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Conceptual Framework for the Mitigation of Accidents on Building Construction Projects

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ABSTRACT

Globally, the construction sector has recorded poor performance in safety management. Accidents occur frequently during construction work. As a result of accidents, worker's loss their lives, or sustained different injuries. Also, the project performance in terms of cost, time and quality is grossly affected. This paper is part of an ongoing Ph.D. research aims to develop a Safety management framework for mitigation of accident on building construction sites in Nigeria. The conceptual framework was developed based on a review of literature. The conceptual framework is divided into five parts: Construction projects' hazards, Safety management roles of project stakeholders, interrelationship among stakeholders' safety management roles, Safety output and Safety outcome. Lastly, the conceptual framework shows that the stakeholders' roles and their relationship will develop an effective system of safety management for mitigation of accident on building construction sites.

Key-words: Building construction, stakeholder' safety management, conceptual framework, accidents mitigation

INTRODUCTION

The construction sector is a significant contributor to the national economy and development, with Nigeria contributing 10.17% to the nominal GDP in 2021 (NBS, 2021). However, construction work is labor-intensive, dynamic, complex, and prone to accidents. The International Labor Organization reports that 2.3 million workers succumb to occupational accidents annually, with the construction industry having a disproportionately high rate (ILO, 2023). The Health and Safety Executive found that 30% of occupational accidents were from construction works (HSE, 2022). Construction-related accident records are not readily available in developing countries, and many organizations do not report accidents in their workplaces (Kamoli, *et al.,* 2021). Abuja, Nigeria's Federal Capital Territory, is one of the cities with the highest number of construction projects with corresponding risk of occupational accidents (Hassan, 2021). Factors affecting construction safety include organizational, environmental, and workers' factors (Elnagar, 2015). To mitigate accidents on building construction sites in Abuja, it is essential to implement a safety management framework that addresses these factors and ensures the safety of workers and the economic development.

THEORITICAL FRAMEWORK

This study used Heinrich's theory of accidents causation, to explain causes and effects among the variables of the study and system dynamic theory for tracing specific roles played by construction stakeholder in the mitigation of accident in building construction sites. Also, the paper has adapted holistic construction safety frame work from the study of Patel and Jha, (2016) as the conceptual framework for the study. The theoretical

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framework is the application of the theories to offer an explanation or shade some light on the interrelationship among the variables of the study. While the conceptual framework on the other hand, is the operationalization of these theories.

Heinrich Theory of accident Causation

Heinrich developed a theory of accident causation in 1931. According to Heinrich, an accident is one of the five factors in a sequence that results to an injury. An injury is invariably caused by an accident. The accident, in turn, is always the result of the factors immediately preceding it (Health and Safety Professional Alliance (HaSPA), 2012). The five factors are Social environment/ancestry, Fault of the person, Unsafe acts, accident and injury. Therefore, accidents can be prevented by removing unsafe acts of a person or a mechanical or physical hazard to break the chain. Weaver fault items three, four and five (unsafe act, accidents and injury) of Heinrich dominoes as errors caused by operations (Shahab and Jabaran, 2012). In essence, what Weaver tried to portray is that, if management knew the safety and relevant standards of the work, why was the worker allowed to continue the work in unsafe conditions? Therefore, it is the responsibility of the management system to stop unsafe acts. Further, Bird's updated the sequence of accident causation as lack of management, primary causes (personal factor, job factor), immediate causes, incident and loss. Unsafe acts may be the primary cause of accidents, but the root is management deficiency (Bavafa *et al.,* 2018). Therefore, these theories predict the possible causes of construction accidents and suggested management approach for mitigation. However, the aforementioned theories were not specific in providing a particular area of management for improving safety performance. Hence, the need for additional theory to complement Heinrich' Domino theory of accident causation and management model.

