To cite this paper:

Han Y., Feng Z., Zhang J., **Jin R.***, and Aboagye-Nimo E.(2018). "An Empirical Study of Employees' Safety Perceptions of Site Hazard/Accident Scenes."*Journal of Construction Engineering and Management*, in Press, DOI: 10.1061/(ASCE)CO.1943-7862.0001590.

An Empirical Study of Employees' Safety Perceptions of Site Hazard/Accident Scenes

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Abstract

Despite the improvement of digital technologies (e.g., building information modeling) in enhancing construction safety management; human factor-related issues such as individual perceptions, attitudes, and behavior in safety cannot be downplayed. Existing studies have adopted safety management approaches which address human factor issues by defining safety climate. From safety climate research, it is evident that certain demographics or subgroup factors can significantly affect safety management. This study aimed to investigate how individual perceptions of safety hazards would be affected by the given hazard's own feature (e.g., probability of occurrence). In addition, the study explored the impacts of subgroup demographic factors (e.g., job position and experience level) on safety perceptions. Eight commonly encountered site hazard/accident scenes were pre-defined according to their occurrence, severity, and visibility. A site survey approach was adopted to investigate howconstruction employees from different demographic subgroups rated

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the degree of danger of the eight pre-defined scenes. The follow-up statistical analysis revealed that: 1) a hazard/accident scene with higher occurrence and lower severity caused a higher variation among employees' opinions in perceiving its degree of danger; 2) entry-level employees tended to evaluate hazards with a higher degree of danger; 3) compared to early career employees and senior peers, the mid-career professionals tended to perceive a lower degree of danger of a given hazard/accident scene. This study contributed to the body of knowledge in construction safety by investigating the effects of the given hazard/accident's feature (e.g., occurrence) in employees' perceptions, as well as integrating different scenes of safety hazards in the subgroup analysis based on employees' job duties or work trades, and their experience levels. Future research was also recommended addressing individuals' safety perceptions and demographic factors in safety management.

Keywords: Construction safety; accident category; safety hazards; individual perception; work trades; human factors; subgroup analysis

Introduction

Occurrence of occupational accidents is a major issue in the construction industry (Yılmaz and Kanıt, 2018). Aiming to prevent site accidents caused by hazards, research in construction safety has often focused on exploring effective safety management programs (e.g., Chen and Jin, 2012), building the framework and models of safety climate and culture (e.g., Choudhry et al., 2009; Li et al., 2017), and also predicting and enhancing safety performance (Fang et al., 2015; Xia et al., 2018). Besides these key research areas in construction safety, digital technologies in safety management has gained more application in recent years (see de Melo et al., 2017, Zou et al., 2017; Dong et al., 2018). A review of scholarly works within construction safety reveal that despite of the increasing application of emerging technologies (e.g., building information modeling) in safety management, human factors still play the key role. Safety performance is highly related to safety culture and safety climate (Choudhry et al., 2009; Molenaar et al., 2009; Li et al., 2017; Martínez-Aires et al., 2018), which is reflected by individuals' perceptions of safety hazards (Chen and Jin, 2015). Also, psychological effects have a significant impact on employees' safety behaviors, and further affecting the overall safety performance (Wang et al., 2018).

Human factors in construction safety include demographic factors, or subgroup variations, which cannot be ignored in safety management. For example, migration workers face language barriers and communication difficulties (Hare et al., 2013). Besides, other subgroup factors should also be considered when implementing safety training, education, or programs. Without proper training or education, individual perceptions towards hazards might be more subjective as perceptions could be affected by multiple factors (e.g., personal values) according to Slovic (1992). These individual factors in construction safety climate include employees' job position, duties and work trades. Understanding the differences in how site hazards are perceived by employees with various individual factors is important in effective safety management (Hinze et al., 2013). Safety practices need multi-party commitment involving workers from different job duties or positions, such as site operatives, management personnel, owners, etc in order to create a safe work environment (ibid). Therefore, the subgroup issues in construction safety must be continually explored in order to achieve a safe work environment.

Some of the gaps in existing research of demographic factors within safety management have been identified as follows: 1) not many studies in safety hazards and accidents have incorporated the nature of these hazards or accidents based on their occurrence, severity, and easiness of being noticed on-site; 2) insufficient research has been performed to investigate how the nature of these safety hazards/accidents would affect individuals' safety perceptions; and 3) there have been limited studies that have been conducted to explore how subgroup factors (e.g., trades and experience levels) affected safety perceptions of hazard/accident scenes.

Adopting a site questionnaire survey-based approach followed by statistical analysis, this study aimed to: 1) categorize eight commonly encountered safety hazards/accidents according to historical safety data and pilot site investigation; 2) develop a valid site survey approach incorporating psychometric paradigm (Slovic, 1992) and image-based scenes representing these hazards/accidents; 3) evaluate the overall perception of site employees towards the eight hazard/accident scenes; 4) conduct subgroup analysis of employees' perceptions according to whether or not they were in a management position; and 5) perform further subgroup analysis by dividing employees based on their job duties/trades, as well as their experience levels. This research contributes to the existing studies within human factors in construction safety by integrating the nature of hazards and accidents. Particularly, how the nature of the hazards/accidents affect individual perceptions is studied. The study also provides insights for researchers and practitioners in the field of construction safety management by shredding lights on how individual employees' perceptions are affected by their job duties, work trades, as well as their site experience. The current study leads to further research on tracking employees' safety perception and attitude changes following their career path, and the exploration of effective safety management which addresses individual differences in terms of career stages and trades.

