A Review of Social, Physiological, and Cognitive Factors Affecting Construction Safety

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Abstract -

Safety improvement in construction remains a high priority due to the significant rate of accidents compared to other industries. Despite the ongoing multitude of safety studies and policy recommendations concerning the high rate of injuries and casualties in construction, the extent of damage sustained is still significant. Major research studies in construction safety are focused on identifying conditions and causal factors leading to near misses, incidents, and accidents. This paper aims to provide a review of such literature in construction safety from social and individual perspectives. Three major categories of construction safety factors, i.e., social, physiological, and cognitive factors, are synthesized, and the main findings in each category are presented. Implications of the findings are further discussed to guide the research and practice in construction safety management.

Keywords –

Construction; Safety; Social Factors; Physiological Factors; Cognitive Factors

1 Introduction

Improvement of safety in construction sites remains a vital concern due to the high rate of accidents compared to other industries [1, 2]. In addition to the high rate of injuries and casualties in construction industry, the complex and unpredictable nature of work is adding to the importance of safety improvement for construction sites [3]. Construction workplace safety has been extensively studied [4], and human unsafe behaviour and error were recognized as some of the direct causes of accidents [5-7]. Many research studies in construction safety are focused on identifying conditions and causal factors leading to near misses, incidents, and accidents, which in this paper will be classified to aid construction industry with the aim of improving safety. This paper provides a review of such literature in construction safety, aiming to clarify reasons leading to an unsafe act, from social and individual perspectives.

Through a systematic review of the literature, aiming to clarify reasons leading to an unsafe act, three major categories have been considered and studied in this research. Due to the connection and collaboration among workers and other construction personnel in construction sites, social factors have been viewed as one of the major categories to identify attributes related to accident occurrence. Furthermore, due to the demanding nature of construction work and the rough environment of its working place, physiological conditions of individuals are another set of factors discussed in this paper. In addition to social and physiological factors, cognition has been considered as another category of factors in construction safety, which relates to the way workers perceive information, think and decide. Therefore, the construction industry can benefit from a systematic review of social, physiological, and cognitive factors that have not been presented in the current body of knowledge.

In the following sections, a literature search for construction safety is presented and significant social, physiological, and cognitive factors extracted from the literature are discussed. Afterward, some discussions on the implications of findings in addition to the challenges and opportunities are presented.

2 Literature Search

In the search of representative factors influencing construction safety in each major category (i.e., social, physiological, and cognitive), keywords have been chosen based on the number of published papers. The number of the literature linked to each keyword was counted in order to see a distribution of the literature in each major categories. Figure 1 shows the number of the literature that appeared relevant to the subject in six different publishers (i.e., ASCE, Elsevier, Taylor and Francis, Springer, IEEE, American Psychological Association). These factors were reviewed in this paper to give readers a broader view while supporting the majority of research in construction safety.

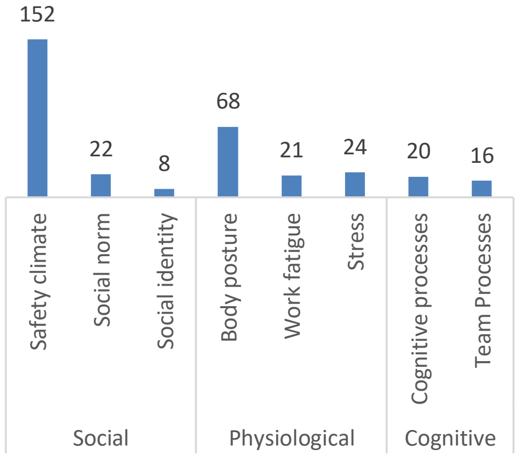

Figure 1. Distribution of the literature in each major categories of factor affecting construction safety

3 Social Factors

Safety in construction sites is not only related to the isolated act of workers, but also the social interactions resulted from the collaboration and communication among workers in such a dynamic environment. Therefore, investigating workers' safety behaviours from a social point of view has attracted researchers' attention. The following section will briefly present safety climate and social norm and identity as the social aspects of workers' safety behaviours.

3.1 Safety climate

Safety climate is defined as a subordinate of organizational climate and management commitment to safety, which determines workers' view toward safety in their workplace [8]. Safety climate has been considered as an effective component in the safe behaviour of construction workers [9] and is considered to have a higher impact on improving safety when compared to factors associated with workers experience (e.g., it is more practical to improve management commitments to safety instead of recruiting workers with more work experience) [10]. Therefore, understanding the factors contributing to the safety climate will have a positive outcome through the safe conduct of work in construction sites.

For measuring safety climate, Zohar in 1980 established an eight-factor model and concluded that a change in management attitudes and increased commitment are essential for safety in industrial workplaces [8]. In 1986, Brown & Holmes established a three-factor structure on an American sample of production workers for assessing safety climate [11]. Following the research conducted by Zohar [8] and Brown & Holmes [11], Dedobbeler & Blend [12] presented a two-factor model by using data on nine nonresidential construction sites in Baltimore, MD. The two selected factors for measuring safety climate were (a) management's commitment to safety and (b) workers' involvement in safety with the overall emphasis on management and workers' participation in safety matters.