SYSTEM DYNAMIC THEORY

In line with existing literature particularly the identified knowledge gap, Phoya and Pietrzyk (2019) recommended the use of system dynamic concept to study the project stakeholders' safety management participation and performance on project development lifecycle. A system dynamic is a branch of system theory developed by Indwig Von Bertallanfy in 1946. System Dynamic (SD) is a theory of solving problem based on the feedback control system. SD employed the used of relevant variables for the problem of the study to defined the system and model the relationship. Bentallanfy defined system as elements in standing relationship (Papachristos, 2018). In addition, system theory is looking at all of the system that make up the entire concept. The concept considers a system as mutual interrelationship of various parts that makes the whole. System dynamic uses simulation modelling based on feedback system theory that complement system thinking. System is a way of making sense of the complexity of the world by looking at it in terms of the whole and interrelationship rather than by splitting it down into its parts. Phoya and Pietrzyk (2019) used the concept of system thinking to develop a Framework for stakeholders' participation in health and safety risk management in construction. The pattern of relationships between different stakeholders and the capacity of certain control in a group of case studies. The study raised the need for the use of system dynamic concept to trace the specific pattern relevant for the actual stakeholders' participation successes and failures. Therefore, these theories are the conceptual framework of this study.

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CONCEPTUAL FRAMEWORK

In order to operationalize the theories mentioned above, this study will use a holistic conceptual framework of construction safety. According to Patel and Jha (2016), the conceptual framework of a construction safety system is broadly categorized into input, process, output and outcome. The inputs are the project nature, project hazard, weather and other natural calamities that exist in the project and may cause accidents. To prevent the occurrence of an accident, these inputs can be controlled by developing a safety management system, which may be called the process. The process is expected to enhance a safe working environment and behavior, becoming outputs. At the same time, the interrelationship among safety practices elements in the process directly or indirectly affects safety performance called outcome. Safety performance enhancement is the proposed intervention program's central aim, which includes minimizing accidents and illness, preserving the company's reputation, and enhancing project success and stakeholders' satisfaction.

Figure 1 is the adapted conceptual framework for mitigating accidents in building construction projects. Some changes were made to the original framework under variables in order to suit the objectives of this study. Project hazards which are the input were grouped under appropriate headings: work site, human, management and external factors as recommended by Jaafar, *et al.,* (2017). Also, the construction safety management process which is intended to control the inherent hazards that exist in every construction were grouped under the stakeholders' safety practices roles and responsibilities. Safety performance outputs are safe work behavior, safe work environment and safety collaboration effort of project stakeholders. Lastly, items under safety performance outcomes are: minimizing accident, project success, enhanced image of construction company and stakeholders' satisfaction. It is expected that the stakeholders' safety practices roles and responsibilities will control various hazards by having direct positive impact on safety performance outputs, and direct or indirect positive impact on safety performance outcome. Construction hazards and stakeholder' safety roles and responsibilities are the independent variables. While safety performance outputs and safety performance outcome are the dependent variables of the study. Figure 1 illustrated the adapted conceptual framework for mitigating accidents in building construction projects.