Literature review

Safety hazard/accidents

Occupational Safety and Health Administration (OSHA, 2011) defined 'Focus 4 Hazards' which included falls, electrocution, struck-by, and caught-in or -between. Among them, working at height (e.g., working with scaffolding) was one of the primary causes of construction accidents involving injuries or fatalities (Rubio-Romero et al., 2013). Different from post-accident investigation (e.g., Zhou et al., 2012; Kim et al., 2013), multiple studies (e.g., Goh and Chua, 2009; Goh and Chua, 2010; Hallowell and Gambatese, 2010; Mitropoulos et al., 2010; Mitropoulos and Namboodiri, 2011; Fortunato, et al., 2012; Gangolells, et al., 2013) focused on identifying hazards, measuring risks, and more importantly, preventing unwanted incidents. To minimize risks associated with these hazards and accidents, it has been suggested that safety education, training, or formal safety programs should be enforced to all site participants, including the management personnel and workers (see Hallowell and Gambatese, 2009; Zou and Zhang, 2009; Chen and Jin, 2012; Esmaeili and Hallowell, 2012Chen and Jin, 2013).

Safety perception and safety climate

Hazards or probability of risks are perceived by individuals in a somewhat subjective way (Slovic, 1992). Workplace safety perception was identified by Chen and Jin (2013), together with safety awareness and attitudes, as well as management involvement (Li et al., 2017) to form part of safety climate. According to Cox and Flin (1998) and NORA (2008), safety climate focuses on workers' perception of the role of safety in the workplace and their attitudes towards safety. Safety climate could be divided into multi-level sub-climate based on whether or not employees hold a management position (Grote and Kunzler, 2000; Chen and Jin, 2012), and even different management levels of employees (NORA, 2008). Therefore, workers and their supervisors form different subgroup safety climates (Melia et al., 2008). Construction employees from different positions, through their own subgroup safety climate, might have varied safety perceptions as indicated by Chen and Jin (2015).

Demographic and subgroup factors in construction safety perceptions

Safety climate could be divided according to subgroup categories (Schein, 1996) and they can be measured by employees' safety perceptions (Zohar, 1980; Brown and Homes, 1986; Dedobbeleer and Béland, 1991; Chen and Jin, 2015). Certain demographic factors and their impact on workers' perceptions towards construction site hazards have been studied extensively. For example, del Puerto et al. (2013) found that Latino workers in the U.S. construction industry were more likely to believe that productivity and quality of work were more important than safety. The participants of the study tended to underestimate site dangers, and they had higher rates of injuries and fatalities (del Puerto et al., 2013). Other demographic factors such as workers' age, employer type (e.g., workers from general contractor or subcontractor), and workers from different trades were studied by Chen and Jin (2015), who concluded that older workers tended to have better safety attitudes and overall perceptions compared to their younger peers.

Methodology

The methodology adopted in this study consisted of jobsite survey and follow-up statistical analysis.

Construction site survey

The psychometric paradigm was adopted in this study. According to Slovic (1992), the psychometric paradigm encompasses the theory that probabilistic risk estimated by individuals is subjective because they may be influenced by a wide range of psychological, social, institutional and cultural factors. The paradigm assumes that, with appropriate survey instruments, these factors and their interrelationships can be quantified and modeled to measure the individuals' responses (Slovic, 2012). The psychometric paradigm has been the most influential model in the field of risk, and the "cognitive maps" of hazards produced by the paradigm could explain how the various risks were perceived (Siegrist et al. 2005). In this study, hazards displayed by eight different scene images were incorporated in the questionnaire-based site survey. Individuals working on construction sites were studied for their perceptions towards the eight safety hazard/accident scenes on-site. Fig.1 displays these eight images.

<Insert Fig.1.>

These eight safety hazard/accident scenes (i.e., from H1 to H8) illustrated in Fig.1 were prepared according to three different categories related to their occurrence (i.e., frequent to occasional), severity (i.e., highly dangerous to less dangerous), and visibility (i.e., easily noticed to not obvious on-site).

