Work-Health and Safety-Risk Perceptions of Construction-Industry Stakeholders Using Photograph-Based Q Methodology

Peihua Zhang[1]; Helen Lingard[2]; Nick Blismas[3]; Ron Wakefield, M.ASCE[4]; and Brian Kleiner[5]

Abstract: Work health and safety (WHS) on construction sites can be influenced by decisions made upstream from the construction stage. The effectiveness of WHS risk management relies on decision makers' ability to decide appropriate strategies to mitigate/control risks. However, it is unclear whether upstream decision makers share similar WHS risk perceptions with those who undertake the construction work. This study used Q methodology to explore WHS risk perceptions of architects, engineers, construction managers, and WHS professionals. Photographs depicting different technologies/methods were used to capture professionals' WHS risk judgments. Data were analyzed to identify the within-group and between-group similarity/difference in professionals' WHS risk perceptions. The data-analysis result indicates the coexistence of within-group difference and similarity, as well as between-group difference and similarity in WHS risk perceptions. The research contributes to the body of knowledge by showing that WHS risk is subjective in nature and that social, psychological, and technical factors interact to shape subjective risk judgments. The research finding challenges traditional risk-management thinking, which assumes risk is objective and easily quantifiable. **DOI:** 10.1061/(ASCE)CO.1943-7862.0000954. *© 2014 American Society of Civil Engineers.*

Introduction

Poor Construction Work Health and Safety Performance

The construction industry in Australia performs poorly in work health and safety (WHS) compared with other industries, although Australia performs better than some countries such as the United States. In 2010–2011, 39 fatalities were recorded in the construction industry, producing a fatality rate of 3.77 (i.e., 3.77 deaths/100,000 workers), which is nearly two times the average fatality rate recorded for all industries (i.e., 1.93 deaths/100.000 workers; Safe Work Australia 2012). The rate of serious injury recorded for the construction industry in 2010–2011 was 18.7 claims/1,000 employees, which is substantially higher than the all-industries rate of 12.2 (Safe Work Australia 2013b). The construction industry has been identified as one of the priority industries in the *Australian Work Health and Safety Strategy 2012–2022*.

[1]Research Fellow, School of Property, Construction and Project Management, RMIT Univ., Melbourne, VIC 3000, Australia (corresponding author). E-mail: rita.zhang@rmit.edu.au; rita.ph.zhang@gmail.com

[2]Professor, School of Property, Construction and Project Management, RMIT Univ., Melbourne, VIC 3000, Australia. E-mail: helen.lingard@rmit.edu.au

[3]Professor, School of Property, Construction and Project Management, RMIT Univ., Melbourne, VIC 3000, Australia. E-mail: nick.blismas@rmit.edu.au

[4]Professor, School of Property, Construction and Project Management, RMIT Univ., Melbourne, VIC 3000, Australia. E-mail: ron.wakefield@rmit.edu.au

[5]Director, Myers-Lawson School of Construction, Virginia Tech, Blacksburg, VA 24061. E-mail: bkleiner@vt.edus

Note. This manuscript was submitted on August 18, 2014; approved on October 27, 2014; published online on December 8, 2014. Discussion period open until May 8, 2015; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, © ASCE, ISSN 0733-9364/04014093(13)/$25.00.

Prevent WHS Risks Upstream

The primary responsibility for site workers' health and safety has traditionally been ascribed to construction contractors (Toole 2002). Legislation establishes substantial obligations on contractors to plan for WHS and assess the risks to their employees (Hare et al. 2006). Therefore, early efforts to improve construction WHS performance mainly targeted construction-contracting companies. A variety of initiatives and strategies have been suggested for contractors to better manage WHS in the construction phase from both technical and managerial perspectives, including providing workers with safety booklets, appropriate safety equipment, safety training, a safe site environment, and appointing safety representatives (Sawacha et al. 1999); improving construction planning (Suraji et al. 2001); identifying critical success factors influencing the effective implementation of safety programs (Aksorn and Hadikusumo 2008); using motivation and reward systems (Koehn and Datta 2003); and improving safety climate or culture (Fang et al. 2006; Mohamed 2002). Although some recent improvements have been noticed, construction WHS performance is still relatively poor and more improvements are desired (Atkinson and Westall 2010).

Recent research has demonstrated that WHS risks on construction sites can be traced back to decisions made upstream from the construction stage. For example, Lingard et al. (2011) found that a client's decision in changing the technical requirements of a constructed facility led to a WHS impact during the construction phase. Haslam et al. (2005) examined the causes of 100 construction accidents in the United Kingdom and reported that almost half of the risks, which led to the accidents, could have been reduced with a change to the design of the permanent works. Similarly, Behm (2005) reviewed 224 fatality investigation reports in the United States and found that 42% of the fatalities could be linked to decisions made during the design stage. Arguably, the design determines how project components will be assembled and how construction tasks will be undertaken (Gambatese and Hinze 1999). Recently, the concept of construction-hazard prevention through design (CHPtD) has received much attention from researchers

J. Constr. Eng. Manage., 2015, 141(5): 04014093

and practitioners (Gangolells et al. 2010; Toole and Gambatese 2008). The evidence suggests that opportunities exist for preventing WHS risks by considering WHS in design. Proponents of CHPtD argue that decision makers should consider WHS when making decisions in the planning and design stages. They need to evaluate the potential impact of their decisions on WHS through every stage of the project lifecycle, including construction, operation, maintenance, and even demolition, and formulate suitable strategies to control or, wherever possible, eliminate WHS risks at source.

Different Risk Perceptions As a Barrier to Effective CHPtD

In practice, it is unclear whether project stakeholders who make decisions in the planning and design stages of construction projects share similar perceptions of WHS risks as those who undertake the construction work. The construction industry is complex and highly fragmented. Design decision makers are usually organizationally and spatially distal from site-based production. Thus, many important decisions with the potential to influence WHS are made before the commencement of construction work. The construction industry is also characterized by adversarial relationships between stakeholders, who sometimes pursue different project interests. In such an environment, it is difficult for decision makers to understand and consider the interests of other stakeholders. Further, research suggests that design professionals may have little knowledge of construction processes due to their formal education and limited site experience, making it very difficult for them to fully appreciate the WHS implications of their decisions (Gambatese and Hinze 1999; Toole 2002).

The effectiveness of technical approaches to WHS risk management relies on decision makers' ability to decide appropriate strategies to mitigate/control risks. If a decision maker cannot perceive a risk accurately, then safe decisions are unlikely to eventuate. Surry's (1979) decision model of accident occurrence, which is depicted in Fig. 1, illustrates that risk perceptions provide sensory cues to individuals, who then cognitively process the sensory cues, and decide the response to the cues by applying decision-making rules. Risk perception is a necessary antecedent to the conceptualization of a risk-control strategy because one cannot respond to a risk that is not recognized or perceived. If stakeholders do not perceive risks in a similar way, it is likely that they will also disagree about how risks should be controlled and/or the adequacy of strategies implemented to control these risks. In the Australian context, existing legislation and codes of practice require that systematic risk-management procedures, that is, risk identification, risk assessment, and risk control, are integrated into the design process (Lingard et al. 2013). Duty holders are expected to make decisions about the implementation of WHS risk-management strategies based on their assessments and judgments about risk. If there is unresolved misunderstanding or disagreement about the nature or magnitude of WHS risks, the whole framework adopted for workplace WHS risk management is unlikely to be effective.

Aim of This Study

This study is part of a research project, which attempts to understand the similarities and differences in professional groups' WHS risk perceptions in the construction industry. This research highlighted areas in which construction-project stakeholders share similar perceptions of WHS risk and also areas in which perceptions of WHS risk differ, between and within professional groups. This study aimed to achieve the following research objectives:

- To use a photographic Q-sort method to explore professionals' judgments of WHS risks associated with different methods/technologies used in the construction of four building elements (i.e., facades, roofs, structures, and building services); and
- To investigate the extent to which members of four professional groups (i.e., engineers, architects, construction managers, and WHS professionals) share similar perceptions of WHS risk with other members of their group and/or have different perceptions of WHS risk to members of other professional groups.