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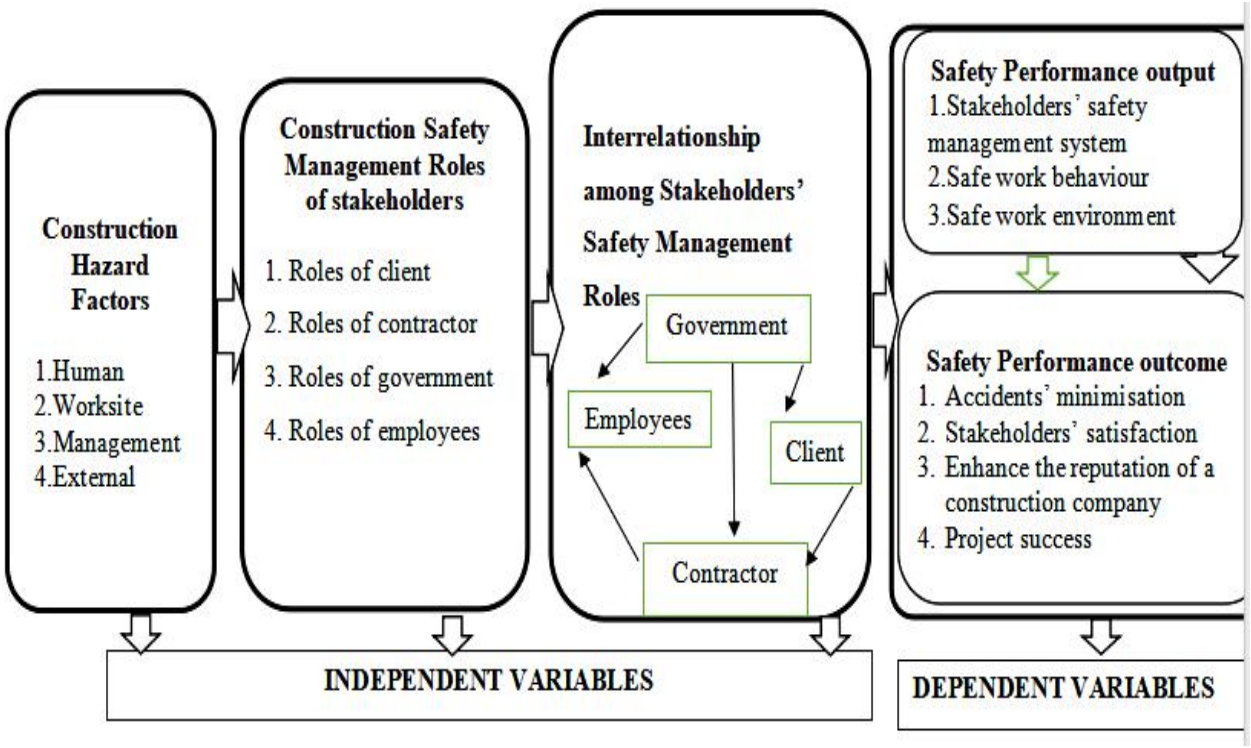

Figure 1: Conceptual Framework for the Mitigation of Accidents in Building Construction Projects

Source: Adapted from Patel and Jha (2016)

Hazards in Building Construction Projects (INPUT)

A hazard is anything that has the potential to cause harm (Hughes and Ferrett, 2016). Building construction is a hazardous activity with much risk of accidents. This is because construction work is labor intensive and outdoor activities with many exposures to different hazards. Patel and Jha (2016) believe that every construction work has an inherent potential risk of accidents. Hence, these hazards must be controlled with an effective safety management system. Jaafar *et al*., (2017) grouped factors affecting construction safety into four (4). These are human, worksite, management and external elements. These factors need effective safety management systems to avert accidents in place of work.

Human Factors

Human resources involved in physical construction are usually casual with unforeseen safety perceptions. As a result, variations in workers ' perception of safety, attitude, experience and knowledge coupled with the complex nature of construction projects and work pressure to meet a set target, construction work is more liable to accidents. In addition, human resources engaged in physical construction work are the major victims of the accidents. Bavafa *et al.,* (2018) report that most construction accidents relate to human factors. According to Jaafar *et al.,* (2017), human elements to consider as immediate causes of accidents are behavior, attitude, physical factors and experience. Other factors to give attention to are age, psychology and health. Therefore, it is vital to

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consider the above mentioned elements in selecting the proper workforce.

(i) Behavior

Behavior is any action a person does in response to internal or external events (Davi *et al.,* 2014). Workers' safety behavior is compliance with the safety system's rules and regulations, procedures, expectations and requirements (Guo *et al.,* 2016). It is the reflection of workers' safety attributes, qualities or characteristics. These attributes are their psychic conditions, which include knowledge, motivation, desire, perception and attitudes (Machfudiyanto *et al.,* 2017). Therefore, workers' behavior is a reflection of their attributes. Most immediate causes of an accident involve workers' unsafe behaviour (Okoye, 2018). Hence, worker behavior should be considered for improving safety performance (Talabi *et al.,* 2015).

