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Application of Q-methodology in studying construction stakeholders' perceptions of OSH risks – An introduction to the preliminary stage

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Abstract

There is increasing recognition that many construction occupational health and safety (OSH) hazards arise as a result of activities in the planning and design stage. Improvement of construction OSH performance can be influenced by various stakeholder groups, not just the appointed construction contractor. It is important for stakeholder groups to take each other's perspective when considering OSH risks. However, different stakeholder groups may have different perceptions of OSH risk, leading to difficulty in establishing a common strategy to eliminate hazards and/or and reduce risk. This study aims to map the similarity/difference between stakeholder groups' OSH risk perceptions. An innovative Q-methodology is adopted for data collection. Q-methodology involves a number of procedures by which respondents sort a set of sample objects (known as a Q-set) into certain order, according to their subjective judgements. Photographs will be used as stimuli for the Q-sort in this study. This paper introduces the rationale of Q-methodology, and describes the process of developing and validating the Q-sort instrument for this construction application.

Key words: **Occupational health and safety, Construction industry, Design, Stakeholders, Q-methodology**

1. Introduction

The construction industry in Australia performs poorly in occupational health and safety (OSH) compared to other industries. Table 1 shows the incidence of worker fatalities in the Australian construction industry from 2003-04 to 2009-10. For each year, the number of deaths in

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construction accounted for more than 10% of the total number for all industries, and the percentage was as high as 18.1% in the year of 2009-10. The fatality rate (i.e. deaths per 100 000 workers) for the construction industry was significantly higher than that for all industries (yet approximately 50% of the U.S. rate).

Table 1: Worker fatalities in construction industry, Australia, 2003-04 to 2009-10; Source: Safe Work Australia, (2012)

	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Number of deaths while working							
Construction	38	28	42	50	40	44	39
All industries	272	253	287	301	292	289	216
Percentage	14.0%	11.1%	14.6%	16.6%	13.7%	15.2%	18.1%
Fatality rate (deaths per 100 000 workers)							
Construction	4.9	3.4	4.8	5.3	4.1	4.5	3.9
All industries	2.8	2.6	2.8	2.9	2.7	2.7	1.9

It has been traditionally assumed that contractors play the main role in construction safety (Toole, 2002). Existing regulations and policies have put obligations on contractors (as employers of workers) to identify, assess and control OSH risks in their planning activities (Hare *et al.*, 2006). Efforts to improve construction OSH performance have mainly targeted construction contracting companies. For example, Aksorn and Hadikusumo (2008) identified a range of safety programs adopted by contractors, including comprehensive safety polices, safety training, site inspections, safety incentive schemes, personal protection programs, safety auditing, safety record keeping, job hazard analysis, etc. Though some recent OSH improvements have been noticed, safety performance remains poor in construction and further improvement is needed (Atkinson, 2010).

There is an increasing awareness that a holistic approach is needed to manage construction OSH (Hare *et al.*, 2006) and there are many preventative opportunities upstream. Many technical and professional contributors make decisions that can potentially impact on OSH. For example, recent studies have demonstrated that on-site accidents are often rooted in design decisions (Behm, 2005; Gambatese *et al.*, 2008). The design of a facility can influence how a project or its components will be assembled and what construction tasks will be undertaken (Gambatese and Hinze, 1999; Toole, 2002). The concept of Construction Hazard Prevention through Design (CHPtD), which is '*a process in which engineers and architects explicitly consider the safety of construction workers during the design process*' (Toole and Gambatese, 2008, p. 225), has gained momentum in recent years. Toole and Gambatese (2008) suggest that one trajectory along which CHPtD could progress is for designers to choose materials and systems that are inherently safer than alternatives. In fact, the selection of a particular building system or construction method is implied by decisions made in the project planning and design stages. Consequently, it is important for professional and technical contributors to 'upstream' decisions to understand the OSH risks implicit in different building systems or construction methodologies, the choice of which may logically flow from their decisions.

