

ANALYSIS OF DIFFERENCE/SIMILARITY BETWEEN CONSTRUCTION PROJECT PARTICIPANTS' WORK HEALTH AND SAFETY (WHS) RISK PERCEPTIONS

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This research aims to analyse the within- and between-group similarity/difference in WHS risk perceptions of construction project participants. This study employs Q-methodology with an innovative photographic data collection method to explore construction project participants' WHS risk perceptions. Specifically, a set of photos were selected to represent a range of commonly used construction methodologies/building systems. Participants invited from four professional groups were requested to 'sort' the set of photos according to their judgements of the likelihood and magnitude of WHS risks associated with constructing these different systems. This paper reports a preliminary analysis of the within- and between-group similarity/difference in WHS risk perceptions related to constructing different façade systems and roof systems. Nonparametric statistic methods, i.e. Kendall's Coefficient of Concordance (W) and Spearman's Rank Order Correlation (r_s), were used to analyse the data. This study finds that professional groups' risk perceptions can be influenced by the different levels of complexity inherent in constructing different building elements. Professional groups share lower within-group and between-group similarities in the judgement of likelihood of risks than in the judgement of severity of risks. Professional groups' risk perceptions are also largely affected by a wide range of social factors such as personal experience, attitude, beliefs and contextual environment. Therefore, participants from the same professional group may show different risk perceptions, while participants from different professional groups may share similar risk perceptions. This research provides the basis for developing an image-based tool in the planning and design stage of a construction project to engage all project team members in discussion about the WHS implications of their decision making. The tool will help construction participant groups to understand each other's WHS perspective. This will facilitate the development of a shared mental model of WHS within construction projects and create a strong and positive safety culture. This research is, to our knowledge, the first attempt to employ Q-methodology in studying construction participants' OSH risk perceptions. It provides a new starting point for other researchers to study risk perception in the construction management area.

Key words: work health and safety, risk perception, construction, Q-methodology

INTRODUCTION

The primary responsibility for site safety has traditionally been ascribed to general/principal contractors (Toole, 2002). Regulations and policies assign substantial obligations to contractors to plan for health and safety, and assess the risks

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to their employees (Hare et al., 2006). Therefore, early efforts to improve construction work health and safety (WHS) performance have mainly targeted contractors. Though some recent improvements have been noticed, construction WHS performance is still relatively poor and more improvements are desired (Atkinson, 2010).

There is increasing recognition among researchers that WHS risks in the construction stage can be traced back to decisions made by project participants in the planning and design stage. For example, Cooke et al. (2011) found that a client's decision to changing the technical requirements of a constructed facility lead to WHS impact on construction workers. Behm (2005) reviewed 224 fatality investigation reports and found that 42% of the fatalities are linked to design decisions. The result is further confirmed in another study conducted by Gambatese et al. (2008). It is the design that determines how project components will be assembled and what construction tasks will be undertaken (Gambatese & Hinze, 1999). Recently, the concept of Construction Hazard Prevention through Design (CHPtD) has received much attention from researchers (see, for example, Toole & Gambatese (2008), Gangoellis et al. (2010)). There is therefore substantial opportunity for reducing WHS risk upstream by ensuring decision-makers take WHS considerations into consideration earlier in the process. They need to evaluate the potential impact of their decisions on WHS in the construction stage, and formulate appropriate strategies to control or eliminate WHS risks at sources.

In real practice, however, the WHS risks perceived by decision makers are sometimes markedly different from the perceptions of personnel involved in the construction process or what actually happens on site. The construction industry is highly fragmented and complex. Decision makers are usually organizationally and spatially distal from productive work, and decisions are usually made before commencement of construction works. The construction industry is also characterized by adversarial relationships between project participants, who usually pursue different project interests. In such an environment, it is difficult for decision makers to 'take the perspective' of persons whose WHS might be affected by their decisions. Practically, the fact that designers usually lack construction process knowledge, lack formal education of construction safety as well as have limited involvement in overseeing site safety create further barriers for them to consider WHS risks properly (Gambatese & Hinze, 1999; Toole, 2002).

AIM

This study is part of a research project that attempts to understand the similarity/differences between different professional groups' risk perceptions. This understanding will inform each professional group of other groups' perspectives, and help in establishing a shared mental model in terms of risk perceptions. This paper reports preliminary findings of within- and between-group similarity/difference in project participant groups' risk perceptions.

RISK PERCEPTION

Risk perception is an individual's subjective judgement about the frequency and severity of hazards associated with an activity or an event (Baradan & Usmen, 2006; Hallowell, 2010). Risk perception is subjective in nature because it is influenced by a large number of sociotechnical factors, including individuals' personal beliefs, attitudes, occupation, perspectives, experience, etc. (see for example, Flin et al.

