APPLICATION OF MODIFIED STATISTICAL TRIANGLE OF ACCIDENT CAUSATION IN CONSTRUCTION HEALTH AND SAFETY

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Abstract. The purpose of the paper is to investigate safety hazard identification in the construction industry towards the improvement of employee's health and safety (H&S). Unidentified hazards in the construction industry are likely to present the most unavoidable risks. Therefore, hazard identification is paramount to construction safety management since risk assessment is the practical means by which hazardous events are managed. The study is mainly literature review with reference to existing theoretical literature, published and unpublished research. The paper presents an overview of hazards and accident causation. The findings from the study have shown that falls at construction sites are the leading cause of death and most of these deaths were attributed to falls from roofs, scaffolds, and ladders. Construction accidents lead to delay in project completion, increase the expenses and ruin the reputation and reliability of constructors. The following were identified as some of the barriers to H&S improvement: lack of information sharing across projects, full-time safety department, subjective nature of hazard identification and risk assessment. The study explores safety hazard identification in the construction industry towards the improvement of employee's H&S. The study presents a strong background on hazard identification in the construction safety management.

Keywords: Accident causation; construction; health and safety; modified statistical triangle

1 Introduction

Construction projects, especially large ones, are complex and dynamic and the workers might work an average of only 1,500 hours in a year while workers in manufacturing, for example, are more likely to work regular 40 hour weeks and 2,000 hours per year (Weeks, 2011).The construction industry has always been blamed for the high rates of accidents and fatalities despite its contributions to economic growth. The construction industry has been placed among the industries with unreasonable rates of accidents, permanent and non-permanent disabilities and even fatalities (Abdul Hamid et al., 2003). The construction industry plays an important role in improvement of any countries' economic growth. The proportion of gross domestic product (GDP) in industrialized countries varies widely and construction is about 4% of GDP in the United States, 6.5% in Germany and 17% in Japan (Weeks, 2011). According to report by National Safety Council (NSC) 1000 construction workers died at work and 350,000suffered disabilities in 1996. Construction workers constitute only 5% of the United States' workforce, an out of proportion rate of 20% of all occupational fatalities and 9% of all disabling occupational injuries relate to construction industry (Abdelhamid & Everett, 2000).

High rates of accidents and fatalities in this industry have placed it among hazardous industries (Hosseinian & Torghabeh, 2012).The costs of injuries, which are direct and indirect, workers' compensation insurance, legal liability as well as legal prosecutions have pushed parties involved to seek ways of mitigating these hazards. The world rates of occupational injuries, illnesses and fatalities are still alarming (Weeks, 2011). Construction workers are exposed to a wide variety of health hazards on the job. Exposure differs from trade to trade, from job to job, by the day, even by the hour. Exposure to any one hazard is typically intermittent and of short duration, but is likely to reoccur (Weeks, 2011). Construction accidents lead to delay in project completion, increase the expenses and ruin the reputation and reliability of constructors (Wang & Chou, 2006). In 2009, falls accounted for more than one third of fatal occupational injuries in construction (34%). Nearly half (48%) of all fatal falls in private industry involved construction workers (OSHA, 2011). In the period 1992- 2005, about one-third of the fatal falls in construction were from roofs, 18% were from scaffolding or staging, 16% were from ladders, and 8% were from girders or structural steel. The other 25% of fatal falls includes falls through existing floor openings, from nonmoving vehicles, from aerial lifts, etc. (OSHA, 2011). According to Gambatese & Hinze (as quoted by Hosseinian & Torghabeh, 2012) high rates of accidents and fatalities have placed the construction industry among hazardous industries. Hazard has been defined by FOCUS 4 (nd) as a condition that is likely to cause injury, illness or death to a worker. Wang and Chou (2006) asserted that the world rates of occupational injuries, illnesses and fatalities are still alarming. Construction accidents can be prevented by identifying the root causes of accident. Since research has shown that fall hazards is the leading cause of accident in construction industry. This paper

presents an investigation of safety hazard identification within the construction industry. It began with a discussion of major types of falls in the construction industry, barriers to improving hazard identification. This is followed by the preventive measures for fall hazards, OSHA's fall protection standards and control and management of hazards in construction based on modified statistical triangle of accident causation within the context of how hazards leads to accidents.