(ii) Experience

Human experience is a collection of skills, training and education gathered during specific periods. Experience plays a vital role in safe work habits. Previous research unanimously agreed that training positively impacts workers' safe work behavior (Shin *et al.,* 2015; Machfudiyanto *et al.,* 2017; Vosoughi *et al.,* 2019). Also, Adeagbo, *et al.,* (2019) recommend safety training for new workers in construction sites. The experience of a worker is determined by training and the skills gathered.

(iii) Age

Normally, people with younger age tend to behave in risky ways than middle and older people. Also, older people lack the necessary stamina to perform in high-hazard work. Betsis *et al.,* (2019) found a positive relationship between accidents and workers under 24 years old. However, younger workers were found to comprehend modern technological safety training more than in old ages.

(iv) Health

Health is a state of physical and mental well-being. Workers' health, primarily mental and physical, plays a vital role in safe work habits. Ja afar *et al.,* (2017) assert that intoxicants and drug effects, physical disability, lack of strength and stamina and general poor health conditions are among the causes of occupational accidents. Construction workers, especially the unskilled ones, were known to have drug abuse habit and other intoxicants intake. Which affect seafety behavior.

(v) Psychology

Psychology refers to the state of the human mind. A mind free from depression, anxiety and worries is expected to perform work more safely. This aligns with Goal Alertness Theory, which states that a psychologically satisfying environment leads to safe work performance. At the same time, an unpleasant environment leads to accidents. Also, rewards (incentives and motivation) and punishment affect workers' mindsets. Panuwatwanich, *et al.,* (2016) found that safety incentive positively impacts safety behavior. In contrast, safety behavior could predict the safety outcome of the construction industry. Organizational safety management practices are expected to impact employees ' safety behavior and psychological well-being positively (Chan *et al.,* 2017). The state of human mind determines what he can do and undo.

Worksite Factors

Worksite factors that contribute to accidents occurrace are: project's complexity, ground condition, weather elements, materials and equipment, site organisation and natural calamities. Each element has some hazard associated with it that needs to be controlled.

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Construction sites are the avenue for physically implementing the safety management process.

(i) Project peculiarities

Project nature, complexity or otherwise determine the difficulty or ease of construction and risk of accident. Construction complexity is reported to affect safety performance negatively (Anthony *et al.,* 2019). Similarly, the height of buildings was reported to have a negative effect on workers' safety behavior. As a result, the most frequently reported nature of construction accidents is falling from height (Betsis *et al.,* 2019; Vosoughi *et al.,* 2019). Therefore, complex and high-rise buildings have a higher risk of accidents than simple and low-rise buildings.

(ii) Use of equipment

The use of construction plants and equipment makes work simple and faster. However, the equipment is hazardous and prone to accidents. John and Mohammed, (2020) found equipment to be the 4th source of occupational accidents and injuries. Accidents from equipment occur due to bridge of safety procedures, poor maintenance and misuse.

(iii) Materials handling

Construction materials like reinforcement bars, roofing sheets, nails and concrete are sharp, heavy and hazardous. Okoye, (2018) found reinforcement handling as high-risk work in construction sites. Types of accidents from materials handling include wounds from sharp objects, being hit by heavy objects, and inhaling toxic substances. Most of these accidents arose from poor handling of the materials.

(iv) Site organisation

Site organisation in terms of temporary fencing, physical working space, lighting and ventilation, access road, waste disposal, materials and equipment storage area are essential in providing safety in construction sites. Morshidiet, *et al.,* (2022) report that adopting lean construction tools, especially the 5S process, which includes sort, set, shine, standardize and sustain, will provide a safe workplace.

(v) Ground condition

The nature of the ground condition typically determines the type of foundation and the soil test to be conducted to transmit and carry the proposed structure's load safely. Failure to do the preliminary ground condition investigation may result in foundation failure, building collapse or part of it. Although John and Mohammed, (2020) found that building collapse or part of it constitutes 1% of the total construction accidents in Abuja, in most cases, its consequences are more than that of the other types of incidents.

(vi) Natural calamity

Natural calamities are unforeseen events which may result in loss of lives and property damage. These include landslides, earthquakes, flooding and hurricanes. Heinrich deduced that construction accidents due to natural calamity are rare and constitute 2% due to unpreventable conditions (Shahab and Jabaran, 2012). Most accidents from natural calamities result in massive loss of lives and properties.