A pilot study on four local jobsites from Jiangsu, China was conducted during April and May of 2016. Scenes representing different safety hazards/accidents were shown to site employees in the study. Their feedback was collected to ensure that these image-based scenes with Chinese text descriptions were reasonable, easily understood, and valid to study employees' perceptions towards the given safety hazards. During the pilot study, employees were also asked to evaluate the visibility of each given scenario. For some scenarios or scenes (e.g., suffocation, choking, and poising), site employees either had varied evaluation of their visibilities, or claimed with little knowledge in them. These types of hazard/accident scenes, were then not adopted in the later formal questionnaire survey. Following the pilot study, eight scenes shown in Fig.1 were selected for the formal questionnaire survey. The formal site visit and questionnaire survey was conducted in eastern China (specifically, Shanghai and Jiangsu regions) from May to August in 2016. A total of nine different jobsites were visited for the questionnaire survey. Administering questionnaire surveys to each jobsite was coordinated between the research team and the site manager. All potential survey participants were fully informed of the purpose of the study. The participants were also informed of the anonymity and confidentiality of all data collected. They were also made aware of their right to participate (or decline) on their own accord. Site employees were asked to rank the degree of danger for all the eight scenes displayed in Fig.1 using Likert-scale scores, with *1* being "not dangerous at all regarding the given safety hazard", *2* meaning "not dangerous", *3* indicating a neutral attitude, *4* inferring "dangerous", and *5* referring to "very dangerous". *S*urvey participants on jobsites were asked of their job roles or trades, and experience level measured by years of experience in construction. First impressions were critical to judgements of threats and lasted long in the later stage (Holmes, 2016). In this study, survey participants were guided to select the Likert-scale option based on their first impression of each given scene.

Statistical analysis

Besides the basic statistical values including mean and standard deviation used to measure the perceptions of the overall survey population, Cronbach's Alpha analysis

(Cronbach, 1951; Tavakol and Dennick, 2011) was also implemented to test the internal consistency of the survey population's perceptions of the eight scenes. Ranging from *0* to *1*, a high Cronbach's Alpha value indicates a higher degree of consistency of site individuals' perceptions among the eight scenes. It was stated that an Alpha value between *0.70* and *0.95* suggested an acceptable internal consistency among Likert-scale items (Nunnally and Bernstein, 1994; Bland and Altman; DeVellis, 2003). A higher Conbach's Alpha value in this survey inferred that a site employee who chose a Likert-scale score to one safety hazard/accident scene was more likely to select similar numerical options to other scenes.

The whole sample was then divided into subgroups according to different demographic factors, including job position, duties or work trades, and experience levels. The survey population was initially categorized into management personnel and workers. The two main categories were then further divided into more subgroups according to their management duties (i.e., safety or non-safety-specialized management) and work trades (e.g., electrical, carpentry, plumbing, etc.). The whole sample could also be divided into subgroups with different experience levels according to their years of working in the construction industry. Several statistical methods were applied in the subgroup analysis, including the two-sample *t*-test and one-way Analysis of Variance (ANOVA), both of which are parametric methods.

Parametric methods (e.g., ANOVA) have been adopted in previous studies in the field of construction engineering and management (e.g., Aksorn and Hadikusumo, 2008;Meliá et al., 2008; Tam, 2009; Jin et al., 2017), specifically for Likert-scale items. The superior performance of parametric methods over non-parametric approach is stated by Sullivan and Artino (2013) in terms of the robustness. Existing studies such as Carifio and Perla (2008) and Norman (2010) have shown that parametric methods are robust for survey samples that are either small-sized or not normally distributed. This robustness was further proved by other studies such as Tam (2009) and Pearson (1931) where non-normally distributed data were involved. Compared to these earlier studies, the overall sample size of *155* and subgroup sizes in this research project were considered adequate.

The two-sample *t*-test was applied to compare the mean value between management personnel and workers for each Likert-scale item. Based on the null hypothesis that management personnel and workers had consistent perceptions towards the given safety hazard/accident scene, a *t* value and the corresponding *p* value would be computed to test the hypothesis. Setting the level of significance at *5%*, a *p* value lower than *0.05* would reject the null hypothesis and suggest that there is a significant difference between management personnel and workers in their perceptions. Similar to the two-sample *t*-test, ANOVA also aimed to test whether subgroups had similar perceptions towards the given safety hazard/accident scene. Based on the similar null hypothesis and the same level of significance, a *F* value and the corresponding *p* value were computed to test the null hypothesis. A *p* valuelower than *0.05* indicates that there are different views among subgroups categorized by job duties/trades or experience levels towards the safety hazard/accident scene. Following ANOVA, post-hoc tests were performed to confirm where the differences occurred between subgroups. Two main post-hoc methods were adopted in the statistical analysis, namely Tukey Simultaneous and Fisher Individual, both of which were based on 95% Confidence Intervals.

Results and findings

Following the safety accidents reported from 2014 to 2017 in China, safety data in terms of number of accidents, fatalities, severe injuries, percentages accounting for total accidents, and severity measurement are summarized in Table 1.

<Insert Table 1>

The eight scenes presented in Fig.1 can be tagged using different combinations of hazard/accident categories according to either Table 1, or the site collected from the pilot study. Table 1 provides the statistical evaluation of occurrence and severity of certain accidents. For example, falling from working at height is a frequent accident; accidents caused by structural collapse (e.g., pit collapse) is highly dangerous due to its high fatality or severe injury rate per accident; struck-by an object may be considered an accident type with lower severity. The visibility of an accident can be determined by feedback collected from the pilot study. For example, H5 shown in Fig.1 is considered a hazard that is not easily detected due to the suddenness of the working platform failure. In comparison, H7 is perceived a hazard that can be easily noticed. Table 2 lists the combination of categories assigned to each of the eight scenes.