(1996); Holmes et al. (1998)). Risk perception is an antecedent to safety-related decisions and behaviours. Surry's (1979) decision model of accident occurrence 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. Previous research has reported the strong link between individual risk perception and one's behaviour toward the risk. For example, Arezes & Miguel (2008) find that industrial workers who have better recognition of noise related risks tend to use hearing protection devices (HPDs) more consistently. On the contrary, any biases in risk perception can cause misinterpretations of potential risk impact, which then lead to inappropriate risk behaviour.

At the risk management level, risk perception provides the basis for the conceptualization of risk control/mitigation strategy. If a decision-maker can't perceive a risk accurately then 'safe' decisions are unlikely to eventuate. In circumstances where multiple participant groups are involved, conflicts in risk perceptions would result in subsequent conflicts in risk control strategy. In an occupational health and safety (OHS) study conducted by Iavicoli et al. (2011), researchers report that there are gaps between stakeholders' (including employers, trade unions and government institutions) perceptions regarding psychological risks and work related stress in the European Union (EU), and the perception gaps cause consequent difficulty in implementing shared prevention/correction strategies. Similarly, the discrepancy between construction project participants' understanding of the nature of WHS risks and/or opportunities for control may significantly hinder the effectiveness of WHS risk management in a construction project. Therefore, it is imperative to study how different participant groups perceive risks and seek opportunities to inform each other's risk perspectives. This would help to promote 'perspective taking' in project decision-making, especially when the decisions have significant impact on WHS in the construction stage.

RESEARCH DESIGN

Q-methodology

An innovative photographic data collection method based on Q-methodology was used to explore construction professional groups' WHS risk perceptions. Q-methodology is recommended to be a suitable technique to study cognitive structure, attitude, and perceptions of people (Anandarajan et al., 2006). Q-methodology requires participants (named as 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.

The Q-set can take different forms, such as statements of opinions, photos, or other stimuli. 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 for Q-sorting in landscaping studies (see, for example, (Green, 2005), (Fairweather et al., 1998)), and also successfully used as experimental stimuli in construction hazard identification (Kleiner and Hallowell, 2012). The detailed processes of developing the photographic tool have been introduced in Zhang, et al.

(2013). As the current paper mainly focuses on reporting the results from a preliminary study by utilizing the photographic tool, only a brief description to the tool development is provided here.

Q-set generation

Q-methodology requires researchers to generate a Q-set which is broadly representative of the issues under investigation (Stenner et al., 2008; Watts & Stenner, 2005). Photographs representing different but commonly used construction methodologies/building systems to four building elements (i.e. façade, roof, structure, and building service) were specifically selected. Those photographs were presented to industrial practitioners and subjected to a pilot validation to ensure that photos are indeed representative and provide sufficient information for participants to make judgements. Finally, eight photographs were retained for each building system. Figure 1 shows sample photographs used in this study.

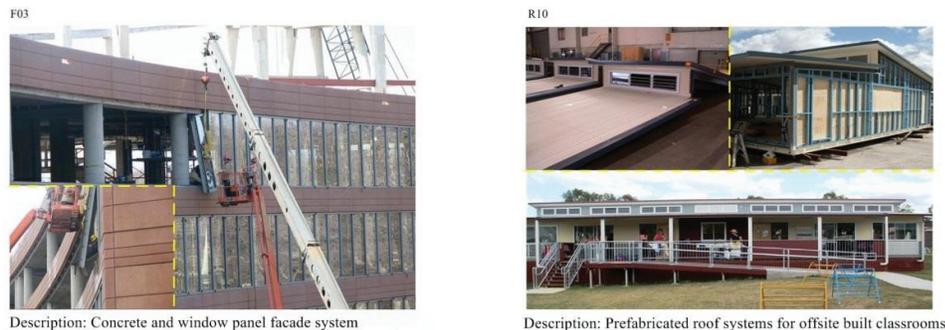


Figure 1: Sample photographs

P-set selection

Among various participants involved in a typical construction project, four participant groups were selected as participants, namely architects, engineers, constructors, and occupational health and safety (OHS) professionals. The underlying rationale is that they either participate in decision making concerning selecting a particular system/methodology (e.g. architect, engineers) or respond to the decision made (i.e. constructors, OHS professionals). In other words, these four participant groups have the most influence on or are most impacted by WHS risks implicit in design decisions. Q-methodology doesn't require a large number of participants as it aims to capture main viewpoints that are shared by a group of people (Watts & Stenner, 2005). The main study will have 20 participants from each group giving a total of 80 participants. For this preliminary study, 10 participants are involved for each group.