(vii) Harsh weather condition

Most of the construction works are outdoor activities with high exposure to a harsh element of weather. Construction workers are exposed to different weather conditions, which affect the safety of their work. Extreme climatic factors like heavy rainfall, cold, heat, increased wind movement and light variation at higher altitudes affect workers' comfort (Li *et al.,* 2018). Poor visibility also affects safe

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work procedures. Therefore, harsh weather affects the work process and increases the risk of accidents.

Management Factors

The construction company management has a more significant role in providing safety or otherwise at the work site than any other project stakeholder. These include safety policy, personnel, PPE (Personal Protective Equipment), first aid and emergency safety provisions. The management role shall start from pre-construction through construction to post-construction. Failure to exercise appropriate safety measures in a particular project stage may lead to accidents, near misses, injury, loss of lives, or property damage.

(i) Safety policy

This is an in-house written policy statement, reflecting management principles and commitment toward health and safety management practices. Agbede *et al.,* (2016) cited a policy document detailing principles of action to achieve health and safety objectives as an example of organisation safety policy. Manu, *et al.,* (2018) found variations in safety policies and implementation among various countries. Effective safety policy and strict implementation will significantly improve safety practices.

(ii) Resource management

This is a general system to allocate and manage safety resources. These resources include human, financial, technical, communication and competence assessment (Agbede *et al.,* 2016). For example, lack of safety equipment, like PPE will expose workers to accidents. Also, the absence of safety personnel will make coordinating safety activities difficult at construction sites. Adeagbo *et al.,* (2019) recommend recruitment of safety personnel in every construction site. Providing human and material resources plays a significant role in safety management.

(iii) Safety culture

Safety culture is the product of individual or group values, attitudes, beliefs, perceptions, competence and behavior patterns that determine commitment to safety (Okolie and Okoye, 2012). In order to develop a safety culture for an organization, these critical steps should be followed: assessment of the state of an organization's safety culture, the identification and strengthening of the areas of weaknesses, monitoring and evaluation, and the encouragement of continuous learning and safety culture improvement (Chan *et al.,* 2012).

(iv) Education and training

Safety education and training aim to equip workers with basic knowledge of safe procedures. These include teaching safety procedures for different tasks. Physical demonstration with pictures, videos and computer applications. Modern safety training methods involve BIM, augmented reality, virtual games, etc. These programs used virtual representations of structures to identify possible hazards in various construction and safety strategies to prevent accidents (Alizadehsalehi, *et al.,* 2018). However, research finding reveals absent of training program for workers and site supervisors, no safety induction, and orientation for new workers in some construction sites (El-nagar, *et al.,* (2015).

Most unskilled construction workers are illiterate with agricultural work background and remain the significant victims of construction site accidents. In order to solve these problems, the Chinese construction industry has implemented an occupational certificate system to guarantee worker quality

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and competence (Li, *et al.,* 2018). All construction workers are to obtain a safety professional certificate that will qualify them to work.

(v) Management commitment

Management commitment is the level of dedication put to safety issues. These include provision of safety training, equipment and meetings. Also, management priorities safety under production pressure or when work falls behind schedule (Chen, *et al.,* 2017). However, when the management of an organisation neglects the provision of safety equipment and safety inspection or when priority is given to productivity, an accident will become rampant in construction sites.

External Factors

External factors are not included in the worksite, human and management factors. These consist of government policy and legislation, which should serve as the overseer of safety activities in the country. In addition, the social factors and the society's safety awareness have a role in accident prevention and control. Also, the economy covers the cost involved in safety issues.

(i) Government policy and legislation

The government has to enact laws and establish regulatory agencies to ensure compliance. Ringen *et al*., (2018) report that government regulation is the backbone of any health and safety system. Several countries have considered government policy implementation as a means of controlling construction accidents. These include the UK, USA, Vietnam, etc. (Manu *et al.,* 2018). Jacobus *et al.,* (2017) also recommended that legislation must be enforced and regularly communicated for improved construction safety performance.