<Insert Table 2>

Following the definition of these eight site hazard/accident scenes shown in Fig.1 and categorizations described in Table 2, the following sections will present the findings from the site questionnaire survey in terms of the background information of the survey sample, overall sample analysis in perceptions, analysis of sub-samples divided into management personnel and workers, subgroup analysis of survey participants among different trades or job duties, and the sub-sample analysis according to their experience levels.

Background information of the survey sample

A total of *155* valid responses from *176* questionnaires received from jobsite survey were used in the sample data analysis. Among the *155* responses, *95* of them were management staff specializing in safety or other management positions(e.g., crew foremen), and the rest *60* participants were site workers. The percentages of respondents crossing different positions and trades are shown in Fig.2. Also displayed in Fig.2 is the distribution of respondents falling into different categories of experience levels based on their years of working on-site.

<Insert Fig.2.>

It can be seen from Fig.2 that demographically, the whole survey sample can be divided into nine different categories in terms of their job duties (safety management or other types of management) or work trades (e.g., scaffolding). Six different subgroups could be identified according to years of experience in the construction industry.

Overall sample analysis

The average and standard deviation of survey respondents' perceptions towards the eight scenes were compared and summarized in Fig.3.

<Insert Fig.3.>

According to Fig.3, H1 (i.e., occasional, easily noticed, and highly severe scene) was perceived most dangerous, followed by H6 (i.e., frequent, easily noticed, and highly severe scene), H4 (i.e., occasional, not easily noticed, and highly severe scene), and then H2 (i.e., frequent, not easily noticed, and highly severe scene). All these four scenes belonging to the category of being highly severe, were found with higher mean scores compared to the remaining four hazards which fell into the category of lower severity. It is indicated that respondents generally made reasonable judgements on the degree of danger based on the severity levels of the eight scenes. The standard deviation analysis conveyed the information that the highest variation of perceptions were related to H3 and H8, both of which belonged to the category of higher frequency and lower severity. It can be inferred that construction employees tend to have a more varied view on more frequently occurring but lower severe accidents. Other hazards with more differed views among respondents (i.e., H2, H5, and H7) also fall into the category of either lower severity or higher frequency.

The Cronbach's alpha analysis was performed to test the internal consistency of the whole survey population's responses to the eight scenes. Table 3 summarizes the test results.

<Insert Table 3>

The overall Cronbach's Alpha value at *0.8977* suggested a high internal consistency of survey participants' perceptions towards the eight scenes. It was indicated that a survey participant who selected a Likert-scale score to one scene was likely to choose similar scores to other scenes. The Item-total Correlation in Table 3 measures the correlation between the given scene and the remaining seven scenes. H2, with the correlation value over *0.800*, suggests that respondents' perceptions towards the scene in the categories of high severity, high occurrence, and low visibility has a highly positive correlation with the overall perception of the remaining scenes. In contrast, respondents' perceptions towards H6 and H8 have the Item-total Correlation below *0.600*, indicating that respondents' perceptions towards these two hazards representing frequent and easily noticed scenes tend to differ from the remaining scenes. These two scenes receiving differed views from the survey sample can be found from their higher individual Cronbach's Alpha values compared to that of the remaining scenes listed in Table 3. H8 with its individual Cronbach's Alpha value (i.e., *0.8990*) higher than the overall value at *0.8977,* infers that it contradicts the overall consistency of the survey sample's perceptions towards these hazard/accident scenes.

Subgroup analysis between management personnel and workers

The whole survey population was divided into two main subgroups, namely the management personnel and workers. The former subgroup contained survey participants of either safety managers or other management personnel (e.g., project manager, assistant project manager, and foremen leading a certain trade of workers, etc.). The latter were workers working on certain trades defined in Fig.2. Using the two-sample *t*-test, these two types of site employees' perceptions towards each scene and the overall view are summarized in Table 4.

<Insert Table 4>

Three significant differences of perceptions towards safety scenes between management personnel and workers can be found according to Table 4. Management personnel perceived more danger in the following three hazards in comparison to workers' views, including: 1) H1 representing the highly severe, occasional, and easily noticed scene; 2) the scene falling into the category of high severity, high frequency, and not being easily noticed; and 3) the scene which is lower in severity but more easily noticed and occasionally occurring. The higher degree of danger perceived by management personnel than workers can be explained by the job nature. According to Feng et al. (2017), management personnel usually have a higher education level and have received more systematic safety training which leads to a higher sense of safety accountability. Due to the job nature and duties, management personnel tend to focus on finishing the construction project with zero accident, while workers are more likely to risk by finishing their work ahead of schedule (Feng et al., 2017).

Subgroup analysis of survey participants among different trades or duties

The management personnel and workers were then further divided according to management duties and work trades according to Fig.2. Based on ANOVA results, the subgroup analysis is displayed in Table 5.

