 (86.8%). Moreover, safety meetings could help in accident detection and prevention, which could enhance the process of establishing corrective actions and improve overall health and safety programs. Therefore, the management should arrange periodic meetings and discussions on the safety programmes [33]. In addition, most of the participants strongly agree that "no safety officer or supervisor" is a major

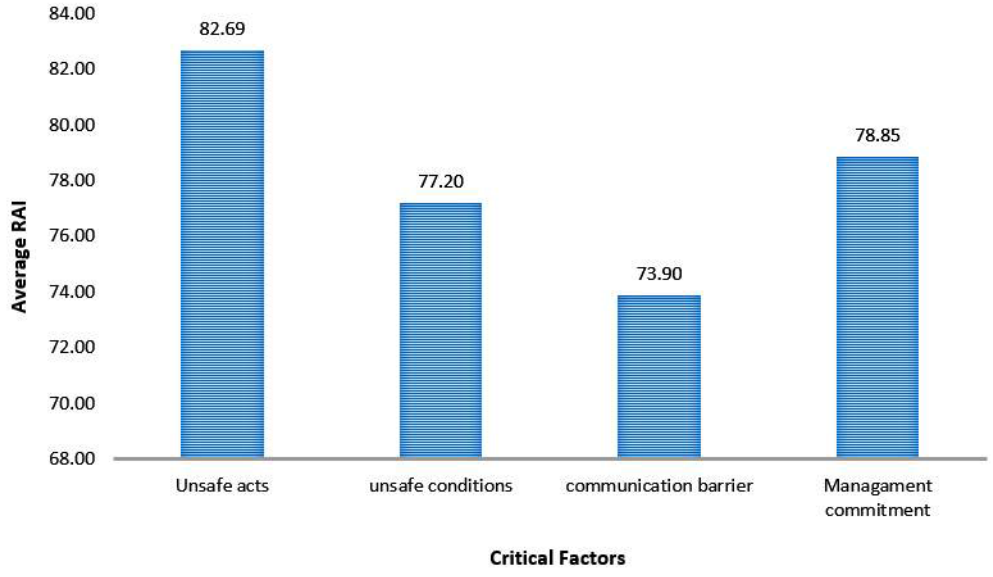


Figure 7.
Comparison of the causative factors of FFH

causative factor of FFH accidents, with an RAI of 0.863 (86.3%). Not having continuous training and failure to provide PPE are associated with the absence of a supervisor or safety officer [25]. The RAI for "management commitment" computed from the RAI of all causative factors in this category is 78.8%.

4.2.5. Comparison of the Categories

A comparison of the different causative factors of FFH accidents in construction is presented in Figure 7. It can be observed that "unsafe acts" have the RAI of 82.69%, "unsafe condition" has 77.20% RAI, "communication barrier" has 73.90% RAI, whereas "management commitment" has 79.12% RAI. "Communication barrier" has the lowest RAI, which indicates that communication between stakeholders is the least causative factor of FFH. On the other hand, "unsafe acts" has the highest RAI. It is worth noting however that the number of causative factors in each group varies, with "management commitment" having the highest number of causative factors. This variance requires that the RAI of the categories be understood in the context of their causative factors.

5. SUMMARY AND CONCLUSIONS

FFH accidents during construction have become a major source of health and safety concern in many countries. Emerging economies where there is a huge investment in developmental projects are witnessing a soaring record of FFH accidents. For instance, in Saudi Arabia, FFH accounts for 27% of construction accidents. The research landscape reveals that there are numerous studies related to FFH in various construction climes, however, there is a dearth of studies addressing this problem in emerging economies. Further, FFH-related research is gaining momentum, especially in the adoption and implementation of Computer and Information Technology (CIT) tools. Despite the current trend of research, the first stage of hazard mitigation is to understand the hazard causes, as a fundamental concept of risk management. Therefore, the research problem of this study was substantially projected. This research intended to answer the question: "what are the causative factors of fall from height accidents in Saudi Arabia?".

The causative factors that are responsible for FFH accidents in the construction industry in Saudi Arabia were examined in the study using a survey questionnaire. The questionnaire contained 31 causative factors categorized into four groups including "unsafe acts", "unsafe conditions", "communication barriers", and "management commitment". Subsequently, the data collected from the respondents were analysed using the relative agreement index (RAI) approach. The study revealed that the top five

causative factors were "lack of training", "no safety inspection", "no safety meeting and seminar between stakeholders", "no safety officer or supervisor", and "Workers fail to wear PPE". On the other hand, the least five factors were "periodic medical examination for workers", "stakeholders are giving priority and value to safety practices", "fall protection provided (e.g., safety harness)", "a language barrier between staff", and "the environment is not suitable for work". The major category of causative factors of FFH was "unsafe acts", while the least contributing category was "communication barrier". It can be reasonably inferred from this study that the establishment of comprehensive health and safety programmes, housekeeping, provision of qualified safety officers and supervisors, and provision of proper warning signs and personal protective equipment is crucial to controlling the risk of FFH accidents in the construction industry.

This study sought to contribute to the body of knowledge on FFH, especially in an emerging economy such as Saudi Arabia. The relevance of this is re-emphasised through the growing rate of construction accidents vis-à-vis FFH accidents, in a fast-growing economy. The understanding of FFH accidents afforded by this study is a first towards promoting risk-centric safety management in the construction industry of Saudi Arabia and similar construction climes. Ultimately, the results will improve the current levels of knowledge on FFH causative factors. The identified causative factors will be instrumental in executing risk assessment studies, with due consideration of the most influential causative factors causing FFH accidents. Additionally, the causative factors could form the basis of training programs, toolbox meetings on-site, and safety awareness campaigns. This will also help top management in demonstrating its commitment to safety through relevant policies.

The potential limitations of this study can be viewed in light of the respondents who participated in the study, as well as the regional nature of this study. This prevents the level of generalisation that can be claimed through the results. However, the study's result may be conveniently interpreted in neighbouring regions with similar construction climes, while it also serves as a foundation for future similar studies. Additionally, future research may seek to develop risk assessment models based on the causative factors identified in this study.

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