(ii) Social

The society in which the project is situated is vital in ensuring workplace safety. When there is a lack of exposure and information about safety, society, clients, and other project stakeholders will neglect safety issues (Ja afar *et al.,* 2017). Consequently, society became exposed to construction hazards without proactive measures to control accidents. Therefore, construction safety management is a collective social responsibility that should not be neglected.

(iii) Economy

The economic factors concern with the direct cost of providing safety measures in construction sites. Because of their financial status, large-scale construction firms (multinational and national companies) have more safety facilities and operate in a safer way than small and medium firms (Kadiri *et al.,* 2014). According to Muiruri and Mulinge (2014), health and safety is a humanitarian and economic activity that requires financial commitment. However, Bavafa, *et al.,* (2016) found that due to the high costs of investing in the relevant safety measures, poor supervision by the governmental enforcement agencies undertaking the measures for entrenching a culture of safety performance is still considered peripheral in some countries.

Role of Project Stakeholders in Construction Health and safety

From the inception of a construction project, a temporary organization is created with roles and responsibilities of parties involved for benefit. The parties with interests, duties and responsibilities in the project are the project stakeholders. Freeman (2010) defines project stakeholders as individuals whose activities are affected by the organization. Althaqafi and Abunar (2017) reports that stakeholders in construction projects are clients, consultants, project managers, employees, contractors, subcontractors, suppliers,

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governments and legal authorities, insurance companies, competitors, customers and visitors. Project stakeholders are further subdivided into primary and secondary. The primary stakeholders directly impact the project and have formal contractual relationships. In contrast, the secondary stakeholders are indirectly engaged in the project activities.

All project stakeholders have vital contributions to make toward the project's success. Molwus (2014) recommends briefing stakeholders about the project's positive and negative aspects of the project. The accident is one of the negative factors that can hinder the project's success. Donkoh and Aboagye-Nimo, (2016) focus on the role of government, client, contractor and employee(s) as key project stakeholders. Roles and responsibilities of project stakeholders in project development life cycle are as follows:

(i) Governments are the custodians of safety policy, enacting laws through legislative approval and rules and regulation enforcement agencies.

(ii) The client is the owner and employer of other stakeholders apart from the government. When the government own a project, the role becomes double (client and regulator). The client has the most influence in promoting health and safety through establishing safety criteria and monitoring the implementation throughout the project's life cycle (Donkoh and Aboagye-Nimo, 2016). The client is responsible for employing designers and other consultants. They act on his behalf. Incorporating safety principles in the design will help promote safety during construction (Mihic *et al.,* 2019).

(iii) The contractor is the primary project constructor. Traditionally, the contractor is seen as the only safety promoter in project construction. However, research shows that other stakeholders have to play a role in ensuring construction safety (Althaqafi and Abunar, 2017). A contractor is responsible for staff safety training and providing resources and logistics to ensure safety compliance.

(iv) Employees are the various categories of labor employed by the contractor. Semi-skilled and unskilled labor are the people that are doing the physical erection of the project. These labor categories are more exposed to hazards, have a high risk of accidents and are the majority of construction accident victims (Wu *et al.,* 2015). Therefore, the safe work behavior of employees is one of the most important determinants of safety performance.

Interrelationship among Stakeholders' Safety Roles

Another important aspect of figure 1 is the network of interrelationship among the various roles and responsibilities of major project stakeholders that make up the system. It is indicated that when a stakeholder participates in construction safety, he has put an input in a system that has significant contribution to the whole. In contrast, lack of safety management input from a particular stakeholder will break the network, and the system become ineffective regardless of the effort of other stakeholders (Phoya and Pietrzyk, 2019).