2 Literature review

According to the construction chart book (CPWR, 2007), more iron workers are killed from falls than workers in any other construction occupation. The rate of work-related deaths among ironworkers is 10 times higher than the construction average. Falls remain the leading cause of death for workers engaged in residential construction, with an average of 40 workers suffering a fatal fall from a residential structure each year (Firl, 2012). According to data from the U.S. Bureau of Labor Statistics an average of two construction workers die each day in the United States. Deaths and injuries from falls represent a major, persistent. In 2010, the 9.1 million construction workers (including self-employed workers) in the United States accounted for 7% of the national workforce, yet experienced 17.1% of fatal work-related injuries. In 2011, the rate of fatal injuries in construction was the second highest of any U.S. industry. Within the industry, falls at construction sites are the leading cause of death, accounting for 35% of deaths among private sector construction workers (not including government or self-employed workers) in 2011; most of these deaths were attributed to falls from roofs, scaffolds, and ladders. Deaths and injuries from falls represent a major, persistent, yet preventable public health problem (CDC, 2013). According to Finneran and Gibb (2013) construction is one of the most hazardous industry sectors with many thousands of workers being killed and seriously injured each year all over the world. Even though there has been progress over the years but there is still a long way to go to reach the vision of an industry where people return home at the end of a shift healthier than when they arrived. Good H&S management leads to project wide benefits. Finneran and Gibb (2013) further asserted that H&S in construction is about using appropriate means to ensure workers are both safe and healthy. Occupational fatalities caused by falls are a serious concern which will help employers to identify fall hazards at construction sites to enable them protect their employees (OSHA, 2011). Accident prevention has been defined by Heinrich as 'an integrated programme, a series of coordinated activities, directed to the control of unsafe personal performance and unsafe mechanical conditions based on certain knowledge, attitudes, and abilities'(Abdelhamid & Everett, 2000).

Some other synonyms for accident prevention have been emerged later such as loss prevention, loss control, total loss control, safety management, incidence loss control (Abdelhamid & Everett, 2000). Since all hazards in construction work-

places are not always possible to be identified and eliminated therefore, effective accident investigation programmes are essential to get the required data (Hosseinian and Torghabeh, 2012 & Cliff, 2012). However, unidentified hazards negate the risk assessment process; risks cannot be assessed and control measures developed and implemented if those involved are not aware of the hazard in the first place. Hosseinian and Torghabeh (2012) in their research on major theories of construction accident causation models concluded that accidents and incidents in construction workplaces are unplanned and unwanted occurrences which involves movement of persons, objects or materials which may result in injury, damage or loss to property or people. They further asserted that not all accidents are preventable since risk is beyond the human intervention. Therefore, manner workers need to be watchful, and strategies are required to manage risk and improve upon it. They concluded by saying that majority of accidents happen when employees disregard safety rules (unsafe acts) and management ignore the presence of unsafe conditions.

3 Major types of falls in the construction industry

Unprotected roof edges, roof and floor openings, structural steel and leading edges have identified as the major types of falls in the construction industry. Since almost all sites have unprotected sides and edges, wall openings, or floor holes at some point during construction. If these are not protected, injuries from falls or falling objects may result, ranging from sprains and concussions to death (OSHA, 2011). Factors such as improperly covered or protected floor holes and openings are a common fall hazard because it is easy for an employee step into a hole or opening when carrying something that blocks his view. This implies that falls to a lower level are a major cause of fatalities in construction.

3.1 Roofing, siding and sheet metal

Roofing, siding and sheet metal work have the highest rate of occupational injuries and illnesses for a non-manufacturing industry. Roofing and fall protection and unprotected sides and edges is one of the most frequently cited serious violations of OSHA. Fall protection, fall hazard training and fall protection for connectors have been cited as the most frequently serious OSHA violations (OSHA, 2011).

3.2 Improper scaffold construction

Without fall protection or safe access, it becomes hazardous for employees working with heavy equipment and building materials on the limited space of a scaffold. Falls from improperly constructed scaffolds can result in injuries ranging from sprains to death (OSHA, 2011). Majority of the employees are injured in scaffold accidents and it is in connection with planking or support giving way, or to lack of guardrails or other fall protection. OSHA's most frequently cited serious scaffold violations include lack of fall protection; scaffold access; use of aerial lifts without body belts and lanyards, platform construction and no worker training (OSHA, 2011).

3.3 Unsafe portable ladders

There is risk in falling if a portable ladder is not safely positioned each time an employee uses it. This may lead to slippery from its supports and an employee may lose balance while getting on or off an unsteady ladder. This incident may cause injuries ranging from sprains to death. According to OSHA, (2011) BLS data show that falls from ladders account for over 100 fatalities each year. Factors that contribute to falls from ladders are ladder slip (top or bottom), overreaching, slipping on rungs/steps, defective equipment and improper ladder selection for a given task. Frequently cited OSHA ladder violations include not having a portable ladder extend 3 feet above the landing, no worker training, and improper use of the top of stepladders.