Approaches to Study Risk Perception

Previous WHS research has primarily used the following three approaches: technical approaches, psychological approaches, and

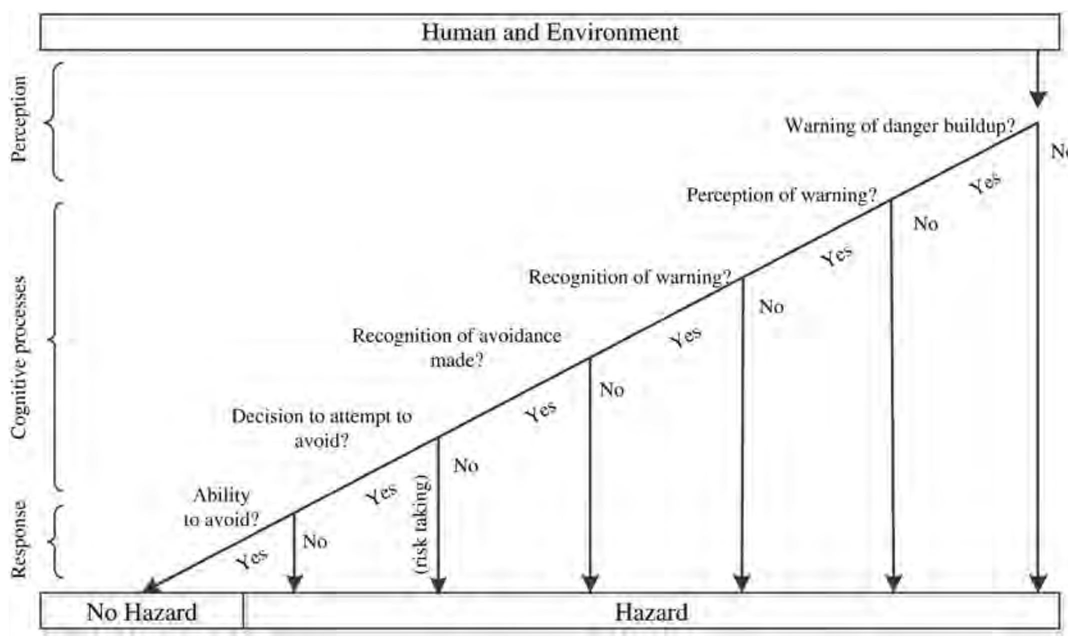

Fig. 1. Surry's decision model of accident occurrence (adapted from Lingard and Rowlinson 2005)

social approaches (Holmes et al. 1998). Technical approaches use technological expertise to define and control risks in a scientific manner (Holmes et al. 1998). They follow the procedures of hazard identification, risk assessment, and risk-control-strategy formulation. Technical approaches have been extensively used in the construction industry for WHS risk management. For example, the risk-assessment model proposed by Jannadi and Almishari (2003) uses risk analysts' experience and knowledge to numerically rate risks associated with activities performed by contractors and quantitatively justify proposed remedies. Baradan and Usmen (2006) used the objective archive data from the Bureau of Labour Statistics to compare risks associated with various building trades.

Psychological approaches aim to examine individuals' cognitive perceptions of risks and identify perceived qualities of riskiness to explain their subjective risk judgments (Holmes et al. 1998). The underlying assumption is that the risk judgments are initiated by qualitative decisions made against the risk qualities. Psychological approaches have often been used in cognitive psychology to compare lay people's risk judgment and experts' scientific/technical risk assessments, and improve the risk communication between lay people, technical experts, and public-policy decision makers (Slovic 1987; Slovic et al. 1982). Researchers use psychometric procedures (e.g., survey instrumentation) to measure people's attitudes toward risks and associated risk qualities (Fischhoff et al. 1978; Slovic 1987). Examples of risk qualities that shape the way people think about risk are *knowledge about risk*, *immediacy of effect*, *control over risk*, *newness*, *whether the risk has a chronic or catastrophic effect*, etc. (Fischhoff et al. 1978). With psychological approaches, researchers assume that the qualities of riskiness are universal and usually determine an a priori list of qualities for participants to rate. The differences in responses between individuals are therefore attributed to individual differences in personal beliefs, attitudes, knowledge, experience, information held, etc. For example, in a study of offshore oil and gas workers, Flin et al. (1996) reported that workers' risk perceptions were significantly influenced by their perceptions of the general working environment and experience.

Social approaches assume that the meanings of risk are socially constructed within social groups, and individuals' risk perceptions are deeply influenced by wider social and cultural contexts (Holmes et al. 1998). Therefore, conflicting risk perceptions between individuals may not necessarily arise as a result of different information held or different personal experience, but reflect more fundamental value commitments associated with particular groups (Pidgeon 1998). With social approaches, qualities of riskiness are not universal but have different meanings to different social groups (Holmes et al. 1998). Researchers attempt to elicit the qualities of riskiness from participants rather than determining these a priori. Social approaches can be adopted to examine similarities and differences between social groups' understanding of risk and explore how the social context determines and constructs their meaning of risk. For example, individuals' risk judgments can be shaped by their employment status. Holmes et al. (1998) report different risk judgments between employers and employees, while Hallowell (2010) reports differences between construction workers and managers. Gherardi et al. (2002) further suggest that understanding of safety and risk is socially constructed and situated in communities of practices (CoPs) within organizations. They studied two CoPs (i.e., engineers and site managers) within the same construction firm, and reported that members of the two CoPs used a different causality model to interpret accidents and had different conceptions of safety. In circumstances where multiple stakeholders/social groups are involved, discrepancy between different groups' understanding of risks may create barriers to achieving a coherent and coordinated strategy to control risks. For example, Iavicoli et al. (2011) report gaps between stakeholders' (including employers, trade unions, and government institutions) perceptions regarding psychological risks and work-related stress in the European Union, and the perception gaps caused subsequent difficulty in implementing shared prevention/correction strategies.

Rohrmann (1994) maintains that it is necessary to supplement *technical* risk research with social-scientific approaches to explore the conceptualization of risk and understand the *psychology of risk*. This is because nonstatistical aspects (e.g., social, psychological, and ethical issues) are influential to risk perceptions, and definitions and criteria differ between groups in risk assessment. Pidgeon (1998) also suggests that evaluations of risk should consider psychological factors such as people's beliefs, attitudes, judgments, and feelings, as well as wider cultural and social dispositions.

The current research adopts the point of view that individual risk perception is the result of an interplay between technical factors (e.g., technical knowledge), psychological factors (e.g., individual attitudes and experience), and social factors (e.g., group practices and norms). This gives rise to the coexistence of within-group similarity/difference and between-group similarity/difference in risk perceptions. Risk perceptions change with personal attitudes, knowledge, and experience, as well as the social groups to which a person belongs due to specific values, norms, and practices associated with that group.

To achieve an integrated and coordinated response to WHS risks across diverse members of construction-project teams, it is important to understand the similarities and differences between the WHS risk perceptions of constituent professional groups. The following section describes a photographic tool used to explore professional groups' risk perceptions.

Research Design

Q Methodology

An innovative photographic Q-methodology data-collection method was used to explore construction-project stakeholder groups' WHS risk perceptions. The Q methodology is recommended as a suitable technique to study cognitive structures, attitudes, and perceptions (Anandarajan et al. 2006). The Q methodology requires participants (the P set) to put a sample of objects (known as a *Q set*) into a rank order according to a condition of instruction. When the objects are arrayed into categories, the resulting pattern is called a *Q sort* (Brown 1980). A Q sort is a reflection of a person's subjective view about a phenomenon, suggesting this person's conception of the way things stand (Brown 1980).

The Q set can take different forms, such as statements of opinions, photographs, or other objects. In this study, photographs representing the construction processes implicit in different building systems were used as stimuli. Photographs are effective and straightforward in depicting a construction scenario, yet maintain the richness of information needed to assess WHS risks. Photographs have been effectively used as stimuli-eliciting perceptions in landscaping studies (Green 2005; Fairweather et al. 1998), and also successfully used as experimental stimuli in areas such as industrial quality assurance (Kleiner and Schewchuk 2001) and construction-hazard identification (Kleiner and Hallowell 2012).

Q-Set Generation

The Q methodology requires researchers to generate a Q set, which is broadly representative of the issues under investigation (Stenner et al. 2008; Watts and Stenner 2005). Photographs representing different but commonly used building systems/construction technologies for the construction of the building elements of roof, facade, structure, and building services were selected. Ten photographs were selected for each building element. It is noteworthy that the purpose of using photographs in this study was to represent different building systems/construction technologies rather than the construction processes of the building systems/construction technologies. Participants were requested to provide their perceptions of the WHS risks inherent in the depicted building systems/ technologies by comparing the characteristics of one building system/technology with other building systems/technologies.