<Insert Table 5>

Two significant differences related to H2 and H7 can be found according to Table 5. Site employees among the nine subgroups had varied views on the scene of falling from uncovered openings which belongs to the category of high severity, high frequency, and not being easily noticed. Seven out of the nine subgroups all perceived H2 a highly dangerous scene, with the average score above *4.000*, except carpenters and electrical workers. Management personnel, who might have a more comprehensive coverage of safety knowledge in terms of different types of hazards/accidents, also believed that H2 was highly dangerous. A further post-hoc analysis using both Tukey Simultaneous and Fisher Individual methods were performed to identify the significant differences of perception between a pair of subgroups. Fig.4 showcases an example of the Tukey test.

<Insert Fig.4>

By considering both Tukey and Fisher's methods, it was found that the main difference of subgroups' perceptions towards H2 came from electrical workers, who perceived H2 with a significantly lower degree of danger. Specifically, according to the Tukey test, other management staff and electrical workers held more significantly different views on H2.

These nine subgroups also had varied views on H7 (i.e., falling from unstable ladder), which is generally considered lower degree of danger, lower occurrence, and being easily noticed. The majority of subgroups also considered it less dangerous, with their average Likert-score between *3.000* and *4.000*, or even below *3.000* among carpenters. The post-hoc analysis using Fisher's individual method revealed significant differences between student interns/other management staff and workers from concrete and carpentry trades. It could be assumed that carpenters generally had a higher chance of working with ladders and feel more comfortable with them at work. Therefore, carpenters tended to be more likely to perceive a lower degree of danger of working with ladders. On the other hand, student interns had a much more serious view on H7, with the average score at *4.333*. Student interns' overestimation of the danger of working with ladders could be due to the fact that they did not have much site experience compared to the professionals who have been working for years. As inexperienced student interns, they might have received more school education emphasizing the importance of site safety and hence tending to pre-assume that most hazards/accidents were very serious. Furthermore, it can be found from Table 5 that student interns had the highest average Likert-scale score assigned to the eight scenes, inferring that they were prone to consider most hazards with a higher degree of danger. In contrast, it was analyzed by Han et al. (2017) that workers tended to be used to the site hazard after being exposed to more site accidents and gaining more experience, and as result, they are prone to perceive a lower degree of danger of hazards.

The effect of experience levels in safety perceptions

Following the finding that student interns had more serious concerns over site safety hazard/accident scenes in the previous section, the effect of experience levels in employees' perceptions towards hazards/accidents were further studied. The whole sample was divided into categories according to respondents' years of construction experience (see Fig.2). The subgroup analysis is summarized in Table 6 based on the ANOVA method.

<Insert Table 6>

Table 6 suggests that subgroups from different experience levels had significantly different views on H8 (i.e., struck-by an object). H8 was considered the hazard with the lowest degree of danger by the survey population according to Fig.3, especially by subgroups with construction experience from *6* to *15* years and *21* to *25* years. Both the Tukey and Fisher's test results indicated that senior employees (i.e., over *25* years' experience) and newer employees (i.e., below five years' experience) perceived H8 with a significantly higher degree of danger compared to their peers with *11* to *20* years' experience.

The average Likert-scale scores of the eight scenes were also found with significant variations among the six subgroups, although only one (i.e., H8) out of the eight given scenes was found with significantly different perceptions among survey participants. It is indicated from Table 6 that newer employees with less than five years' experience and their peers with more than *25* years' experience tended to be more cautious on safety hazard/accident scenes, with both average Likert-scale scores over *4.000*. In contrast, those in their mid-career (i.e., with site experience between *6* and *15* years) were more likely to be risk-takers by underestimating the danger of hazard/accident scenes. The post-hoc analyses further revealed that the major difference with average perceptions came from the mid-career employees, especially those with 11 to 15 years' experience who were more likely to perceive a lower degree of danger of site hazards.

Employees from the various subgroups (i.e., site experience less than five years, between *6* and *15* years, between *16* and *20* years and over *25* years) all had lower standard deviations, indicating that they tended to have higher consistency of perceiving safety hazards. Employees with experience between *21* and *25* years had the highest variation of perceptions of the scenes, i.e. according to the standard deviation value of *1.190*. Based on the perception variations among these six subgroups, they can be further reduced into three main categories, namely early career construction employees with less than five years of experience, mid-career professionals with site experience between 6 and 15 years, and senior professionals with more than 16 years' experience. The mean values and standard deviations of Likert-scale-based average perceptions towards all the given scenes are displayed in Fig.5.

<Insert Fig.5>

The ANOVA test was also performed to analyze the overall perceptions towards the eight scenes among the three different subgroups shown in Fig.5. All lower standard deviations below *1.000* indicate that survey participants generally held somewhat consistent perceptions within their own subgroups. With the F value at *4.200* and the corresponding p value at *0.017*, it is inferred that there were significantly different overall perceptions towards the eight scenes among the three redefined subgroups. Fig.6 demonstrates the post-hoc test using Fisher's Individual method.