Condition of instruction

The 'Condition of Instruction' establishes the rules by which participants are asked to perform the sorting task. In this study, participants were requested to perform two rounds of photograph sorting for each building element. Participants were firstly instructed to sort the photographs into a grid according to their evaluation of the likelihood of an accidental injury arising when a depicted construction methodology is used. The grid contains five columns with a rating scale ranging from '-2 Rare' to '+2 Almost certain'. Then participants were asked to sort the photographs into another grid based on their judgements of the severity of consequential injury should an

accident occur. The rating scale ranges from ‘-2 Minor’ to ‘+2 Catastrophic’. After each round of sorting, respondents were asked a number of open questions to explain the reasons underlying the sorting patterns.

DATA ANALYSIS METHOD

This preliminary study provides a quick view to construction project participants’ risk perceptions. Nonparametric analysis methods were used to reveal the within and between group similarity/difference in risk perceptions related to the selected building systems. In this paper, two building elements were used as examples to present the data analysis results, namely façade and roof.

The within-group risk perception similarity/difference is assessed by the Kendall’s Coefficient of Concordance (W), which indicates the level of agreement regarding the ranking of photographs among participants of the same group. The between-group risk perception similarity/difference is measured by the Spearman’s Rank Order Correlation (r_s), which indicates the level of association between photo rankings ranked by different groups. The photo ranking was determined by the mean scores, which were derived from the ranking scores (i.e. -2 to +2) assigned to the photographs by participants of each group. The data analysis was processed with the statistic software of SPSS 21.0.

DATA ANALYSIS RESULTS

Within-group similarity/difference in risk perceptions

Table 1 shows the photo ranking and Kendall’s Coefficient of Concordance (W) within each professional group based on participants’ risk judgements for different façade systems. The results indicate that only the constructor group shows significant levels of within-group similarity ($W = 0.367$; $p = 0.001$) in the perceptions of the likelihood of risks associated with construction of the different façade systems. The other three groups have much discrepancy in the likelihood component of risk perceptions for the façade systems. Regarding the perception of the severity of any consequential injury in constructing the different façade systems, all four groups show significant levels of within-group similarities.

Table 1: Photo ranking and Kendall’s Coefficient of Concordance (W) for each professional group – Façade systems

	Façade – Likelihood							
	OHS		Constructor		Engineer		Architect	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
F01	.30	5	.10	5	-.20	1	.10	5
F02	.10	1	.40	8	.00	4	.00	4
F03	.60	8	.10	5	.20	6	.20	6
F04	.10	1	-.50	2	-.20	1	-.20	1
F05	.10	1	-.50	2	-.10	3	-.20	1
F06	.30	5	-.20	4	.10	5	.20	6
F09	.50	7	.30	7	.40	7	.30	8
F10	.10	1	-1.00	1	.40	7	-.20	1
Kendall’s Coefficient of	.128		0.367		.192		.082	

Concordance (W)								
Sig. (<i>p</i>)	.254		0.001		0.062		.571	
Façade – Severity								
	OHS		Constructor		Engineer		Architect	
	Mean score	Rank						
F01	1.70	7	1.20	7	1.00	3	1.20	5
F02	1.70	7	1.40	8	1.40	7	1.40	8
F03	1.10	3	1.10	6	1.40	7	1.20	5
F04	.90	2	.30	2	.80	2	.70	3
F05	1.10	3	.60	4	1.10	4	.90	4
F06	1.10	3	.80	5	1.10	4	1.20	5
F09	1.10	3	.50	3	1.10	4	.60	2
F10	.60	1	-.60	1	.20	1	-.70	1
Kendall's Coefficient of Concordance (W)	.309		.302		.326		.473	
Sig. (<i>p</i>)	.003		.004		.002		.000	

Table 2 indicates that all four professional groups show significant levels of within-group similarity in terms of likelihood and severity components of risk perceptions for different roof systems. The results indicate high level group homogeneity in risk perceptions regarding construction of alternative roof systems.