The photographs were presented to three industry professionals and subjected to a pilot validation to ensure the photographs were representative of different building systems/construction technologies for each building element and provided sufficient information for participants to make WHS judgments. The industry professionals suggested removing a number of photographs because some of them were similar in content with other photographs and some of them lacked sufficient detail for participants to make meaningful WHS risk judgments. The detailed process of the pilot validation has been described in Zhang et al. (2013). Following piloting, eight photographs were retained for each building element.

In this paper, facade systems and roof systems are used as examples to demonstrate the data-collection and analytical procedures deployed. Table 1 presents the photograph codes and corresponding descriptions, and Fig. 2 shows sample photographs used in this study.

P-Set Selection

Data were collected from four stakeholder groups, namely, architects, engineers, constructors, and WHS professionals working in the construction industry in Australia. The underlying rationale for the selection of these groups was that they either participate in decision making, which could influence the selection of a building system/technology (e.g., architects, engineers, and construction managers), or they respond to WHS risks inherent in the construction of a building system or technology (e.g., construction managers and WHS professionals). In other words, these four stakeholder groups have substantial influence on or are substantially impacted by WHS risks implicit in construction planning and design decisions.

Table 1. Photograph Codes and Descriptions

Photo	Descriptions
F01	Precast concrete panel system for housing
F02	Precast concrete panel system for car parking
F03	Concrete and window panel facade system
F04	Full-story prefabricated facade system
F05	Glazed panel facade system
F06	Mixed glass and concrete panel facade system (concrete sections are covered by glass panels)
F09	In situ RC walling
F10	Concrete block wall facade system
R01	Metal-roof canopies
R02	Flat in situ RC roof with bitumen-membrane waterproofing
R03	Steel-roof-sheeting system to a frame building
R04	Timber-rafter system for curved roof panels
R05	Tiled roof on timber rafters
R06	Plywood sheathings installed to roof trusses
R09	Preassembled timber roof canopy system
R10	Prefabricated roof systems for offsite built classrooms

Note: F = facade; R = roof.

The Q methodology does not require a large number of participants as it aims to capture the main viewpoints that are shared by a group of people (Watts and Stenner 2005). In this study, 10 participants were invited from each stakeholder group, making a total of 40 participants. The participants were mainly approached through the researchers' personal networks, and a *snowball* sampling strategy was adopted whereby participants were asked to suggest other people whom the research team could contact to participate in the research. It is acknowledged that the snowball sampling strategy is not random because the selection of participants depends on the participants identified through researchers' personnel networks at the beginning of the study (Kumar 1999). However, a more important principle in Q-methodology sampling is the degree to which participants have well-developed views about the topic under study. Purposefully selecting participants through this snowball technique was therefore acceptable. Demographic information about the participants is presented in Table 2.

Condition of Instruction

The *condition of instruction* establishes the rules by which participants perform the Q-sorting task. Risk perception is defined as the subjective judgment made by a person about the frequency and severity of particular risks (Hallowell 2010). In this study, participants were requested to perform two rounds of sorting exercise for photographs of each building element. Participants were first instructed to sort the photographs into a grid according to their evaluation of the likelihood of an accidental injury arising when a depicted construction technology/method is used. The grid contained five columns with a rating scale ranging from –2 *Rare* to +2 *Almost certain*.

Participants were then asked to sort the photographs into another grid based on their judgments of the severity of consequential injury should an accident occur. The rating scale ranged from –2 *Minor* to +2 *Catastrophic*.

It is understood that each photograph may represent multiple hazards. Given that the research aimed to explore the extent to which participants had similar or different judgments of risks (including the specific hazards they focused on), those hazards were not preemptively identified for participants. Participants were asked to consider the most serious hazards they could perceive from the photographs, weigh the building systems/technologies against one another, and indicate the relative likelihood of accidental injury arising during the construction of each system/technology. Similarly, participants were not provided with objective definitions to severity scales. They were asked to subjectively define the severity scales (e.g., they needed to consider what a *catastrophic* consequence meant to them and how this compared with a *minor* consequence). For example, some participants considered a *single fatality* to be catastrophic, whereas others indicated that catastrophic meant *multiple fatalities*. The reasons for participants' judgments were elicited through qualitative interviews with open-ended question after sorting exercise (this information is not presented in this paper).

Data-Analysis Method

Data used for analysis were collected from 40 participants. Table 3 provides descriptive statistics of the rating scores for each photograph. This study reports the quantitative results of the Q-sorting exercise. Each Q sort can be interpreted in two ways. First, the rating given to each photograph can be ascertained. The rating scores indicate participants' judgment of risks implicit in the construction process depicted in each photo against the criteria of likelihood

Fig. 2. Sample photographs used in this study (images courtesy of the School of Property, Construction, and Project Management at RMIT University)

and severity. Second, the relative ranking of the photographs can be considered. The relative ranking indicates participants' risk comparison between photographs.

In this study, the within-group similarity/difference and between-group similarity/difference are assessed using both rating scores and relative rankings to provide a holistic description.

Within-Group Similarity/Difference

The within-group risk perception similarity/difference is first examined by interrater reliability (IRR), which indicates whether participants in the same group rate targets in a consistent manner (James et al. 1984, 1993). IRR is calculated by Eq. (1)

$$r_{\mathrm{WG}(I)} = 1 - (S_{x_j}^2/\sigma_{\mathrm{EU}}^2) \tag{1}$$

where $r_{\mathrm{WG}(I)}$ = within-group IRR for a group of K judges on a single item X_j; Sxj^2 = observed variance on X_j; and σ_{EU}^2 = variance on X_j that would be expected if all judgments are due exclusively to random measurement error. σ_{EU}^2 is calculated as Eq. (2)

$$\sigma_{\mathrm{EU}}^2 = (A^2 - 1)/12 \tag{2}$$

where A = number of alternatives in the response scale for X_j varying from 1 to A, that is, 5 in this study. An $r_{\mathrm{WG}(I)}$ value of 0.7 is required by rule of thumb for good within-group homogeneity (LeBreton and Senter 2008).

The within-group risk perception similarity/difference is further assessed by the nonparametric analysis method of Kendall's coefficient of concordance (W), which indicates the level of agreement regarding the ranking of photographs among participants of the same stakeholder group. It is calculated by Eq. (3)

$$W = \frac{\sum_{i=1}^{n} (\bar{R}_i - \bar{R})^2}{n(n^2 - 1)/12} \tag{3}$$

where n = number of photos being ranked; $\bar{R}_i$ = average of the ranks assigned to the ith photograph; $\bar{R}$ = average of the ranks assigned across all photographs; A W value significant at the 0.05 level indicates that there is a significant level of similarity in participants' rankings of photographs within the same group.

J. Constr. Eng. Manage., 2015, 141(5): 04014093

Table 2. Demographic Information of Participants

Participants	Professional background	Working position	Years of working experience
Cons1	Construction management	Project coordinator	7
Cons2	Construction management	Project coordinator	10
Cons3	Construction and marketing	Project coordinator	2
Cons4	Management	Commercial manager	20
Cons5	Civil engineering	Project engineer	13
Cons6	Architect	Design manager	30
Cons7	Building	Construction manager	20
Cons8	Building construction management/estimating	Site manager	32
Cons9	Civil engineering	Senior engineer	20
Cons10	Building	Project manager	15
WHS1	Safety	Safety manager	25
WHS2	OHS	OHS coordinator	25
WHS3	Carpentry, OHS consultant, work-safety inspector	OHS manager	25
WHS4	Commercial construction-safety management	Health, safety, and environmental manager	20
WHS5	Environmental scientist	Head of safety and environment	13
WHS6	Building	Construction-management consultant	38
WHS7	System engineering	Safety officer	30
WHS8	Health and safety	H&S advisor	9
WHS9	Health and safety	H&S manager	7
WHS10	OHS and electrical engineering	OHS coordinator	25
Eng1	Engineering	Senior structure engineer	9
Eng2	Mechanical engineering	Mechanical engineer (building service)	2
Eng3	Land surveyor	Project leader	27
Eng4	Structural engineering	Technical director	35
Eng5	Engineering/project management	Project manager	2
Eng6	Engineering	Senior project manager	11
Eng7	Structural engineering	Associate technical director	38
Eng8	Engineering/project management	Associate technical director	15
Eng9	Construction	Diagnostics engineer	12
Eng10	Engineering	Executive	10
Arch1	Architecture	Architect/project manager	25
Arch2	Architecture	Architect	10
Arch3	Property, design and construction	Architect	6
Arch4	Architecture	Architect	12
Arch5	Architecture	Project architect	19
Arch6	Architecture	Director	35
Arch7	Architecture	Project leader	20
Arch8	Architecture	Manage director	40
Arch9	Architecture	Project architect	9
Arch10	Construction management, building design	Associate architect	7

Note: Arch = architect; Cons = construction manager; Eng = engineer; H&S = health and safety; OHS = Occupational Health and Safety; WHS = work health and safety professional.