<Insert Fig.6>

Fig.6 indicates that the main difference among subgroups of different work experience levels came from the mid-career employees. Early career professionals had similar views with their senior peers. Both subgroups had significantly more serious views on the given scenes compared to the mid-career professionals. It can be further assumed that though early career employees had consistent perceptions with their senior peers, the rationale behind that could be different. The former subgroup, due to their less site experience, tended to be more careful of their safety behavior aiming to either prevent injuries or to gain incentives of working safely. The latter group, with more years spent in the industry, were likely to have experienced or witnessed more accidents/incidents, prone to behave more mature, and less likely to take risks to complete job duties as they might think that there were being relatively closer to retirement. Therefore, safety is more important to them compared to rushing to complete work in a more risky way. In comparison, mid-career professionals, with years of site experience but still had more professional time left compared to their senior peers, tended to a lower degree of danger of hazards or accidents. They might be more ambitious in being more productive and were more likely to take risks in order to complete site jobs.

Discussions

Based on the theory of psychometric paradigm and the site questionnaire survey-related research method, construction site employees' perceptions towards eight pre-defined hazard/accident scenes were studied in this research. Guided by Slovic (1992), researchers believed that construction employees' opinions on certain safety scenes were related to their own psychological, social, and cultural factors. Previous studies have focused on subgroup factors' effects in safety perceptions which formed part of safety climate in construction, such as employees' profession or position (Zohar, 1980), worker's trades (Chen and Jin, 2015), and employees' experience levels (Chen and Jin, 2013). In this study, hypotheses were established regarding whether individuals' perceptions were affected by these subgroup factors. Eight different types of safety hazard/accident scenes were prepared for the site survey to construction employees. These eight scenes belonged to different combinations of safety categories according to their severity, occurrence, and ease of being noticed. Using safety accident data summarized from Division of Safety Supervision (2017) in China and the feedback from the pilot site study, categories of these eight scenes were determined. For instance, falling from working at height was determined as the scene with higher occurrence compared to pit collapse.

The overall sample analysis revealed that survey respondents generally had reasonable judgement on the degree of danger between more severe scenes (e.g., loss of balance and falling) and less severe scenes (e.g., hand injury due to being struck). Generally, safety hazards/accidents with lower occurrence would be perceived with a higher degree of danger by site employees compared to these with higher occurrence. The higher occurrence and lower severity of a safety hazard/accident would lead to more varied views among construction employees. In contrast, scenes corresponding to hazards/accidents with low occurrence but high severity would more easily arouse the concern of construction employees. It is inferred that the nature of a safety scene in terms of occurrence, would affect an individual's subjective judgement of its degree of danger. Individuals' perceptions towards a certain scene would be more consistent when the accident is less frequently occurring, especially when it is also highly severe. The internal consistency analysis of the eight scenes demonstrated that the overall perceptions of individuals were highly correlated to the perception towards the scene representing high severity, high occurrence, but low visibility. It is also worth noticing that individuals tended to have different views on frequently occurring and highly visible hazards, compared to how they perceived the overall site safety hazards.

The subgroup analysis suggested that compared to workers, management personnel tended to perceive a few hazard/accident scenes with higher severities. That could be explained by the more education and more comprehensive safety training received by management personnel, who may also have a higher sense of safety accountability. By further dividing the whole survey sample into totally nine subgroups according to their job duties or work trades, the subgroup analysis revealed that trades or duties could affect employees' perceptions towards certain site safety hazard/accident scenes. For example, carpenters and electrical workers perceived falling from uncovered floor holes much less dangerous compared to other trades (e.g., plumbing). Student interns, with more college education but less site experience, tended to consider higher severities of these scenes (e.g., falling from unstable ladders). In contrast, full-time professionals, after experiencing more site accidents and gaining more practice, were more likely to perceive a lower degree of danger of the same hazard/accident scene.

This study also divided the whole survey sample into subgroups based on employees' levels of experience measured by number of years spent in construction. Initially the whole sample was categorized into six different subgroups. Following the initial sub-sample analysis using ANOVA, three subgroups (i.e., employees in their early career and mid-career, as well as senior employees) were re-defined. Mid-career construction employees (i.e., with site experience between *6* and *15* years), were more likely to perceive a lower degree of danger of safety hazards/accidents compared to their early career and senior peers. This could be due to the characteristics of mid-career professionals. Being more experienced in site jobs compared to their entry-level starters and being more ambitious compared to their senior peers, mid-career employees tended to be more over-optimistic of completing jobs without being injured by perceiving safety hazards/accidents with lower degree of danger. As perceptions have a direct effect in human behaviors (Dijksterhuis and Bargh, 2001), mid-career professionals' underestimation of safety hazard/accident scenes could lead to unsafe behaviors. Therefore, it is suggested that safety orientation, training, and education should not only focus on entry-level or early career employees, but also to employees in their mid-career phase. Effective approaches in reinforcing the safety awareness and accountability of mid-career employees can be further studied in the future, such as using holistic approach incorporating case studies of safety accidents belonging to the category of high severity and low occurrence, design for safety in the preconstruction stage (Weinstein et al., 2005), and adopting digital technologies for automated construction safety checking (Lu et al., 2015), etc.

