

Factors that Impact Construction Workers' Hazard Recognition Ability and their Technological Solutions

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Abstract: Hazard recognition is considered as one of the pre-requisites for effective hazard management and injury prevention. However, in complex and changing environments, construction workers are often unable to identify all possible hazards that can occur in the jobsite. Therefore, identification of factors that impact hazard recognition in the work environment is necessary to reduce safety incidents as well as to develop strategies that can improve worker's hazard recognition performance. This study identified factors/problems that impact worker's hazard recognition abilities and suggested some potential technologies that can mitigate such problems. Literature reviews of journal articles and published reports related to hazard recognition studies were conducted to identify the factors. The study found out that the major factor responsible for affecting worker's hazard recognition abilities were human-related. Industry factors, Organizational factors and Physical factors of the site were the other factors identified from the study that impact worker's hazard recognition performances. The findings from the study can help site personnel recognize areas where effective measures can be directed towards worksite safety of workers while working in complex construction environments.

Key words: Hazard recognition, Construction, Factors, Hazard performance, Impacts

1. INTRODUCTION

The construction industry involves working in dangerous and hazardous environments. Statistics has shown that the number of occupational work fatalities recorded in the United States in year 2020 was 4,764 with an injury rate of 3.4 fatalities per 100,000 full-time equivalent workers [1]. Furthermore, the statistics in Figure 1 shows that construction industry led all industries in total number of work fatalities (1,008 fatal injuries) in the year 2020. These numbers suggest the need for more research and innovations in the field of hazard recognition and construction safety. The dynamic and changing nature of workplaces makes it difficult to identify all the hazards in the

jobsite. Therefore, it is important to identify areas where prevention efforts can be directed towards job site safety along with providing effective measures for preventing safety incidents [2].

Number of fatal work injuries

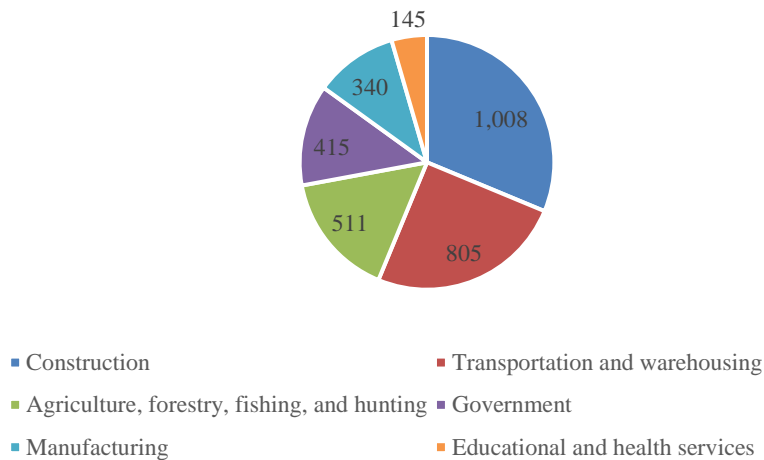


Figure 1: Number of fatal work injuries in construction industry in year 2020[1]

In the jobsite, construction workers are required to identify hazards in the work environment and assess the potential outcomes that can emerge from the identified hazards. Due to the diverse and dynamic nature of construction sites, construction workers are often unable to recognize hazards, and they are challenged to properly and timely identify all possible hazards that can occur in the jobsite. When hazards remain unrecognized, the likelihood of injuries increases in a site. Hazard recognition is considered as one of the pre-requisites for effective hazard management [3] and injury prevention [4]. Hazard recognition efforts are important to maintain workplace safety and reduce safety incidents. The identification of factors that impact hazard recognition is necessary to reduce possible injuries as well as to develop strategies that can improve worker’s hazard recognition performance.

This study aims to identify the problems associated with worker’s hazard recognition abilities using literature review. The identified problems were categorized in case-by-case basis. After identification of the problems, potential technologies that can mitigate the problems was also investigated from relevant literatures.

2. METHODOLOGY

Based on the research objective, literature review was conducted to identify the problems associated with worker’s hazard recognition abilities and potential technologies that can address the problems. The research methodology in this review process consists of three steps as shown in Figure 2. We first conducted literature search by using specific keywords, such as hazard recognition, construction, factors and impacts in the “Scopus” search engine. Then, after thoroughly reviewing the retrieved articles, a list of factors that impact workers’ hazard recognition ability was prepared. After identification and listing process, these factors were grouped into case-by-case basis along with their potential mitigation measures/technologies. Detailed analysis on these found articles follow in the next section.