Table 3. Descriptive Statistics for the Rating Scores of Photographs

Building element		Likelihood					Severity				
	Photo	N	Minimum	Maximum	Mean	SD	N	Minimum	Maximum	Mean	SD
Façade	F01	40	–1	2	0.08	0.829	40	–2	2	1.28	0.987
	F02	40	–1	2	0.13	0.791	40	0	2	1.48	0.679
	F03	40	–2	2	0.28	0.847	40	0	2	1.20	0.723
	F04	40	–2	2	–0.20	0.911	40	–2	2	0.68	1.023
	F05	40	–2	2	–0.18	0.931	40	–2	2	0.93	0.971
	F06	40	–2	2	0.10	0.810	40	–1	2	1.05	0.749
	F09	40	–1	2	0.38	0.705	40	–1	2	0.83	0.874
	F10	40	–2	2	–0.18	0.903	40	–2	2	–0.13	1.181
Roof	R01	40	–1	2	0.28	0.751	40	–2	2	1.13	0.939
	R02	40	–2	1	–0.73	0.960	40	–2	2	–0.73	1.062
	R03	40	–1	2	0.18	0.844	40	–1	2	1.03	0.862
	R04	40	–1	2	0.28	0.987	40	–1	2	0.58	0.903
	R05	40	–1	2	0.80	0.648	40	–1	2	0.98	0.800
	R06	40	0	2	0.78	0.577	40	0	2	1.35	0.700
	R09	40	–2	2	–0.13	0.911	40	–1	2	1.23	0.832
	R10	40	–2	1	–0.73	0.816	40	–2	2	–0.15	0.975

Note: F = facade; R = roof.

Between-Group Similarity/Difference

The group means of risk judgments for each photo were calculated by averaging individual scores given by participants in the group. The group means were then plotted to show the between-group similarity/difference in rating risks for the selected facade systems and roof systems. This method also reveals specific systems for which the four groups share the highest differences and similarities in their rating.

The between-group similarity/difference is further assessed by Spearman's rank-order correlation (r_s), which indicates the level of association between photo rankings ranked by different groups. The photograph ranking is derived from group means for each photo. Spearman's rank-order correlation is calculated by Eq. (4)

$$r_s = 1 - \frac{6\sum d^2}{N(N^2 - 1)} \tag{4}$$

where d = difference in ranks assigned by two groups; N = number of responses regarding rank; If r_s is significant at the 0.05 level, there is certain association between the rankings of different groups.

The data analysis was processed using *SPSS 21.0*.

Data-Analysis Results

Within-Group Similarity/Difference

Table 4 presents the IRR values for photographs depicting the construction of facade systems and roof systems.

Participants in the WHS professional and the construction manager groups share high within-group similarity in rating the likelihood of accidental injury associated with constructing the facade systems, but relatively low within-group similarity in rating the consequence of accidental injury for each facade system. Participants in the architects group indicated relatively high within-group similarity in rating the consequence of accidental injury for facade systems, but low within-group similarity in rating the likelihood of accidental injury. Participants in the engineers group indicated the least within-group similarity in terms of both likelihood and consequence judgments.

Regarding the selected roof systems, the within-group consistency in ratings was high for some photographs and low for others. All four groups achieved relatively high similarity in rating both severity and likelihood of accidental injury for photographs R05 (tiled roof on timber rafters) and R06 (plywood sheathings installed to roof trusses).

Table 5 presents photo ranking and Kendall's coefficient of concordance (W) within each group based on participants' risk judgments for the selected building systems.

Regarding the facade systems, the results indicate a significant level of within-group similarity ($W = 0.367$; $p = 0.001$) in ranking the likelihood of accidental injury within the construction managers group. All four groups showed significant levels of within-group similarity in ranking the severity of consequential injury associated with constructing the facade systems.

All values of Kendall's coefficients of concordance (W) for risk judgments for the roof systems are significant at the 0.000 level, indicating that all four professional groups share high consensus in ranking the likelihood and consequence of risks associated with constructing the roof systems.

Between-Group Similarity/Difference

Figs. 3(a and b) indicate that overall the WHS professionals in the sample perceived the risks associated with constructing the facade systems to be the highest, whereas the construction managers perceived the risks to be the lowest. The engineers and architects in the study sample had very similar risk perceptions for all photographs except for F10 (concrete block wall facade system).

For the likelihood judgment of accidental injury associated with the facade systems, the four groups show the highest deviation in group means for F10 (SD=0.602), and the lowest deviation for F09 [in situ reinforced concrete (RC) walling; SD = 0.096] and F02 (precast concrete panel system for car park; SD = 0.189). Regarding the judgment of consequence of injury, the highest deviation in group means was found for F10 (SD = 0.629), and the lowest deviation for F03 (concrete and window panel facade system; SD = 0.141) and F02 (SD = 0.150). All four groups consider that the most severe accidental injury might happen in constructing the facade system depicted in F02, whereas the least severe accidental injury would be in the case of F10.

Figs. 4(a and b) show group means for judging WHS risks associated with the construction of the different roof systems. Overall, the construction managers in the study sample perceived the WHS risks to be low compared with the other three professional

Table 4. IRR in Rating Risks Associated with Constructing the Selected Systems

		WHS professional		Construction managers		Engineer		Architect	
Building element	Photo	Likelihood	Severity	Likelihood	Severity	Likelihood	Severity	Likelihood	Severity
Façade	F01	**0.883**	**0.883**	**0.728**	0.133	0.467	0.222	0.506	**0.800**
	F02	**0.950**	**0.883**	**0.756**	0.644	0.333	**0.756**	0.667	**0.756**
	F03	**0.756**	0.617	**0.728**	**0.839**	0.356	**0.756**	0.689	0.689
	F04	**0.728**	0.617	**0.750**	0.661	0.356	0.356	0.467	0.217
	F05	**0.728**	**0.728**	0.639	0.533	0.394	0.506	0.467	0.283
	F06	**0.772**	**0.728**	**0.911**	**0.800**	0.283	0.506	0.689	**0.800**
	F09	**0.861**	0.506	**0.772**	0.639	0.533	0.617	**0.772**	**0.756**
	F10	0.617	0.422	**0.889**	0.089	0.644	0.356	0.689	**0.772**
Roof	R01	**0.728**	0.467	**0.839**	0.244	0.644	**0.861**	**0.772**	**0.756**
	R02	0.506	0.328	0.506	0.556	0.533	0.194	0.528	0.550
	R03	0.617	0.667	0.578	0.533	0.550	0.617	**0.861**	**0.756**
	R04	0.306	0.506	**0.756**	**0.800**	0.550	0.422	0.661	0.644
	R05	**0.889**	**0.861**	**0.950**	**0.839**	**0.889**	**0.728**	**0.728**	0.533
	R06	**0.911**	**0.867**	**0.889**	**0.883**	**0.778**	**0.772**	**0.883**	0.689
	R09	0.644	0.556	0.578	0.506	0.617	**0.756**	0.467	**0.756**
	R10	**0.728**	0.467	0.667	0.661	**0.750**	0.661	0.528	0.533

Note: Bold IRR values are higher than 0.7, indicating acceptable within-group homogeneity.