Table 2: Photo ranking and Kendall's Coefficient of Concordance (W) for each professional group – roof systems

Roof – Likelihood									
	OHS		Constructor		Engineer		Architect		
	Mean score	Rank							
R01	-.10	4	.10	6	.40	5	.70	8	
R02	-.90	1	-.90	2	-.60	1	-.50	1	
R03	.10	5	-.20	4	.30	4	.50	7	
R04	.50	6	-.70	3	.70	6	.30	5	
R05	1.00	8	1.10	8	1.00	7	.10	3	
R06	.80	7	1.00	7	1.00	7	.30	5	
R09	-.40	3	-.20	4	-.10	3	.20	4	
R10	-.90	1	-1.00	1	-.50	2	-.50	1	
Kendall's Coefficient of Concordance (W)	.627		.642		.587		.332		
Sig. (<i>p</i>)	.000		.000		.000		.002		

Roof – Severity									
	OHS		Constructor		Engineer		Architect		
	Mean score	Rank							
R01	.80	3.00	.80	5	1.50	8.00	1.40	6	
R02	-.70	1.00	-1.00	1	-.50	1.00	-.70	1	
R03	1.00	5.00	.60	4	1.10	5.00	1.40	6	
R04	.90	4.00	.20	3	.60	3.00	.60	4	
R05	1.50	7.00	1.10	6	.90	4.00	.40	3	
R06	1.60	8.00	1.70	8	1.30	6.00	.80	5	
R09	1.00	5.00	1.10	6	1.40	7.00	1.40	6	
R10	.20	2.00	-.70	2	.30	2.00	-.40	2	
Kendall's Coefficient of Concordance (<i>W</i>)	.693		.606		.484		.672		
Sig. (<i>p</i>)	.000		.000		.000		.000		

Between-group similarity/difference in risk perceptions

Table 3 lists the results of Spearman's Rank Order Correlations between groups regarding risk perceptions related to construction of alternative façade systems. It shows that only the OHS group and Architect group share significant levels of similarity in the likelihood component of risk perceptions ($r_s = 0.902$; $p \leq 0.01$). No significant correlation is found between other groups regarding the likelihood judgement. The results suggest a high level of between-group difference in the likelihood judgement for risks associated with constructing the different façade systems.

Table 3 also shows that professional groups share much similarity in the severity judgment for risks associated with constructing the façade systems. Significant correlations were identified for OHS group and Constructor group ($r_s = 0.932$; $p \leq 0.01$), OHS group and Architect group ($r_s = 0.811$; $p \leq 0.05$), Constructor group and Engineer group ($r_s = 0.712$; $p \leq 0.05$), and Constructor group and Architect group ($r_s = 0.952$; $p \leq 0.01$). Surprisingly, no significant correlation was found between Engineer group and Architect group, which belong to the same functional group of designers. Nor was any significant correlation found between the OHS group and Engineer group.

Table 3: Spearman's Rank Order Correlations between groups – risk judgement for façade systems

Façade – Likelihood				
	OHS	Constructor	Engineer	Architect
OHS	1.000	.472	.368	.902**
Constructor	.472	1.000	.061	.677
Engineer	.368	.061	1.000	.422

Architect	.902**	.677	.422	1.000
Façade – Severity				
	OHS	Constructor	Engineer	Architect
OHS	1.000	.932**	.606	.811*
Constructor	.932**	1.000	.712*	.952**
Engineer	.606	.712*	1.000	.704
Architect	.811*	.952**	.704	1.000

** . Correlation is significant at the 0.01 level (2-tailed).
* . Correlation is significant at the 0.05 level (2-tailed).

Table 4 indicates that high similarity is shared between OHS group and Constructor group ($r_s = 0.807$; $p \leq 0.05$), OHS group and Engineer group ($r_s = 0.964$; $p \leq 0.01$), and Constructor group and Engineer group ($r_s = 0.819$; $p \leq 0.05$) regarding the likelihood judgement for risks related to construction of the selected roof systems. It is noticeable that the Architect group does not share any similarity with any of the other three groups.

Regarding the severity component of risk perceptions for the roof systems, significant correlations were noticed between the Constructor group and OHS group ($r_s = 0.898$; $p \leq 0.01$), Constructor group and Engineer group ($r_s = 0.755$; $p \leq 0.05$), Engineer group and Architect group ($r_s = 0.903$; $p \leq 0.01$). Correlations for other pairs of groups were not significant.

Table 4: Spearman's Rank Order Correlations between groups – risk judgement for roof systems

Roof – Likelihood				
	OHS	Constructor	Engineer	Architect
OHS	1.000	.807*	.964**	.412
Constructor	.807*	1.000	.819*	.461
Engineer	.964**	.819*	1.000	.467
Architect	.412	.461	.467	1.000
Roof – Severity				
	OHS	Constructor	Engineer	Architect
OHS	1.000	.898**	.503	.442
Constructor	.898**	1.000	.755*	.565
Engineer	.503	.755*	1.000	.903**
Architect	.442	.565	.903**	1.000

** . Correlation is significant at the 0.01 level (2-tailed).
* . Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION OF RESULTS

The preliminary study has revealed some interesting findings in terms of professional groups' risk perceptions related to construction of a range of façade systems and roof systems.