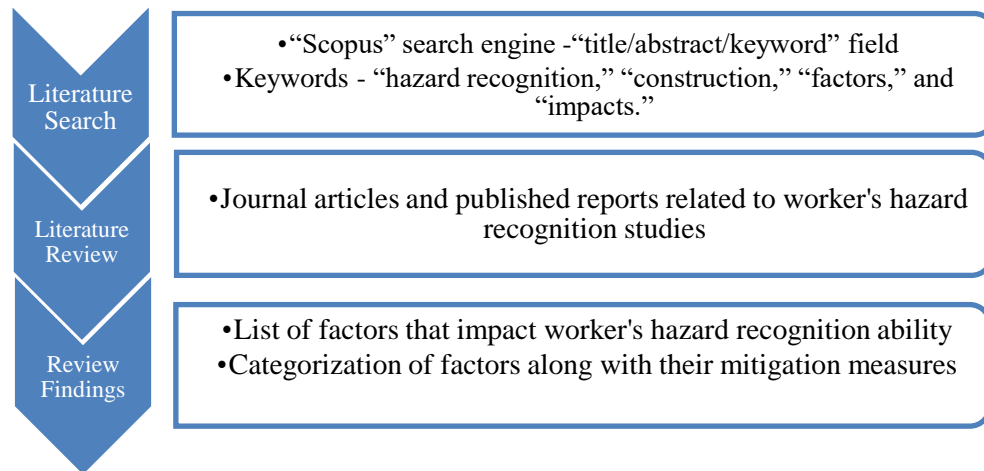


Figure 2. General Approach of the Study

3. ANALYSIS AND DISCUSSION FROM THOROUGH REVIEW

3.1. Factors impacting hazard recognition

Literature reviews on previous hazard recognition studies were conducted for the study. Using construction case images from real construction workplaces in the United States, Jeelani et al (2017) found that 'selective attention or inattention to certain hazard types' is the most common reason that led to unrecognized hazards. Furthermore, the study concluded that 'unknown potential hazard set' and 'the perception that certain hazards impose low levels of safety risk' were the other factors that can impede hazard recognition.

Similar study by Uddin et al [4] emphasizes in understanding certain hazard categories that construction workers are proficient to recognize as well as certain categories the workers fail to recognize. To achieve the research objective, the authors collected 16 construction case images from actual construction workplaces and assessed with a group of 17 construction industry safety professionals to enlist all safety hazards that were represented in the case images. The study provided evidence suggesting that the workers are more proficient in recognizing certain hazard categories that include gravity, electrical, motion and temperature hazards whereas the workers are less proficient in recognizing hazards related to pressure, chemical and radiation hazard categories.

Previous studies have been successful in demonstrating the relationship between hazard detection and eye movements. Hasanzadeh et al [5] used construction scenario images to determine relationship between worker's hazard identification skills and their visual attention. Using multivariate ANOVA analysis, the study found that the worker's hazard identification skills can significantly impact the worker's visual search strategies related to ladders, falls to lower levels, fall -protection systems, struck by situations and housekeeping. Upon investigating worker's hazard identification skills, the authors concluded that certain eye movement metrics like fixation count can be helpful in predicting workers' hazard identification capabilities.

Abdelhamid & Everett [2] investigated various root causes, which are responsible behind occupational hazards using accident root causes tracing model (ARCTM). The study concluded

that construction workers have difficulties in identifying potential safety hazards in workplace due to one of these factors: (1) Human factors (2) Non-human-related events (3) Inexperienced worker or new worker on site (4) Physical factors of site. Moreover, OSHA [6] states that physical worksite characteristics such as working in confined spaces could also impair worker's ability to recognize threat and escape from the space in the event of injury. Bhandari et al [7] focused on summarizing progress made in the construction safety field on measuring and improving hazard recognition performance of workers. Using literature review, the authors concluded that human cognitive skills are not naturally attuned to recognize hazards and the problems gets compounded when the work environments are unplanned or dynamic.

Derived from literature review, Table 1 shows the list of factors that can affect construction worker's hazard recognition capabilities.