Table 5. Photo Ranking and Kendall's Coefficient of Concordance (W) for Each Professional Group

		WHS professional				Construction manager				Engineer				Architect			
		Likelihood		Severity		Likelihood		Severity		Likelihood		Severity		Likelihood		Severity	
Building element	Photo	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
Façade	F01	0.30	5	1.70	7	0.10	5	1.20	7	–0.20	1	1.00	3	0.10	5	1.20	5
	F02	0.10	1	1.70	7	0.40	8	1.40	8	0.00	4	1.40	7	0.00	4	1.40	8
	F03	0.60	8	1.10	3	0.10	5	1.10	6	0.20	6	1.40	7	0.20	6	1.20	5
	F04	0.10	1	0.90	2	–0.50	2	0.30	2	–0.20	1	0.80	2	–0.20	1	0.70	3
	F05	0.10	1	1.10	3	–0.50	2	0.60	4	–0.10	3	1.10	4	–0.20	1	0.90	4
	F06	0.30	5	1.10	3	–0.20	4	0.80	5	0.10	5	1.10	4	0.20	6	1.20	5
	F09	0.50	7	1.10	3	0.30	7	0.50	3	0.40	7	1.10	4	0.30	8	0.60	2
	F10	0.10	1	0.60	1	–1.00	1	–0.60	1	0.40	7	0.20	1	–0.20	1	–0.70	1
	Kendall's coefficient of concordance (W)	0.128		0.309[a]		0.367[b]		0.302[a]		0.192		0.326[a]		0.082		0.473[b]	
	Significance (p)	0.254		0.003		0.001		0.004		0.062		0.002		0.571		0.000	
Roof	R01	–0.10	4	0.80	3.00	0.10	6	0.80	5	0.40	5	1.50	8.00	0.70	8	1.40	6
	R02	–0.90	1	–0.70	1.00	–0.90	2	–1.00	1	–0.60	1	–0.50	1.00	–0.50	1	–0.70	1
	R03	0.10	5	1.00	5.00	–0.20	4	0.60	4	0.30	4	1.10	5.00	0.50	7	1.40	6
	R04	0.50	6	0.90	4.00	–0.40	3	0.20	3	0.70	6	0.60	3.00	0.30	5	0.60	4
	R05	1.00	8	1.50	7.00	1.10	8	1.10	6	1.00	7	0.90	4.00	0.10	3	0.40	3
	R06	0.80	7	1.60	8.00	1.00	7	1.70	8	1.00	7	1.30	6.00	0.30	5	0.80	5
	R09	–0.40	3	1.00	5.00	–0.20	4	1.10	6	–0.10	3	1.40	7.00	0.20	4	1.40	6
	R10	–0.90	1	0.20	2.00	–1.00	1	–0.70	2	–0.50	2	0.30	2.00	–0.50	1	–0.40	2
	Kendall's coefficient of concordance (W)	0.627[b]		0.693[b]		0.649[b]		0.606[b]		0.587[b]		0.484[b]		0.332[a]		0.672[b]	
	Significance (p)	0.000		0.000		0.000		0.000		0.000		0.000		0.002		0.000	

[a]Correlation is significant at 0.01 level (two tailed).
[b]Correlation is significant at 0.001 level (two tailed).

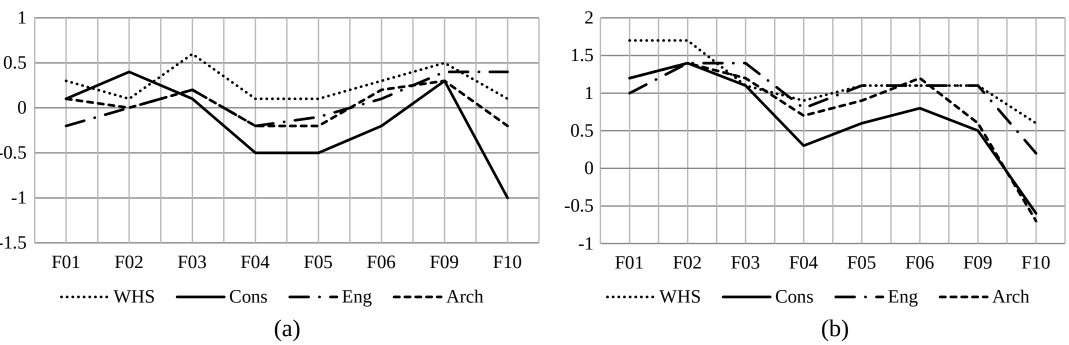

Fig. 3. Group means for judging risks associated with constructing the facade systems: (a) likelihood; (b) severity; Arch = architects; Cons = construction managers; Eng = engineers; WHS = work health and safety

groups. However, this was not the case for the roof systems depicted in R05 (tiled roof on timber rafters) and R06 (plywood sheathings installed to roof trusses). All four professional groups perceived the construction of roof systems depicted in R02 (flat in situ RC roof with bitumen-membrane waterproofing) and R10 (prefabricated roof systems for offsite built classrooms) to be the least risky. Fig. 4(a) indicated that three of the professional groups (i.e., the WHS professional, engineers, and construction managers) have similar likelihood perceptions for most photographs except for R04 (timber-rafter system for curved roof panels). The architects in the study sample have considerably different likelihood perceptions to the other groups especially in terms of photographs R05 and R06. The greatest deviations in likelihood ratings between professional groups were found for R04 (preassembled timber roof canopy system; SD = 0.479) and R05 (SD = 0.469), and lowest deviations were found for R02 (SD = 0.206) and R09 (SD = 0.250). Fig. 4(b) illustrates that the discrepancy in rating the consequence of risks between groups was highest for R10 (SD = 0.480), R05 (SD = 0.457), and R06 (SD = 0.404), and lowest for R02 (SD = 0.206) and R09 (SD = 0.206).

Table 6 presents the results of Spearman's rank-order correlations between groups regarding the ranking of photographs depicting the different facade systems and roof systems.

Between groups, only the WHS professionals and architects shared significant similarity in the way that they ranked the likelihood of accidental injury associated with the different facade systems ($r_s = 0.902$; $p \leq 0.01$). No significant rank-order correlation was found between other groups regarding their likelihood judgments. The professional groups were more similar in their ranking of the severity of consequence associated with accidental injury should it occur during the construction of the facade systems. Significant rank-order correlations were found between the WHS professionals and the construction managers ($r_s = 0.932$; $p \leq 0.01$), the WHS professionals and the architects ($r_s = 0.811$; $p \leq 0.05$), the construction managers and the engineers ($r_s = 0.712$; $p \leq 0.05$), and the construction managers and the

J. Constr. Eng. Manage., 2015, 141(5): 04014093

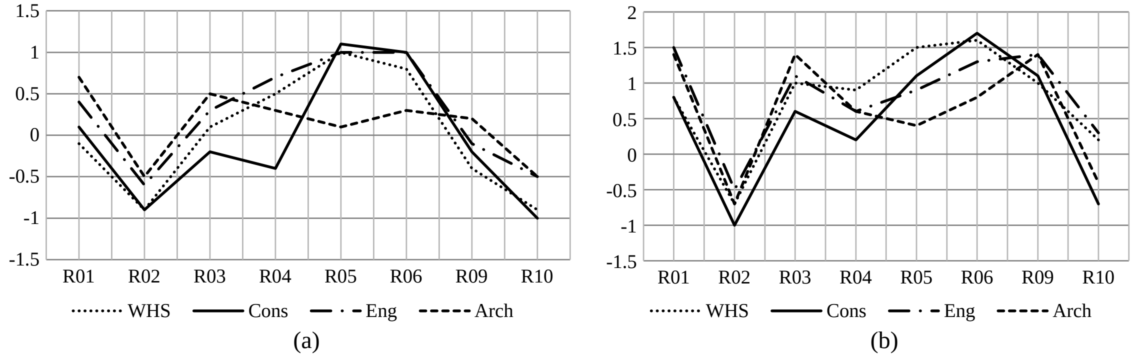

Fig. 4. Group means for judging risks associated with constructing the roof systems: (a) likelihood; (b) severity; Arch = architects; Cons = construction managers; Eng = engineers; WHS = work health and safety