4 Barriers to improving hazard identification

Carter & Smith (2006) in their research on Safety Hazard Identification on Construction Projects identified the following as barriers to H&S improvement.

1. Knowledge and information barriers:
   - Lack of information sharing across projects;
   - Lack of resources on smaller projects, e.g., industry publications, full-time safety department, etc.
   - Subjective nature of hazard identification and risk assessment
   - Reliance upon tacit knowledge.

2. Process and procedures barriers:
   - Lack of standardized approach;

- Undefined structure for tasks and hazards (Carter & Smith, 2006).

5 Preventive measures for fall hazards: Use fall protection equipment

The three generally acceptable methods of protection for workers on a construction site who are exposed to vertical drops of 6 feet or more are guardrails, safety net systems and personal fall arrest systems. Guardrails are considered prevention systems, as they stop an employee from having a fall in the first place.

Safety net systems are designed to catch an employee and break his fall. They must be placed as close as practicable under an employees working surface, but never more than 30 feet below. A personal fall arrest system consists of an anchorage, connectors, and a full-body harness that work together to break any fall (OSHA, 2011). It is advisable to use fall prevention systems, such as guardrails, than fall protection systems, such as safety nets/fall arrest devices, because prevention systems provide more positive safety means. Scaffold work requires guardrails or a personal fall arrest system on any platform 10 feet or higher. Safe access must be provided by employers for employees to prevent them from climbing cross-bracing as a means of access (OSHA, 2011).

6 Training

Employees should be trained on how to protect themselves whenever they are exposed to fall hazards. Employees must be able to recognize the hazards of falling and explain the procedures to be followed in order to minimize fall hazards. The training should include the use of scaffolds (OSHA, 2011).

6.1 OSHA's fall protection standards

OSHA's fall protection standards require employers to provide fall protection for employees when they are exposed to a fall hazard. The standards cover hazard assessment, fall protection and safety monitoring systems. Controlled access zones, safety nets, and guardrail, personal fall arrest, warning line and positioning device systems are also addressed (OSHA, 2011). Employers are required to assess the workplace to determine if the walking/working surfaces on which they are to work have the strength and structural integrity to safely support workers. Employees are not permitted to work on those surfaces until it has been determined that the surfaces have the strength and structural integrity to support all workers.

Once employees have determined that the surface is safe for workers, the employer must select one of the permitted types of fall protection for the work operation if a fall hazard is present. Works at a falling height of 6 feet or more from an unprotected side or edge requires a guardrail system, safety net system, or personal fall arrest system to protect the employee (OSHA, 2011).

6.2 Proper scaffold construction

Employers must construct all scaffolds according to the manufacturer's instructions. A "competent person" must supervise as scaffolds are erected, moved, taken apart or changed, and must inspect the scaffolding. A guardrail system or a personal fall arrest system is required for scaffolds more than 10 feet above a lower level. In addition, employers must provide safe access to scaffold platforms (OSHA, 2011).

6.3 Worksite maintenance

Poor worksite maintenance can lead to clutter and debris on a construction site, creating additional slip, trip and fall hazards. Poor maintenance of ladders, scaffolds and fall protection equipment can also lead to serious injuries. Employers are required to keep worksites free of form and scrap lumber with protruding nails and other waste and trash, including combustible debris (OSHA, 2011).

6.4 Control and management of hazards in construction

Control and management of hazards in construction are in two main forms namely: avoidance of occurring of hazardous event and restricting the severity potential of hazards when the hazard happens. The first step is preventive control measures which include practices to restrict the entrance of hazardous event into the triangle by lessening the probability of happening of the hazard. Precautionary control measures are at the second step which is designed to restrict the movement of hazardous event through the upper part of the triangle; this step lessens the risk via lessening the severity of the hazard if it happens (Carter & Smith, 2006).