Core components of safety climate approach have been identified as (a) safety priority, (b) safety supervision, training, and communication, (c) safety involvement, and (d) safety rules and procedures [13].

In addition to the identified factors in safety climate, the impact of five specific safety climate factors (i.e., safety management systems and procedures, management's commitment, safety attitudes, workmate influence, and employees involvement), and four other factors associated with workers' experience were investigated. The results indicated the higher impact of safety climate factors on improving safety when compared to workers' experience factors [10].

3.2 Social norm and social identity

The other social factor that has been considerably studied in the literature is the effect of social norms and social identities on workers' safety behaviour. This is due to the importance of social influence on construction worker's safety behaviour. [14] demonstrated the effect of social influence by adopting a virtual reality system in a hazardous situation. Social norm driven from co-workers and managers influences workers' safety behaviour and could be responsible for workers' unsafe act [15].

In social context, social identity theory explains that people categorize themselves and others into different social groups with specific group members' behaviour [16]. When a specific group identity is salient in an individual's mind, that person considers herself or himself as a representative of the group and is eager to align with group norms, which would affect her or his behaviour [17]. Choi et al. studied the role of social norm and social identity on construction workers' safety, and the chosen group identity included trade, workgroup, union, project, and company [18]. The results showed the strong influence that group norms have on personal standards since trade identity and workgroup identity were more prominent in construction workers' mind, as they identified themselves a representative of trade and workgroup. Consequently, workers' safety behaviour is more likely to be influenced by trade and workgroup norms. Project identity, however, was identified as the least relevant group among the construction workers. Therefore, workers' safety behaviour is not strongly affected under project managers' influence. The findings indicate that improvement in the project identity could enhance the relationship that the perceived management norms have on workers' safety behaviour.

In [19] the effect of different cultural backgrounds and organizational structures on achievement from [18] was investigated. United States, Korea, and Saudi Arabia were chosen to study the impact of social norms (i.e., perceived management norms, perceived workgroup norms) and project identity on construction workers' safety behaviours in different settings. The results showed the lessening effect that project identity has on the relationship between social norms and safety behaviour in the U.S. and Korea. However, Saudi Arabia with a direct hiring system that leads to a strong project identity did not show an effective impact that project identity and social norms could have on safety behaviour (the reason recognized as the project manager did not show enough strictness to influence workers' safety behaviours).

In [20] the effects of three different safety management interventions on workers' safety behaviour along with three different site risks were investigated. The three safety management interventions, i.e., stricter management feedback, more frequent management feedback, and fostering workers' project identification were found effective for reducing incident rate. Based on the results, improving workers' project identification in moderate-risk site condition was recommended as the best policy as their risk acceptance would be aligned with their perceived management norms rather than workgroup norms. Also, in the low-risk site condition, rigorous management feedback is needed to see the improving results of other interventions.

4 Physiological Factor

Construction work is a physically demanding job, and a considerable number of workers go beyond the accepted and safe physiological level for manual work [21]. In addition to the physical demands of the work, workers' physical status can affect the safety and productivity in the work setting. Therefore, measuring and monitoring workers' physiological status can provide valuable information for safety in construction. Three major physiological aspects of construction workers, i.e., body posture, work fatigue, and stress, are identified from the literature and will be discussed in detail below [22-28].

Implementing new technologies for monitoring workers' unsafe actions and providing instructions on conducting safe activities have been suggested by Bernold and Guler [29]. For collecting data on workers' physical status, Lee et al. [30] investigated the applicability of wearable sensors on roofing crews. Data were collected during and after work hours for measuring heart rate, energy expenditure, metabolic equivalent, and sleep efficiency aiming to observe workers' physiological status and well-being. This study confirmed the feasibility of using wearable sensors for construction safety and individual health monitoring and management.

4.1 Body posture

Excessive physically demanding work such as manual material handling tasks in construction activities could lead to musculoskeletal injuries [31], which is a risk to workers' safety and health. To identify and locate unsafe postures of workers, Cheng et al. [32] presented an automatic remote monitoring approach focusing on bending postures. Different physical status such as heart rate and bending angle recorded using physical status monitoring (PSM) tools (BioHarness BT 1 and Equivital EQ-01) were synchronized with ultra-wideband (UWB) signal to give the accurate time and locations of unhealthy bending postures. Moreover, PSM tools were validated to be an effective tool for unobtrusive and remote monitoring and control tool to manage workers' health and safety [33].