Table 6. Spearman's Rank-Order Correlations between Groups for Risk Judgments

Risk judgment		Correlations			
Façade: likelihood		WHS professional	Construction manager	Engineer	Architect
	WHS professional	1.000	0.472	0.368	0.902[a]
	Construction manager	0.472	1.000	0.061	0.677
	Engineer	0.368	0.061	1.000	0.422
	Architect	0.902[a]	0.677	0.422	1.000
Façade: severity		WHS professional	Construction manager	Engineer	Architect
	WHS professional	1.000	0.932[a]	0.606	0.811[b]
	Construction manager	0.932[a]	1.000	0.712[b]	0.952[a]
	Engineer	0.606	0.712[b]	1.000	0.704
	Architect	0.811[b]	0.952[a]	0.704	1.000
Roof: likelihood		WHS professional	Construction manager	Engineer	Architect
	WHS professional	1.000	0.807[b]	0.964[a]	0.412
	Construction manager	0.807[b]	1.000	0.819[b]	0.461
	Engineer	0.964[a]	0.819[b]	1.000	0.467
	Architect	0.412	0.461	0.467	1.000
Roof: severity		WHS professional	Construction manager	Engineer	Architect
	WHS professional	1.000	0.898[a]	0.503	0.442
	Construction manager	0.898[a]	1.000	0.755[b]	0.565
	Engineer	0.503	0.755[b]	1.000	0.903[a]
	Architect	0.442	0.565	0.903[a]	1.000

[a]Correlation is significant at the 0.01 level (two tailed).
[b]Correlation is significant at the 0.05 level (two tailed).

architects ($r_s = 0.952$; $p \leq 0.01$). No significant rank-order correlation was found between the engineers and the architects in this sample nor was a significant rank-order correlation found between the WHS professionals and the engineers.

Regarding the roof systems, the WHS professionals and construction managers in the study sample share similar perceptions of the likelihood of an accidental injury in the use of the different roof systems, as evidenced by a significant rank-order correlation ($r_s = 0.807$; $p \leq 0.05$). Significant correlations were also found for the WHS professionals and engineers ($r_s = 0.964$; $p \leq 0.01$), and the construction managers and engineers ($r_s = 0.819$; $p \leq 0.05$). The architects' photograph ranking was not correlated with that of any other professional groups. Significant rank-order correlations in severity rankings were found between construction managers and WHS professionals ($r_s = 0.898$; $p \leq 0.01$), construction managers and engineers ($r_s = 0.755$; $p \leq 0.05$), and engineers and architects ($r_s = 0.903$; $p \leq 0.01$). Correlations for other group pairs were not significant.

A comparison between facade systems and roof systems indicates that participant groups in the study sample share much higher similarity in ranking the likelihood of risks associated with constructing roof systems than facade systems.

Discussion

The results reveal that there is no absolute within-group homogeneity among professional groups nor are between-group differences always evident with respect to participants' WHS risk perceptions associated with the selected building systems/technologies. Given the small sample size, the results may not be generalized to general professional groups. However, the coexistence of within-group difference and similarity, as well as between-group difference and similarity identified in professionals' risk perceptions in this study does imply that WHS risk perceptions are not entirely shaped by the education, training, and normative influences associated with being a member of a given profession. Rather, WHS risk perception may be better explained by a more complex interaction between multiple perspectives, that is, social, psychological, and technical factors.

Technical and Psychological Factors

Participants in a single professional group may perceive WHS risk quite differently. This is indicated by low IRR scores reflecting the fact that members of the same professional group rated the WHS risks inherent in some of the photographs differently, as well as the low within-group consensus in photo ranking in relation to the likelihood of accidental injury associated with constructing the façade systems. This may relate to the diverse disciplinary background of engineers in the sample (e.g., mechanical engineers, electrical engineers, structural engineers). Differences in technical knowledge may produce different understandings of (and perhaps tolerances to) WHS risk. However, low similarity among the other professional groups indicates that different personal or psychological factors may lead to different WHS risk perceptions, even when group members have similar training and technical knowledge.

Previous studies have indicated that risk perceptions can be influenced by individual personality traits, such as emotional stability, neuroticism, and anxiety (Bouyer et al. 2001; Fyhri and Backer-Grłndahl 2012), as well as beliefs about the characteristics of risk and self-efficacy in controlling risks (Kouabenan 2009). Individual experience is also a significant predictor of WHS risk perceptions (Flin et al. 1996). It is possible that within-group differences could be explained by participants' direct experiences of the use of a particular building system/technology or their knowledge or experience of a workplace accident (Kirschenbaum et al. 2000).

Social Group Factors

The research results also indicate that membership of a particular social group can influence WHS risk perceptions. The construction managers in the study sample had high levels of agreement about the likelihood of an accidental injury associated with constructing the facade systems. A possible explanation is that construction managers are actually engaged in the construction process and have direct responsibility for managing WHS on-site, and thus they may have developed a more consistent understanding of the WHS risks inherent in building systems/technologies compared with other professional groups. A strong relationship between risk knowledge and risk perception has been reported in a previous research (Sjöberg and Drottz-Sjöberg 1991).

The comparison of participant group means revealed that overall the construction managers in the study sample perceived WHS risks associated with the facade systems to be the lowest, whereas the WHS professionals in the study sample perceived risks to be the highest. Risk sensitivity has been reported as a strong predictor of individuals' risk perceptions in a previous research (Sjöberg 2000) and it is possible that WHS professionals are more risk sensitive due to their professional training and job role. Construction managers develop WHS plans and on-site WHS controls. Perceived control over risk has been identified to be an important variable to risk perception in previous studies (Greening 1997; Sjöberg 2000) and it is possible that construction managers' perceptions were shaped by their beliefs about the controllability of WHS risks. Architects and engineers rated the WHS risks associated with the different facade systems similarly, possibly because they are both mainly involved in the design stage of a construction project, and are typically removed from site-based production activities.

Photographs R05 (tiled roof on timber rafters) and R06 (plywood sheathings installed to roof trusses), both used in domestic construction, were rated consistently within each group but differently between groups. The explanatory comments provided by participants revealed that WHS professionals considered intensive manual-construction processes and work at height to increase the risk associated with these systems. The majority of construction managers thought that the fall-protection measures depicted in the photographs were insufficient to protect workers from falling. However, several engineers and architects perceived that working at relatively low height and using small building components make these roofing systems relatively safe, compared with the others. Among 203 fall-related fatalities with the height of the fall recorded in Australian workplaces during 2003–2004 to 2010–2011, 31% resulted from falling from 2 m or less, and another 19% involved falling from between 2 and 3 m (Safe Work Australia 2013c). The research results illustrate the subjectivity inherent in judging WHS risk and suggest that norms and practices attached to specific social groups may be influential (Gherardi et al. 2002; Pidgeon 1998).

The architects' ratings and rankings of WHS risk for the roofing systems deviated considerably from the other groups. It is possible that architects emphasize the functional performance and appearance of a roof but are less familiar with the process of constructing the various types of roof systems, leading them to differing WHS risk perceptions. These discrepancies highlight the need for communication between project stakeholders to ensure WHS risk implications of design choices are well understood.

Industrywide Factors

Participants in the four professional groups rated some photos very similarly but also rated some photos quite differently. For example, the four groups rated F09, depicting in situ RC walling with formwork being lifted to the concreting position, similarly. All groups considered that this system presented a relatively high likelihood of accidental injury because a large number of processes happen onsite compared with other facade systems/methods with prefabricated components. By contrast, all four groups rated F10, depicting a concrete block wall facade system being used in domestic construction, differently in terms of both likelihood of accidental injury and severity of consequence. If a particular system is widely used (as in F09), familiarity and common industry knowledge may create more consistent risk perceptions. However, in domestic construction (as in F10), WHS risk management is less systematic, and risk information is less explicit to stakeholders (Wadick 2010). Blockwork is labor intensive with a high-level manual handling. A major type of injury associated with the construction of blockwork walls is musculoskeletal-related injury (MSI). Compared with other injuries that need immediate treatment or hospitalization, MSIs receive less attention in the construction industry (Moriguchi et al. 2013). MSIs are chronic in nature and the effect is delayed, which may have contributed to the inconsistent ratings of WHS risk within and between the professional groups for F10. It is recorded that MSIs accounted for 34% of claims from 2008–2009 to 2010–2011 in the Australian construction industry (Safe Work Australia 2013a). The variation in professional groups' understanding of WHS risk inherent in blockwork is a concern as it may inhibit the implementation of CHPtD solutions for MSIs.

A particularly high discrepancy was observed in WHS risk ratings for photographs R04, R05, and R06, which are all related to domestic construction. The photographs depicted roofing systems deployed in the residential sector in the United States. These systems and construction methods are not generally used in the Australian context, which may explain the divergence in risk ratings. All groups (except architects) rated the risks associated with these three roofing systems to be high. However, the architects in the sample did not have similar perceptions, suggesting that roof-system-selection decisions should be informed by consultation and communication between different stakeholders.