It is found that participants share different levels of within-group similarities in risk perceptions for different building elements, i.e. they show more agreement on risk judgements for roof systems than for façade systems. A possible reason is that the construction process for façade systems is inherently more complicated than that of roof systems. Complicated construction processes introduce more variables or perspectives for participants to consider when making risk judgements. More variables or perspectives further lead to high discrepancy in participants' risk judgements. The result implies that professional groups' risk perceptions can be influenced by the different levels of complexity associated with the construction processes of different building elements.

The results of risk perception relating to constructing different façade systems revealed that there is no absolute within-group homogeneity in risk perceptions. Participants from the same professional group may view risk differently. This result is in accordance to previous researchers' arguments that risk perception is socially constructed, thus would be influenced by a wide range of factors (e.g. personal beliefs, attitudes and experience, contextual environment) apart from professional background (Pidgeon, 1998). The Constructor group is the only group that showed high level similarity in this round of judgement. This is because constructors are those who are actually engaged in the construction process, and therefore have a better understanding of the risks associated with constructing the façade systems than other groups.

The results of risk perceptions for façade systems also show that professional groups show more within-group difference in the likelihood component of risk perceptions than in the severity component of risk perceptions. One possible reason is that participants consider far more attributes/factors in the likelihood judgement for risks than in the severity judgement for risks. This was confirmed in participants' answers to the open questions, which were designed to explore why participants sort the photographs in a particular way. When judging the likelihood of risk, participants consider many attributes, including complexity of a system, level of machinery required, level of labour force involved, number of trades involved, the location of installation (e.g. external or internal), level of familiarity with a specific system, etc. However, when judging the consequence of risk, the main attributes considered are the impacts of a potential risks (e.g. first aid, hospitalization, single fatality, multiple fatalities).

Similar patterns were found for the between-group similarities/differences in risk perceptions, i.e. professional groups share higher between-group similarity in risk perceptions for the façade systems than for the roof systems, and they show more between-group difference in the judgement of likelihood of risks than in the judgement of severity of risks. The results could also be explained by the reason that construction of façade systems is more complex than construction of roof systems, and more factors can be taken into account for judgement of the likelihood of risks than for judgement of the severity of risks. It is also evident that the Architect group does not share significant levels of similarity with any other group in the likelihood

judgement for risks associated with constructing the selected roof systems. It is recommended that more risk-related communication should be conducted between architect groups and other professional groups. The input of other professional groups' risk perspectives will enable architects to have better understanding of potential impact of their design decisions on WHS in the construction stage, and thus better reduces or even eliminate risks at the design stage.

CONCLUSION AND FUTHER STUDIES

This study reported a preliminary analysis of within- and between-group similarity/difference in project participants' risk perceptions. An innovative photographic data collection method based on Q-methodology was designed for collecting data from four construction professional groups. Participants were requested to make risk judgements against the likelihood of any accidental injury relating to construction of a range of selected building systems as well as the severity of consequence should any accident happen. The research found that there is no absolute within-group homogeneity in participants' risk perceptions, which is indicated by the low Kendall's Coefficient of Concordance (W) values for ranking the façade systems in terms of the likelihood of accidental injuries. Nor distinct between-group difference was found, which was suggested by a number of significant correlations between groups regarding ranking the likelihood and magnitude of risks associated with constructing the building systems. The research results suggest that individual risk perceptions are not only shaped by knowledge, practice, and norms associated with a specific profession, but also influenced by a wide range of personal and social factors such as personal characteristic, belief, attitude, experiences and contextual environment. Therefore, participants from the same professional group may show different risk perceptions, while participants from different professional groups may share similar risk perceptions.

The understanding that risk perceptions are influenced by various factors suggests a multidisciplinary approach to risk management in the construction industry. Technical approach to risk analysis is inadequate to reflect the complete picture of risk. Risk should be interpreted as the integral of perceptions, social construction and object outcomes (Renn, 1998). In the construction project environment, risk management strategies need to consider the risk perceptions of all participant groups, whose have an impact or who could be impacted by risk assessment and control decisions. The results also have implications for the practical application of the concept of 'design for safety' in construction project. 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.

In future, more comprehensive analysis will be conducted on a larger sample to provide a more robust insight into project participant groups' risk perceptions. For example, factor analysis with PQ-method will be conducted to categorize participants into different groups, within which participants share similar sorting patterns. Further, participants' responses to open questions will be systematically coded to reveal the various attributes/factors that participants used to make risk judgements. The coding results will also be used to characterize the groups identified from factor analysis.

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