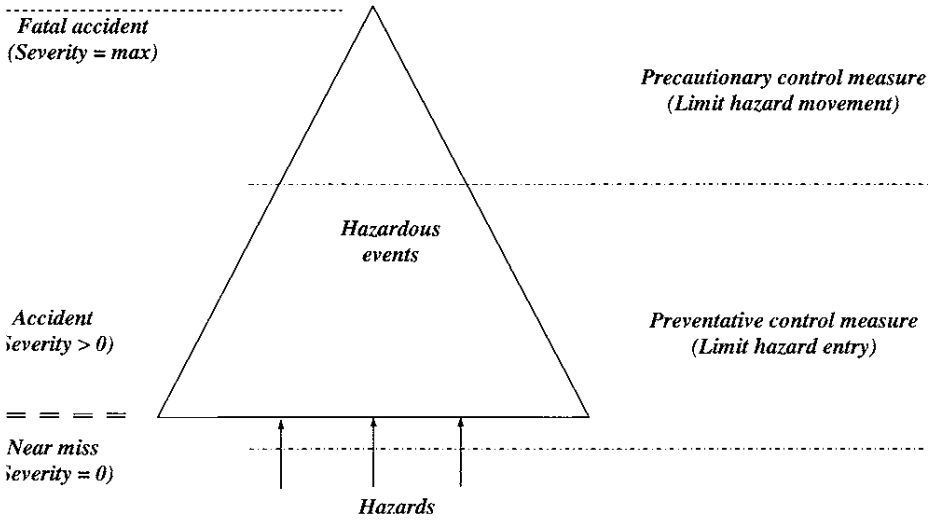

Figure 1: Modified statistical triangle of accident causation
Adapted from Hosseinian and Torghabeh (2012) & Carter and Smith (2006).

The location where hazard will be placed when hazard happens is known as 'hazardous event' which is the base of the triangle as shown in (figure 1).The severity of the hazard will 'determinism' the term used for the lower base of the triangle. This means that a hazardous event with no physical injury for instance zero severity (Carter & Smith, 2006). The intermediate part of the triangle represents the area of severity greater than zero. This implies that the hazardous event causes an accident with physical injuries. The highest point of the triangle represents the most hazardous event. This on the other hand implies the accident occurs and the result is fatality and loss of human life in the movement of the hazard up the triangle (Carter & Smith, 2006).

Carter and Smith (2006) asserted that to obtain the general rationale for performing all safety risk assessments the hazards should be considered in terms of their probability of occurrence and severity of consequence as shown below:

1. Estimate the probability of a hazard's occurrence, i.e., its frequency, and its probable severity if it does occur;
2. Evaluate the risk associated with the hazard based upon the frequency and severity estimations
3. 3. Respond to the hazard by implementing suitable control measures

The discussed accident causation and risk control scenario shown in (figure 1) has one major assumption. That is the hazard is identified in the first place. If a hazard is not identified it will have the following:

1. Complete freedom of entry into the triangle, i.e., the hazard will have an uncontrolled probability of occurrence
2. Complete freedom of movement within the triangle, i.e., the hazard will have an uncontrolled severity if it does occur (Carter and Smith 2006).

7 Findings

The study shows that construction is one of the most hazardous industry sectors with many thousands of workers being killed and seriously injured each year all over the world. Construction accidents lead to delay in project completion, increase the expenses and ruin the reputation and reliability of constructors. These incidents have placed it among the industries with unreasonable rates of accidents both permanent and non-permanent disabilities and even fatalities. Falls at construction sites are the leading cause of death and most of these deaths were attributed to falls from roofs, scaffolds, and ladders. Deaths and injuries from falls represent a major, persistent, yet preventable public health problem. The following were identified as barriers to H&S improvement: lack of information sharing across projects, lack of resources on smaller projects such as industry publications, full-time safety department, subjective nature of hazard identification and risk assessment, reliance upon tacit knowledge, lack of standardized approach and undefined structure for tasks and hazards. Not all accidents are preventable since risk is beyond the human intervention and majority of accidents happen when employees disregard safety rules (unsafe acts) and management ignore the presence of unsafe conditions. However, unidentified hazards negate the risk assessment process; risks cannot be assessed and control measures developed and implemented if those involved are not aware of the hazard in the first place.

8 Conclusion

It can be concluded from the findings that construction accidents lead to delay in project completion, increase the expenses and ruin the reputation and reliability of constructors. Falls at construction sites have been identified as the leading cause of death and most of these deaths were attributed to falls from roofs, scaffolds, and ladders. The findings has also shown that not all accidents are preventable since risk is beyond the human intervention and majority of accidents happen when employees disregard safety rules (unsafe acts) and management ignore the presence of unsafe conditions. However, unidentified hazards negate the risk assessment process; risks cannot be assessed and control measures developed and implemented if those involved are not aware of the hazard in the first place.

These accidents can be prevented by identifying the root causes through accident investigation techniques such as modified statistical triangle of accident causation.

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