All the professional groups perceive that the construction of a prefabricated roof system (R10) and large-scale flat in situ concrete roof (R02) posed the lowest level of WHS risk. Prefabrication has received much attention from both industry and research communities in Australia, and the benefit of reducing WHS risks on construction site by adopting prefabricated system has been recognized by practitioners (including clients, designers, constructors, and suppliers) in the Australian construction industry (Blismas and Wakefield 2009). In addition, minimizing the roof pitch to protect workers from falling has also been recognized as a safety feature in the construction industry (Construction Industry Institute 2011).

Number of Attributes Used for Risk Judgments

The professional groups show less within-group similarity in ranking the likelihood of a WHS risk than they do in ranking the consequence of WHS risks for the facade systems. This may be because participants consider far more attributes in making likelihood judgments than they do when making consequence judgments. This was confirmed in participants' answers to the open questions designed to explore reasons for participants' sorting patterns. When judging the likelihood of risk, participants considered a large number of attributes, such as different construction methods, complexity of construction processes, extent of use of machinery and the nature of machinery used, labor intensity, the number of different trades involved, the location of installation (e.g., external or internal), and level of familiarity with a specific system. However, when judging the consequence of risk, the main attributes considered are accident type (e.g., slip, trip, fall, struck by), the weight of the building component involved, and the potential height that someone could fall. The four professional groups also showed less between-group similarity in ranking the likelihood of accidental injury associated with the different facade systems than they did in ranking the consequence of accidental injury should it occur.

Complexity Associated with Constructing a Building Element

The comparison of WHS risk judgments for facade systems and roof systems indicates that the professional groups in the study sample share higher within-group similarity in ranking WHS risks for the roof systems than for the facade systems. Facade systems are arguably more complex than roofing systems requiring more attributes to be considered in judging the WHS risks. The professional groups were also found to share lower between-group similarity in ranking the WHS risks associated with facade systems than roof systems.

Conclusions

This study reported a preliminary analysis of within-group similarity/difference and between-group similarity/difference in project stakeholders' perceptions of WHS risks. An innovative photographic data-collection method based on Q methodology was designed for collecting data from four construction stakeholder groups. Participants were requested to make judgments about the likelihood of an accidental injury associated with the construction of a range of selected building systems, as well as the severity of consequence should any accident happen. The quantitative data analysis indicates the coexistence of within-group similarity and difference, and between-group similarity and difference in WHS risk perceptions. The research contributes to the overall body of knowledge by showing that WHS risk is subjective in nature and individual risk perception is the result of the interplay between factors, including technical factors, psychological factors, and wider social and industrial factors.

The understanding that risk judgments are also shaped by psychological and social factors suggests a multidisciplinary approach to WHS risk management in the construction-project environment. Using a technological approach alone to WHS risk analysis is inadequate to reflect the complexity of perceptions and judgments made by project participants. One reason is that technical estimates usually do not represent the *objective* probability or magnitude of harm because technical professionals (e.g., WHS professionals) are also members of a social group, and their risk judgments are also subject to various explicit or implicit assumptions associated with membership of that group (Lingard and Rowlinson 2005). A purely technical approach to risk analysis assumes that all causal pathways to events can be identified, which is unlikely to eventuate due to the complexity inherent in the interplay of human and technological systems (Lingard and Rowlinson 2005). Risk should be understood as being the manifestation of a combination of perceptions, social construction, and objective outcomes (Renn 1998). In the construction-project environment, risk-management strategies need to consider the WHS risk perceptions of all the stakeholders, who have an impact or who could be impacted by WHS risk assessment and control-related decisions.

The research results also have implications for the practical application of CHPtD in construction projects. Construction-project participants perceive WHS risks in different ways. It is possible that a design solution perceived to be safe by one participant group may be perceived to be associated with high chance of injury by another participant group. It is recommended that all relevant project participants' risk concerns be communicated and considered in the design stage to achieve equitable and satisfactory WHS risk-control outcomes. Participants perceive risks by referring to relevant attributes (DeJoy 1994). These attributions can be subject to certain biases and distortions that shape the way that people respond to WHS. The research highlights the usefulness of a photographic Q-sort process in bringing to light differences in ways of thinking about WHS within and between stakeholders groups. These differences are useful in helping to identify biases, misperceptions, and differences of experience or opinion in relation to WHS risks. It is suggested that all stakeholder groups who could impact WHS, or whose WHS could be impacted by project decision making, should be engaged in a consultative processes to explore their WHS risk judgments and evaluation criteria early in the construction-project lifecycle. Through communication and rational discourse about the magnitude of and best ways to control WHS risks, it is anticipated that the WHS experiences and perceptions of all project stakeholders can be considered in decision making. This is likely to lead to more comprehensive and accurate assessments of WHS risk, as well as more equitable and effective WHS risk-control measures.

Limitation and Future Studies

This preliminary analysis was conducted with a small sample size. In future, more comprehensive analysis will be conducted with a larger sample to provide a more robust insight into stakeholder groups' risk perceptions. For example, factor analysis with PQMethod (Schmolck 2013) will be conducted to categorize participants into different groups, within each of which participants share similar sorting patterns. Further, participants' responses to open questions will be systematically coded to reveal the salient attributes that participants used to make risk judgments. The coding results will also be used to characterize the groups identified from factor analysis to explore the perspectives that are adopted by each group to make risk judgments.

The purpose of adopting image-based Q methodology was to elicit professionals' perceptions of WHS risks inherent in constructing various building systems. Therefore, participants were instructed to make risk judgments solely focusing on the building systems themselves and ignore the contextual information presented in the photographs, that is, worker, housekeeping, and surrounding power lines. However, it is recognized that some participants found it was difficult to ignore the contextual *noise* in photographs. It is recommended that future research adopting image-based Q methodology use photographs or drawings depicting building systems only without showing contextual information.

Acknowledgments

This work was supported by Cooperative Agreement OH009761 from the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention (CDC). Its contents are solely the responsibility of the writers and do not necessarily represent the official views of the CDC.

References

Aksorn, T., and Hadikusumo, B. H. W. (2008). "Critical success factors influencing safety program performance in Thai construction projects." *Saf. Sci.*, 46(4), 709–727.

Anandarajan, M., Paravastu, N., and Simmers, C. A. (2006). "Perceptions of personal web usage in the workplace: AQ-methodology approach." *Cyberpsychol. Behav.*, 9(3), 325–335.

Atkinson, A. R., and Westall, R. (2010). "The relationship between integrated design and construction and safety on construction projects." *Constr. Manage. Econ.*, 28(9), 1007–1017.

Baradan, S., and Usmen, M. A. (2006). "Comparative injury and fatality risk analysis of building trades." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2006)132:5(533), 533–539.

Behm, M. (2005). "Linking construction fatalities to the design for construction safety concept." *Saf. Sci.*, 43(8), 589–611.

Blismas, N., and Wakefield, R. (2009). "Drivers, constraints and the future of offsite manufacture in Australia." *Constr. Innovation*, 9(1), 72–83.

Bouyer, M., Bagdassarian, S., Chaabanne, S., and Mullet, E. (2001). "Personality correlates of risk perception." *Risk Anal.*, 21(3), 457–466.

Brown, S. R. (1980). *Political subjectivity: Applications of Q methodology in political science*, Yale University Press, New Haven, CT.

Construction Industry Institute. (2011). *Design for construction safety toolbox*, Univ. of Texas, Austin, TX.

DeJoy, D. M. (1994). "Managing safety in the workplace: An attribution theory analysis and model." *J. Saf. Res.*, 25(1), 3–17.

Fairweather, J. R., Swaffield, S. R., and Simmons, D. G. (1998). "Understanding visitors' experiences in Kaikoura using photographs of landscapes and Q method." *Tourism Research and Education Centre (TREC) Rep. No. 5*, Tourism Research and Education Centre, Lincoln Univ, New Zealand.

Fang, D., Chen, Y., and Wong, L. (2006). "Safety climate in construction industry: A case study in Hong Kong." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2006)132:6(573), 573–584.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., and Combs, B. (1978). "How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits." *Policy Sci.*, 9(2), 127–152.