However, professional groups in the construction process may have different perceptions of OSH risks associated with alternative design systems/methodologies. Researchers have identified a number of barriers which prevent designers from considering safety issues, e.g. lack of construction process knowledge, lack formal education of construction safety and limited involvement in overseeing site safety (Gambatese and Hinze, 1999; Toole, 2002). The construction industry is characterized by a high level of fragmentation and the interests of different stakeholder groups can lead them to think about OSH risks differently. Lingard *et al.* (2012) revealed how poor interest alignment among project stakeholders in the planning and design stages of a project contributed to increased OSH risk during construction. Differences in stakeholder groups' perceptions of OSH risks may result in difficulty in establishing a common strategy to identify hazards and take appropriate risk control actions early in the project life cycle. Surry's (1979) decision model of accident occurrence illustrates that people need to perceive a risk in order to respond to it appropriately. 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. If a decision-maker cannot recognise a hazard or perceive a risk accurately then 'safe' decisions are unlikely to eventuate. Therefore, it is worthwhile to investigate the OSH risk perceptions of decision-makers in construction projects and perhaps ultimately, to develop a shared understanding.

Existing studies have adopted different approaches to assess construction professionals' risk perceptions, including asking respondents to rate a list of hazards according to their degree of riskiness (e.g. Holmes *et al.* (1997)), quantifying the level of risk perceived by professionals with an objective algorithm method (e.g. Hallowell (2010) and Jannadi and Almishari (2003)), using self-report questionnaires to compare different groups' risk attitudes and perceptions (e.g. Findley *et al.* (2007)), and requesting participants to rank risk qualities such as the prevalence, level of exposure and control over risk (e.g. Leiter *et al.* (2009)). These approaches identified groupings of people with similar perceptions about specific hazards presented to them by researchers. In reality, however, people need identify situational hazards for themselves and decide how to respond to them. In the context of a construction project, decision-makers are expected to identify hazards implicit in the design of a facility or in a planned construction sequence, and evaluate the level of risk against certain attributes/criteria.

This study employs Q-methodology with an innovative photographic data collection method to explore construction industry stakeholder groups' OSH risk perceptions. Q-methodology requires participants 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). The Q-set can take different forms, such as statements of opinions, photos, or other articles. In this study, photos representing the construction processes implicit in different building systems will be used as stimuli. Using photos allows participants to identify hazards and subjectively judge the level of OSH risk in the depicted scenarios. This paper reports the process of developing and validating the photographic Q-set instrument.

2. Q-methodology

Q-methodology was developed in as early as the 1930s, with its main proponents being Stephenson (1953) and Brown (1980). It emphasizes the concept of ‘operant subjectivity’ (Brown, 1980). So, the rationale is to explore participants’ subjective views about a phenomenon. A Q-sort is a picture of an individual’s conception of the way things stand, and it is self-referent (Brown, 1980). There is no right or wrong way to do a Q-sort. Studies using Q-methodology seek to understand and interpret human experience and individual differences rather than generalize results to a population.

Though Q-methodology has gained wide application in research areas, such as psychology, human personality, politics and attitude study and, more recently, in landscape design, it has not been used extensively in the construction management or OSH areas. However, recently Q-methodology was used to explore construction workers’ experiences of work-family fit in one Australian study (Turner and Lingard, 2011). The current research is, to our knowledge, the first attempt to use Q-methodology in studying construction stakeholders’ perceptions of OSH risk.

3. Q-set development procedures

3.1 Research question

The research question determines the nature and structure of the Q-set to be generated (Stenner *et al.*, 2008), and affects the ‘condition of instruction’, which is used to guide participants to perform the sorting task (Watts and Stenner, 2005). The aim of the present research is to compare construction industry stakeholders’ OSH risk perceptions. In particular, we are interested in finding out: (i) whether different stakeholder groups (e.g. architects, engineers, constructors and OSH professionals) share similar (within-group) understandings of OSH risks in construction work, and (ii) whether there are between-group differences among these stakeholder groups. Understanding points of similarity and/or difference will help encouraging stakeholders to consider the OSH implications of their professional practice for others ‘downstream’ of decision-making processes (e.g. construction workers). It could also lead to interventions such as training to improve risk identification and mitigation.