Conclusion

Incorporating the theory of psychometric paradigm, this research aimed to evaluate construction site employees' safety perceptions of eight designed hazard/accident scenes. The study firstly adopted the whole survey sample in evaluating site employees' perceptions towards these eight scenes, and later divided the survey sample into subgroups according to their job position, trades, and experience levels. Through the site survey followed by multiple statistical analysis methods in this research, several findings and corresponding recommendations guiding future research are provided below:

- construction employees had more varied views on hazard/accident scenes with higher occurrence and lower severity, and their opinions of the scenes with lower occurrence but higher severity tended to be more consistent. It was indicated that the occurrence of a hazard/accident scene would affect employees' perceptions of the given hazard/accident. Furthermore, it was suggested that a scene with low occurrence, high severity, and low visibility could be more effective in being used in safety training and education;
- scenes easily noticed and more frequently occurring were more likely to be perceived differently by construction employees as they did with other types of scenes. Evaluation of employees' safety perception should also consider the nature of the hazard or accident;
- student interns tended to view safety hazards/accidents with higher degree of danger. After entering the job market and gaining more experience in construction safety, they may become used to witnessing and handling site safety issues. As a result, they were more likely to perceive a lower degree of danger of safety hazards. Future research could target tracking the career path of entry-level construction employees to study how their safety attitudes, safety perceptions, and safety behaviors change as they develop professionally. Corresponding strategies addressing the continuous safety training and education following employees' career path can be proposed;
- safety education and training should consider subgroup differences between management personnel and workers, as well as workers from different trades. It is suggested that while safety policies should be consistently implemented to all site employees, demographic or subgroup factors should also be addressed, especially

to those subgroups that tend to perceive a lower degree of danger of safety hazards.

- the issue regarding the safety perceptions of mid-career site employees was also addressed in this study. As mid-career professionals might perceive a lower degree of danger of safety hazards (possibly leading to unsafe behaviors), it is recommended that safety awareness and safety education be reinforced to employees in their mid-careers.

This research focused on human factors in construction safety management in two main aspects: firstly, this study investigated the variation of construction employees' perceptions caused by the feature of the hazard/accident scene (i.e., occurrence, severity, and visibility); and secondly, it explored the effects of demographic factors (i.e., job positions, duties or trades, and experience levels) in the safety perceptions of site hazard/accident scenes with different levels of severity, occurrence, and ease of noticing. By adopting influencing factors involving both hazards' features and construction employees' demographic subgroups, this study contributed to the body of knowledge in construction safety climate by investigating how employees' perceptions towards hazards would be affected by these factors.Though the site investigation conducted in China, the findings could be applied to a wider context; across the regions or countries. Future work will continue exploring more demographic factors in safety management, such as employees' educational background, gender, and age, etc. Further work in the field of construction safety management, as suggested, can focus on exploring effective safety training methods targeting non-early-career construction employees, especially those in their mid-career stage.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request.

Acknowledgement

This research is supported by the National Natural Science Foundation of China (Grant No. 51408266), MOE (Ministry of Education in China) Project of Humanities and Social Sciences (Grant No.14YJCZH047), Foundation of Jiangsu University (Grant No. 14JDG012), and Writing Retreat Fund provided by University of Brighton.

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Table 1. Safety data analysis (data summarizedaccording to accident reports from Division of Safety Supervision, 2017)

Type of accidents	Number of accidents	Fatality	Severe injuries	Percentage	Severity (fatality or severe injury rate per accident)
Falling from working at height	1013	1081	37	53%	1.1
Structural collapse	237	454	90	12%	2.3
Struck-by	277	289	8	15%	1.07
Electrocution	48	50	0	3%	1.04
Injuries by manual handling or lifting	166	245	34	9%	1.68
Injuries by heavy equipment	109	120	17	6%	1.26
Hit by site vehicles	27	30	0	1%	1.11
Suffocation, choking, and poising	20	37	3	1%	2
Total	1897			100%	

Table 2. The combination of categorization of eight safety hazard/accident scenes on-site

Category	H1	H2	H3	H4	H5	H6	H7	H8
Occurrence	Lower frequency	High frequen-cy	High Freque-ncy	Lower frequenc-y	Lower frequenc-y	High frequen-cy	Lower frequenc-y	High frequen-cy
Severity	High severity	High severity	Low severity	High severity	Low severity	High severity	Low severity	Low severity
Visibility	Easily noticed	Not easily noticed	Not easily noticed	Not easily noticed	Not easily noticed	Easily noticed	Easily noticed	Easily noticed

Table 3. Internal consistency analysis of the overall survey sample's perceptions towards the eight safety scenes (Overall Cronbach's Alpha = *0.8977*)

Hazards	H1	H2	H3	H4	H5	H6	H7	H8
Item-total Correlation	0.6515	0.8049	0.7424	0.7207	0.7829	0.5554	0.6895	0.5700
Cronbach's Alpha	0.8895	0.8726	0.8788	0.8819	0.8748	0.8953	0.8839	0.8990

Table 4. Two-sample *t*-test results for subgroup analysis between management personnel and workers