Table 1: Factors that impact worker's hazard recognition

S. No.	Group Categories	Factors that impact hazard recognition
1	Human factors	Selective attention or inattention of workers to certain hazard types [3]
		Perception of workers that certain hazards impose low levels of safety risk[3]
		Human cognitive skills [7,8]
		Workers with low hazard-identification skills[5]
		Unsafe position or posture of workers[2]
		Use of defective tool or equipment[2]
		Overexertion, Cumulative trauma disorders, Fatigue, Toxic poisoning, Mental disorders [2,9]
2	Industry factors	Unknown potential hazard set[3]
		Less proficiency of workers in recognizing hazards related to pressure, chemical and radiation hazard categories[4]
		Unplanned work environments[7]
		Hazard visibility (hot surfaces)[8]
3	Organizational factors	No sufficient training or knowledge /New or inexperienced workers[2]
		Improper assignment of personnel[2]
4	Physical factors of site	Confined spaces [6]
		Weather conditions (heat stress)[8]
		Housekeeping practices [2]
		Hazardous arrangements[2]

3.2. Use of technologies for improved hazard recognition of workers

Past studies have shown that most of the factors that impacts hazard recognition is human related and the problems get even worse in loud and harsh environments. In complex construction work environment, workers have difficulties in recognizing hazards due to limited sensing abilities. Addressing this issue, Cho & Park [10] developed an embedded tactile sensory system which enabled construction workers to better perceive their surroundings about impending hazards. This system offered workers an artificial sensing ability by using tactile signals which delivered safety information to the workers effectively. Sakhakarmi et al [11] proposed a communication method for workers using tactile based wearable system to communicate potential hazard information through vibration signals. This system helped alerting workers for potential collision hazards even in harsh environments where their vision and hearing are limited.

Contact-driven hazards of workers with mobile equipment and vehicles (mobile robots) can also arise in construction work environments. Kim et al [12] predicted risk of impending collision between mobile robots and workers using computer vision and deep neural network program. This proximity prediction enabled mobile robots to detect impending collision in advance and accordingly take alternative paths beforehand. The system is also capable of providing advance alerts to workers through wearable devices. Furthermore, Park et al [13] developed a Bluetooth low energy (BLE) based proximity safety alerts system to provide proximity alerts for workers and equipment operators. The proposed method was also able to address the limitation of variations caused by different equipment settings such as equipment types and approaching speeds.

Study by Li et al [9] used eye-tracking technology to measure and quantify mental fatigue level of equipment operators' and their hazard detection ability. The study found that the operator's hazard detection performance decreased when they experienced mental fatigue through the application of eye-tracking technology thereby providing a basis for developing safety interventions. Additionally, the use of eye tracking technology have been adopted to evaluate worker's hazard detection capabilities by investigating the impact of site conditions on workers' cognitive ability[14]. The use of radio frequency identification RFID based technologies like real time locating system (RTLS) have been discussed to provide alerts to the workers by monitoring equipment and workers in site [15].

Table 2 shows the summarized list of potential problems with hazard recognition and some technologies used to address them.

Table 2: Problems and technologies associated with hazard recognition

S. No.	Problems	Technology based solutions
1	Limited sensing abilities of workers in complex working environments	Embedded tactile sensory system[10]
2	Potential collision hazards in complex working environments	Tactile based wearable system [11]
3	Potential collision between workers and mobile equipment/robots	Computer vision and deep neural network program[12]

4	Potential collision between workers and equipment operators	BLE based proximity safety alert system[13]
5	Hazard detection capabilities of workers	Eye tracking technologies[9,14]
6	Monitor equipment and workers in site	RFID based technologies [15]

4. CONCLUSION

Using literature reviews, this study identified factors associated with worker’s hazard recognition ability in construction industry. The study found out that the major factor responsible for affecting worker’s hazard recognition abilities were human-related. Furthermore, literature reviews showed that workers’ sensing abilities get limited in complex environments which affect their abilities to perceive impending hazards. The secondary factors identified from the study impacting worker’s hazard recognition were Industry factors, Organizational factors, and Physical factors of the site.

In addition, the study explored some technologies that can address problems associated with worker’s abilities for hazard recognition. The use of such technologies addressed the challenge of limited sensing abilities of workers and helped workers to better perceive the harsh construction environments. This consequently reduced the chance of human error in work environments and enhanced the safety and security of workers in the site. The findings from the study can help recognize areas where effective measures can be directed towards worksite safety of workers while working in complex construction environments. In addition, this study can serve as a basis for site personnel to become aware of the problems associated with hazard recognition especially in complex and dynamic working environments and develop appropriate strategies or technological solutions.

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