3.2 Generation of the Q-set

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). Typically, a structured approach is used to generate a Q-sort, i.e. identifying the key dimensions of the study topic first and then selecting stimuli to represent all the dimensions (Brown, 1993; Fairweather *et al.*, 1998). Stimuli should enable participants to easily grasp the central issue they reflect

(Stenner *et al.*, 2008). In the present research, photographs are used as stimuli as they are effective and straightforward in representing a construction scenario, yet can maintain the richness of information needed to assess OSH risks. Photographs have previously been used as experimental stimuli successfully in such areas industrial quality assurance (Kleiner, 2001) and construction hazard identification (Kleiner and Hallowell, 2012).

Participants' risk perceptions will be explored by showing them photographs of the use of different construction methodologies or building systems. This method is meaningful because each building system or construction methodology has particular OSH risk attributes, and the use of a particular system or methodology is determined by decision making in the project planning and design stages. Compared to for example, providing photographs of actual hazards this approach requires decision making in addition to search cognitive processes. Participants will be asked to provide their assessment of the likelihood of an accidental injury arising when a depicted construction methodology or building system is used. They will then make an assessment of the severity of consequential injury should an accident occur. The separate assessment of likelihood and consequence was preferred because this will enable participants to distinguish between construction scenarios with the potential for high impact/low probability and low impact/high probability events.

To develop the Q-set, four main building elements were selected as follows: (i) façades; (ii) roofs; (iii) building structures; and (iv) building services. Each of these elements has a range of different systems or methods by which it can be constructed. These systems/methods are implicit in decisions made about the design of a building/structure. For example, whether a building uses steel or a concrete structural frame is a design decision which ultimately influences the methods/processes used during construction, and arguably also the prospective hazards to which construction workers are exposed.

Various sources were used to identify photos to represent the different building methods/systems for the four building elements. These included web construction databases, researchers' and colleagues' collections and Flicker (with photo use permission sought). Following review and evaluation, a set of 40 photographs was compiled, comprising ten photographs for each building element. Usually, a Q-set size of 40 to 80 is considered to be satisfactory (Stainton Rogers, 1995; Watts & Stenner, 2005).

3.3 Development of the Condition of Instruction

The 'Condition of Instruction' establishes the rules by which participants are asked to perform the sorting task. It specifies the criteria for participants to rate the sample of objects in the Q-set. The condition of instruction can force a particular distribution of responses (e.g. quasi-normal distribution in a forced Q-sort) or it can allow participants to rate each object freely. In this research, researchers decided to use a free sorting method after the instrument was tested with several industry participants. One participant commented that a forced distribution presented a problem for some categories of photograph. For example, the primary risk for the "roof" building element category was falling. A fall from a roof would most likely result in a serious injury or death and thus the participant could not rate any of the "roof" photographs as being of insignificant or minor consequence.

Block (1956) states that forced sorting requires participants to make the same number of discriminations between objects, which makes comparisons between the ordering of different participants straightforward. However, other researchers criticize that as conditional probabilities are involved, the probability of each alternative (i.e. *p* of placing card k in pile x) is reduced in a forced Q-sort (Cronbach and Gleser (1954), Gaito (1962)). Gaito (1962) also argues from psychological perspective that the use of forced distribution destroys spontaneity and affects participants' motivation. Some researchers have statistically compared the results obtained from using different sorting methods and observed that there is not much difference between the results of forced and unforced Q-sorts (Brown, 1971; Brown, 1980; Hess and Hink, 1959; Block, 1956). Thus, Brown (1980) concludes that '*distribution effects are virtually nil, the existence of factors being affected almost entirely by the pattern of item placement*' (Brown, 1980, p. 289).

The researchers also decided to ask participants to sort photographs depicting each of the building elements separately. This is because one of the test participants commented that sorting all of the cards simultaneously was difficult due to the number of cards and difficulties in comparing the OSH risks inherent in one building system with those inherent in other building systems (e.g. roofing systems were not comparable with building service systems).

The condition of instruction requests participants to perform two rounds of sorting for photographs of each building element. Participants are firstly instructed to sort the photos onto a grid according to their subjective judgements of likelihood of an accidental injury occurring during the construction process depicted. The grid contains five columns with rating scale ranging from '-2 Rare' to '+2 Almost certain'. Then participants will be asked to sort the photos into another grid based on their judgements of the severity of consequence if an accidental injury occurred. The grid is designed with a rating scale ranging from '-2 Insignificant' to '+2 Catastrophic'. After each round of sorting, respondents will be asked with a number of open questions to explicate the reasons underlying the sorting patterns.