Flin, R., Mearns, K., Gordon, R., and Fleming, M. (1996). "Risk perception by offshore workers on UK oil and gas platforms." *Saf. Sci.*, 22(1–3), 131–145.

Fyhri, A., and Backer-Grøndahl, A. (2012). "Personality and risk perception in transport." *Accid. Anal. Prev.*, 49, 470–475.

Gambatese, J., and Hinze, J. (1999). "Addressing construction worker safety in the design phase: Designing for construction worker safety." *Autom. Constr.*, 8(6), 643–649.

Gangolells, M., Casals, M., Forcada, N., Roca, X., and Fuertes, A. (2010). "Mitigating construction safety risks using prevention through design." *J. Saf. Res.*, 41(2), 107–122.

Gherardi, S., Nicolini, D., and Odella, F. (2002). "What do you mean by safety? Conflicting perspectives on accident causation and safety management in a construction firm." *J. Contingencies Crisis Manage.*, 6(4), 202–213.

Green, R. (2005). "Community perceptions of environmental and social change and tourism development on the island of Koh Samui, Thailand." *J. Environ. Psychol.*, 25(1), 37–56.

Greening, L. (1997). "Risk perception following exposure to a job-related electrocution accident: The mediating role of perceived control." *Acta Psychol.*, 95(3), 267–277.

Hallowell, M. (2010). "Safety risk perception in construction companies in the Pacific northwest of the USA." *Constr. Manage. Econ.*, 28(4), 403–413.

Hare, B., Cameron, I., and Duff, A. R. (2006). "Exploring the integration of health and safety with pre-construction planning." *Eng. Constr. Archit. Manage.*, 13(5), 438–450.

Haslam, R. A., et al. (2005). "Contributing factors in construction accidents." *Appl. Ergon.*, 36(4), 401–415.

Holmes, N., Gifford, S. M., and Triggs, T. J. (1998). "Meanings of risk control in occupational health and safety among employers and employees." *Saf. Sci.*, 28(3), 141–154.

Iavicoli, S., et al. (2011). "Occupational health and safety policy and psychosocial risks in Europe: The role of stakeholders' perceptions." *Health Policy*, 101(1), 87–94.

James, L., Demaree, R., and Wolf, G. (1984). "Estimating within-in group interrater reliability with and without response bias." *J. Appl. Psychol.*, 69(1), 85–98.

James, L. R., Demaree, R. G., and Wolf, G. (1993). "RWG: An assessment of within-group interrater agreement." *J. Appl. Psychol.*, 78(2), 306–309.

Jannadi, O. A., and Almishari, S. (2003). "Risk assessment in construction." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2003)129:5(492), 492–500.

Kirschenbaum, A., Oigenblick, L., and Goldberg, A. I. (2000). "Well being, work environment and work accidents." *Soc. Sci. Med.*, 50(5), 631–639.

Kleiner, B. M. and Hallowell, M. R. (2012). "Progress Rep." Construction Industry Institute, Univ. of Texas, Austin, TX.

Kleiner, B. M., and Shewchuk, J. P. (2001). "Participatory function allocation in manufacturing." *Hum. Factors Ergon. Manuf.*, 11(3), 195–212.

Koehn, E., and Datta, N. (2003). "Quality, environmental, and health and safety management systems for construction engineering." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2003)129:5(562), 562–569.

Kouabenan, D. R. (2009). "Role of beliefs in accident and risk analysis and prevention." *Saf. Sci.*, 47(6), 767–776.

Kumar, R. (1999). *Research methodology: A step-by-step guide for beginners 1999*, Sage, London.

LeBreton, J. M., and Senter, J. L. (2008). "Answers to 20 questions about interrater reliability and interrater agreement." *Organ. Res. Methods*, 11(4), 815–852.

Lingard, H., Cooke, T., Blismas, N., and Kleiner, B. (2011). "A sociotechnical systems analysis of OSH decision-making in the early stages of construction projects." *Proc., CIB W099, Prevention: Means to the End of Construction Injuries, Illnesses, and Fatalities*, Virginia Tech, Washington, DC, 1–16.

Lingard, H., Pirzadeh, P., Harley, J., Blismas, N., and Wakefield, R. (2013). *Safety in design*, RMIT Centre for Construction Work Health and Safety (WHS), Melbourne, VIC, Australia.

Lingard, H., and Rowlinson, S. (2005). *Occupational health and safety in construction project management*, Taylor & Francis, London.

Mohamed, S. (2002). "Safety climate in construction site environments." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2002)128:5(375), 375–384.

Moriguchi, C. S., et al. (2013). "Occupational posture exposure among construction electricians." *Appl. Ergon.*, 44(1), 86–92.

Pidgeon, N. (1998). "Risk assessment, risk values and the social science programme: Why we do need risk perception research." *Reliab. Eng. Syst. Saf.*, 59(1), 5–15.

Renn, O. (1998). "The role of risk perception for risk management." *Reliab. Eng. Syst. Saf.*, 59(1), 49–62.

Rohrmann, B. (1994). "Risk perception of different societal groups: Australian findings and crossnational comparisons." *Aust. J. Psychol.*, 46(3), 150–163.

Safe Work Australia. (2012). "Work-related traumatic injury fatalities Australia 2010-2011." ⟨http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/traumatic-injury-fatalities-2010-11⟩ (Nov. 21, 2013).

Safe Work Australia. (2013a). "Construction fact sheet." ⟨http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/430/Construction-Fact-Sheet-2011-12.pdf⟩ (Apr. 28, 2014).

Safe Work Australia. (2013b). "Key work health and safety statistic 2013." ⟨http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/758/Key-WHS-Statistics-2013.pdf⟩ (Mar. 15, 2014).

Safe Work Australia. (2013c). "Work-related injuries and fatalities involving a fall from height, Australia." ⟨http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/812/Falls-from-Height.pdf⟩ (Apr. 28, 2014).

Sawacha, E., Naoum, S., and Fong, D. (1999). "Factors affecting safety performance on construction." *Int. J. Proj. Manage.*, 17(5), 309–315.

Schmolck, P. (2013). *PQMethod software (version, 2.33)*, ⟨http://schmolck.userweb.mwn.de/qmethod/downpqwin.htm⟩.

Sjöberg, L. (2000). "Factors in risk perception." *Risk Anal.*, 20(1), 1–12.

Sjöberg, L., and Drottz-Sjöberg, B. M. (1991). "Knowledge and risk perception among nuclear power plant employees." *Risk Anal.*, 11(4), 607–618.

Slovic, P. (1987). "Perception of risk." *Science*, 236(4799), 280–285.

Slovic, P., Fischhoff, B., and Lichtenstein, S. (1982). "Why study risk perception?" *Risk Anal.*, 2(2), 83–93.

SPSS Statistics for Windows version 21.0 [Computer software]. Armonk, NY, IBM.

Stenner, P., Watts, S., and Worrell, M. (2008). "Q methodology." *The SAGE handbook of qualitative research in psychology*, C. Willig and W. Stainton-Rogers, ed., Sage, London, 10–11.

Suraji, A., Duff, A. R., and Peckitt, S. J. (2001). "Development of causal model of construction accident causation." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2001)127:4(337), 337–344.

Surry, J. (1979). "Industrial accident research: A human engineering appraisal." Ontario Labor Safety Council, Toronto, ON.

Toole, T. M. (2002). "Construction site safety roles." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2002)128:3(203), 203–210.

Toole, T. M., and Gambatese, J. (2008). "The trajectories of prevention through design in construction." *J. Saf. Res.*, 39(2), 225–230.

Wadick, P. (2010). "Safety culture among subcontractors in the domestic housing construction industry." *Struct. Surv.*, 28(2), 108–120.

Watts, S., and Stenner, P. (2005). "Doing Q methodology: Theory, method and interpretation." *Qual. Res. Psychol.*, 2(1), 67–91.

Zhang, P., Lingard, H., Blismas, N., Wakefield, R., and Kleiner, B. (2013). "Application of Q-methodology in studying construction stakeholders' perceptions of OSH risks: An introduction to the preliminary stage." *Proc., 19th Triennial CIB World Building Congress*, A. O. J. V. McCarthy, S. Kajewski, K. Manley, and K. Hampson, eds., Queensland Univ. of Technology, Brisbane, QLD, Australia, 1–12.

J. Constr. Eng. Manage., 2015, 141(5): 04014093