Safety Performance Output

Safety practices roles of key project stakeholders is expected to control the negative impact of construction hazards to produce safety output. These comprises: safe work environment, safe work behavior and coordinated safety system. Safe work behavior consists of safety compliance and safety participation. Safety compliance is the obedience to safety rules and regulations. The performance of workers' safety behaviour can be measured by the level of their safety

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compliance (Shin *et al.,* 2015). Many researchers recommend the use of the level of workers' safety behaviour while at work as a proactive approach to measure safety performance (Patel and Jha, 2016). Safety compliance include the use of right PPE and strict adherence to safety rules and procedures. Safety participation refers to the level of workers' involvement in safety activities. How workers involve in the promotion of safety in their interaction with other workers and safety officer in construction site. The performance of workers' safety behaviour can also be measure by the level of their safety participation (Shin *et al.,* 2015). It is also part of proactive approach to control accidents and measure safety performance. Safe work environment can be achieved through effective site organisation. Site organisation in terms of temporary fencing, physical working space, lighting and ventilation, access road, waste disposal, materials and equipment storage area are essential in providing safety in construction sites. Morshidiet, *et al.,* (2022) reported that adopting lean construction tools, especially the 5S process, which include sort, set, shine, standardize and sustain, will provide a safe workplace.

Safety Performance Outcome

Safety performance improvement is the overall outcome of health and safety management. It is the measure of the achievement recorded by safety practices. Patel and Jha (2016) identified safety performance indicators as number of fatal and non-fatal accident, illness, stakeholders' satisfaction, reputation of company and project success at the end of the project completion. Shin *et al.,* (2015) described workers' safety behaviour as a leading indicators of safety performance when work is in progress. But Patel and Jha, (2016) classified workers' safety behavior as safety output. While Li *et al.,* (2018) describe it as critical success factors of safety performance. Both reactive and proactive measures have advantages and disadvantages. Therefore, safety performance outcome described the overall achievement of safety practice.

Minimizations of Accident

Safety performance is linked to the occurrence of fatal and nonfatal accident at site. According to Patel and Jha, (2016) if the number of accident is lower the safety performance is higher and vice versa. Access to exact construction accidents figure is one of the constrain of research in safety performance in Nigeria (Eguh and Adenaiya, 2020). But various research findings indicate high rate of accident in construction industry. Therefore, construction safety performance is low and there is need for further improvement.

Project success

A project is said to be successful when it met the expected time, cost and specified quality target. Construction accident is known to have significant negative effect on project success. According to Jacobus *et al.,* (2017) project management team paid more attention on time, cost and quality and neglect health and safety issues. When accident occur, project success parameter became grossly affected. Therefore, level of project success as a result good health and safety management is one of the parameters to assess safety performance.

Preserve Reputation of company

Construction accident has a negative effect on the image and reputation of the construction company. Asanka and Ranasinghe, (2015) are with the view that accidents may change the organizational goals or it could even make the company uncompetitive in the industry. Also, large construction firms maintain safety standard in order to maintain and enhance the image of the firm. There is also agitation that companies with high accident rate should be

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penalized. Also, Donkoh and Aboagye-Nimo, (2016) recommend that prospective contractors' track record of safety performance should be a criterion for tender evaluation. One of the punitive way is to disqualify a company with poor safety performance in securing future work. This will consequently affect the company's reputation.

Stakeholders Satisfactions

Stakeholders are said to be satisfied when project objectives were met. Construction accident has a negative effect on the image and reputation of a company. Asanka and Ranasinghe (2015) are with the view that accidents may change the project objectives. Stakeholders become dissatisfied with project success when expected target were not meet.

CONCLUSION

This paper used Heinrich domino theory of accident causation and System Dynamic theory to explain various causes of accident in building construction work appropriate intervention measure for control. The review of the theories highlights the significance of the stakeholder safety management roles in accident prevention and control. To operationalise the theories, this paper developed a conceptual framework that will simplified the safety management process of

Recommendation

This paper gives highlight of the theoretical and conceptual framework for stakeholders' safety management framework for the mitigation of accident in building construction projects. As mentioned earlier, this paper is part of an ongoing PhD thesis titled Safety Management Framework for Mitigation of Accidents on Building Construction Projects in Abuja, Nigeria. Therefore, there is need to carry out an appraisal in the study area in order to find out what is the practices and what is need to be done to improve safety performance. The result of the evaluation will guide the development of the final framework.

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