Safety Hazards	Management personnel		Trade workers		Statistical comparison	
	Mean	Standard Deviation	Mean	Standard Deviation	*t* value	*p* value
H1	4.726	0.750	4.433	0.909	**2.09**	**0.039***
H2	4.330	1.030	3.920	1.340	**2.02**	**0.046***
H3	3.650	1.110	3.500	1.510	0.68	0.501
H4	4.450	1.030	4.250	1.020	1.20	0.232
H5	4.110	1.090	3.900	1.300	1.02	0.310
H6	4.580	1.020	4.450	1.030	0.76	0.447
H7	3.800	1.070	3.420	1.230	**1.99**	**0.049***
H8	3.120	1.340	2.870	1.460	1.07	0.287
Average	4.095	0.803	3.842	0.947	1.72	0.089

* A *p* value lower than 0.05 indicates the significant difference between management personnel and workers

Table 5. Subgroup analysis of survey samples divided by job duties or trades

Trades or job duties		H1	H2	H3	H4	H5	H6	H7	H8	Avera-ge
Safety managem-ent personnel (N=11)	Mean	4.929	4.455	3.545	5.000	4.364	4.818	3.455	2.636	4.159
	Standard Deviation	0.267	0.934	1.293	0.000	0.924	0.603	1.368	1.286	0.657
Other managem-ent personnel (N=81)	Mean	4.691	4.310	3.667	4.381	4.071	4.548	3.845	3.179	4.086
	Standard Deviation	0.791	1.041	1.090	1.074	1.106	1.057	1.024	1.346	0.824
Student intern(N =9)	Mean	4.667	4.500	4.167	5.000	5.000	5.000	4.333	3.667	4.542
	Standard Deviation	0.516	1.225	1.329	0.000	0.000	0.000	0.816	1.633	0.600
Carpente-r (N=7)	Mean	4.571	3.571	3.286	3.857	3.286	4.143	2.571	2.714	3.500
	Standard Deviation	0.535	0.976	1.704	1.215	1.496	1.464	0.976	1.496	0.820
Scaffold-ing workers (N=3)	Mean	4.000	4.000	3.667	4.333	4.333	3.330	4.000	4.667	4.042
	Standard Deviation	1.000	1.000	1.155	1.155	1.155	2.080	1.000	0.577	1.003
Concrete workers (N=20)	Mean	4.500	4.000	3.500	4.100	3.750	4.550	3.150	2.850	3.800
	Standard Deviation	1.000	1.338	1.504	0.852	1.293	0.686	1.137	1.309	0.820
Electrical workers (N=13)	Mean	4.000	3.154	3.000	4.000	3.462	4.231	3.538	2.077	3.433
	Standard Deviation	1.155	1.772	1.871	1.291	1.391	1.301	1.450	1.320	1.235
Plumbing workers (N=4)	Mean	5.000	4.750	3.250	4.750	5.000	5.000	3.750	3.000	4.313
	Standard Deviation	0.000	0.500	0.957	0.500	0.000	0.000	1.258	1.633	0.415
Steel workers (N=7)	Mean	4.571	4.429	4.143	4.571	4.000	4.571	3.571	3.000	4.107
	Standard Deviation	0.787	0.787	1.215	1.134	1.291	0.787	1.272	1.528	0.897
F value		1.70	**2.07**	0.79	1.55	1.98	1.17	**2.03**	1.84	1.70
p value		0.103	**0.042** *	0.610	0.145	0.053	0.321	**0.046** *	0.074	0.103

*: A *p* value lower than 0.05 indicates significant differences among subgroups towards the given scene

Table 6. Subgroup analysis of survey samples divided according to site experience

Years of experience		H1	H2	H3	H4	H5	H6	H7	H8	Avera-ge
Below five years (N=61)	Mean	4.738	4.279	3.754	4.459	4.164	4.623	3.869	3.311	4.150
	Standard Deviation	0.630	0.985	1.059	1.010	1.019	0.897	0.922	1.272	0.693
6-10 years (N=27)	Mean	4.667	4.148	3.370	4.333	3.815	4.556	3.296	2.370	3.819
	Standard Deviation	0.734	1.231	1.275	0.920	1.241	1.050	1.353	1.245	0.838
11-15 years(N= 25)	Mean	4.440	3.800	3.080	4.080	3.760	4.080	3.240	2.400	3.610
	Standard Deviation	0.917	1.384	1.470	1.222	1.332	1.498	1.300	1.472	1.030
16-20 years (N=11)	Mean	4.727	4.727	4.000	4.636	4.182	4.909	3.818	3.364	4.295
	Standard Deviation	0.647	0.647	1.265	0.674	1.328	0.302	1.250	1.362	0.793
21-25 years (N=14)	Mean	4.143	3.714	3.571	4.286	3.714	4.287	3.571	2.929	3.777
	Standard Deviation	1.406	1.590	1.604	1.326	1.383	1.139	1.158	1.492	1.190
Above 25 years (N=17)	Mean	4.647	4.353	3.882	4.471	4.412	4.765	4.000	3.765	4.287
	Standard Deviation	0.862	1.115	1.317	0.874	1.004	0.437	1.000	1.200	0.775
F value		1.50	1.64	1.59	0.69	1.21	1.76	2.06	**4.15**	**2.54**
p value		0.192	0.153	0.166	0.632	0.306	0.124	0.074	**0.001***	**0.031***

*: A *p* value lower than 0.05 indicates significant differences among subgroups towards the given scene