4.2 Work fatigue

Analysing sleep deprivation and fatigue among construction workers showed the 8.9% increase in the risk of having an accident [34], and the construction industry needs to avoid fatigue especially for workers in higher risk that need priority in training and monitoring. In general, crewmembers are more prone to physical fatigue than machine operators and they routinely exceed acceptable levels of energy expenditure, oxygen consumption, and heart rate [35]. Among different occupation of crewmembers, Chang et al. [26] investigated work fatigue and physiological symptoms in order to identify occupations in need of more attention regarding health and safety. The scaffolders, steel fixers, and form workers were categorized as the most physically-demanding work groups, and scaffolders experienced the highest average heart rate during work hours. Furthermore, Techera et al. in [36] investigated a fatigue predictor model and showed that predictors vary by trades in a construction setting.

4.3 Stress

Job stress has been recognized as a risk factor in different industries that affect workers' health and safety [37-39]. Finance, inadequate personal time, and the nature of work have been recognized as the main source of daily stressors among construction workers [40]. Construction environment with a dynamic setting, complicated ongoing tasks, and various threatening hazards, shakes workers' stress level and their behaviour toward safety. Goldenhar et al.'s paper [41] investigated the relationship between different job stressors (job-task demands, organizational stressors, and physical/chemical hazards and protection from them) and near misses among construction workers. Moreover, Leung et al. [42] conducted research to identify the relationship between job stressors (safety equipment, supervisor support, co-worker support, job control, and job certainty), physical stress (i.e., biological reactions), psychological stress (i.e., traumatizing experience), safety behaviour, and accident. The result showed that (1) having a job certainty, co-worker support, and safety equipment would result in decreased physical stress; (2) the level of psychological stress is predicted by supervisor support and lack of job certainty; (3) safety behaviour would be achieved by supervisor support and minimum physical stress; and (4) accidents could be prevented by safety behaviour.

5 Cognitive Factors

Understanding the way construction workers perceive information and decide to take a specific action is undoubtedly a critical way of discovering why an unsafe act has been chosen and how information collected by workers can affect their decisions. In this section, critical cognitive factors in the literature are discussed to better understand workers' cognition and its impact on safety in construction sites.

5.1 Cognitive processes

Knowing human error as the most frequent cause of accidents [5-7], different cognitive models in high-risk industries (e.g., nuclear plants [43], aviation [44], and mining [45]) have been developed to describe human cognition. For construction worker's unsafe behaviour, Fang et al. [46] proposed a cognitive model that contains stages of a construction worker cognitive process while encountering with a potential hazard, namely obtaining information, understanding information, perceiving responses, selecting response, and taking action.

As described in [5], an unsafe behaviour could be derived from a failure at any stage of cognition. In a construction setting, limitations in worker's senses due to unfavourable site conditions (e.g., loud noise or obstructed views) could prevent a worker from observing the hazards and consequently result in a failure in obtaining information [46]. Also, workers' lack of attention could prevent a worker from identifying an incident that leads to an accident [47]. Certain eye movements can represent the state of worker's attention and therefore be used to predict human error [48]. Furthermore, workers' selected response is likely to be influenced by the high production and coordination pressure rather than safe conduct of the job [46].

5.2 Team Processes

Team process is an essential factor for construction safety since a team can stop errors from happening and manage a situation that affects safety. The relationship between team members could help workers with learning and adopting safety behaviours. Moreover, from a resiliency perspective, the team recognizes, collaborates, and adjusts to unplanned events and manages to stabilize the situation [49]. Teamwork as a component of a team performance includes cognition, attitude, and behaviour leading to the dynamic processes of performance [50]. Team cognition is a cognitive activity happening at a team level and not individually [51], which has different dimensions, namely team mental model, transactive memory, group learning, shared team situation awareness, and strategic consensus [52]. Compatible environment, anticipation to balance workload, and instant information are essential for a team's cognition, performance, and safety in construction [49].

6 Concluding Remarks

This study presented significant factors affecting construction safety through a review of the literature in this realm from social, physiological, and cognitive viewpoints. Three major categories of construction safety factors, i.e., social, physiological, and cognitive factors, were synthesized to guide the research and practice in construction safety management.

It was identified that improvement in safety behaviours in construction site can be achieved by improving management commitment and engagement in safety programs. The study also presented that improving safety climate is more effective than paying attention to the individual's work experience. In a work setting, workers' safety behaviour is more likely influenced by the trade and workgroup norms rather than the project norm. Improving project identity to increase project managers' influence on workers' safety behaviour would be a solution to align workers safety behaviour with project manager attitude.

With high volume of manual and physical work in a construction, monitoring workers physical factors such as bending angle, heart rate, energy expenditure, and oxygen consumption can help manage and control workers physical status during working hours. Eliminating job stressors (i.e., safety equipment, supervisor support, co-worker support, job control, and job certainty) is another way of improving workers safety behaviour.

Studying individual cognition and team cognition is instrumental in understanding the reasons in taking an unsafe act. Different stages of cognition are important since a failure in any stage could lead to an accident.

Providing appropriate circumstances in favour of accurate cognition is essential to eliminate accidents.

7 References

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