3.4 Testing the instrument

To ensure that the photographs were representative and the condition of instruction was clear and effective, instrument testing was conducted to test the Q-sort method with industry professionals. The purpose of the testing was to evaluate whether: 1) the photographs provided sufficient detail and information for professionals to make meaningful judgements about OSH risks; 2) the photographs were representative of different construction methodologies/building systems for each building element; 3) the condition of instruction was clear and enabled participants to undertake the Q-sort appropriately; and 4) the time required to undertake the Q-sort was not excessive and would be acceptable to participants.

The photographs were individually printed and, brief descriptions were added to each photograph. These descriptions were succinct, value-neutral statements about the construction methodology/building system depicted. None of the statements contained any reference to OSH hazard or risk. Each photograph was also given a unique identification code. Table 2 shows the photograph codes and corresponding descriptions, and Figure 1 show two sample photographs.

Table 2: Photograph codes and descriptions

Photo codes	Descriptions
S01	In-situ reinforcement concrete column construction
S02	Steel framed structural system
S03	Precast reinforced concrete tilt-up system
S04	Precast reinforced concrete columns, beams and slab panels
S05	Reinforced concrete structural frame with post-tensioned slabs
S06	Steel structural frame with precast concrete decking
S07	Steel structural frame with steel decking to receive concrete cover
S08	In-situ reinforced concrete core wall under construction
S09	Reinforcement fixing for in-situ concrete slab and columns
S10	Precast concrete columns erected with brackets to receive further elements
F01	Precast concrete panel system for housing
F02	Precast concrete panel system for car park
F03	Concrete and window panel façade system
F04	Full storey prefabricated façade system
F05	Glazed panel façade system
F06	Mixed glass and concrete panel façade system. Note: concrete sections covered by glass panels
F07	Prefabricated glass panel with aluminium shading façade system
F08	Trespa Meteon panels installed to a back drained rainscreen façade
F09	In-situ RC walling
F10	Concrete block wall façade system
R01	Metal roof canopies
R02	Flat in-situ reinforced concrete roof with bitumen membrane water proofing
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
R07	Stone roof panel installation
R08	Roof-top plant room construction
R09	Pre-assembled timber roof canopy system
R10	Prefabricated roof systems for offsite built classrooms
B01	Services suspended from steel roof structure
B02	Services suspended from concrete structure
B03	Services suspended from concrete structure
B04	Services suspended from steel structure with spray-on fire retardant
B05	Services for ceiling void
B06	Services installation
B07	Services suspended from concrete structure
B08	Services suspended from steel panel
B09	Modular wiring systems
B10	Pre-assembled building service modular installed offsite

Note: S – Structure; F – Façade; R – Roof; B – Building services

Figure 1: Sample photographs

Three industry professionals participated in the testing. They were a general manager (civil engineering) of a large construction contractor (participant 1), a safety manager from a medium sized construction company (participant 2), and a building surveyor with considerable industry experience of risk management (participant 3). After one sorting interview with one professional, the photograph set and condition of instruction were modified according to the professional's feedback, and then used for the next sorting interview and subjected to further modification.

Apart from the two comments given by participant 1 mentioned above (i.e. free sorting the photographs in a set by set way), participant 1 and participant 2 also commented that some photos were similar in content (especially for the category of building services), while some photos lack sufficient detail for them to make meaningful OSH risk judgements. Table 3 lists the codes of photos that considered deficient by the participants and the reasons they gave.

Table 3: Deficient photographs identified by participants

Category	**Participant 1**	**Participant 2**
Façade	F07 lack details	
Structure	S10 insufficient information	S08 insufficient information
Roof		R08 more related to building service
Building service systems	B04 and B05 are similar B07, B02 and B03 are similar	B04 B05 are similar B06 B07 are similar

A total of eight photos were removed for the third sorting interview. The ID codes of the removed photos are F07, F08, S10, S08, R07, R08, B05, and B06. The photos of F08 and R07 were removed because the permissions to use the photos were still pending. Participant 3 commented that the condition of instruction was clear, and the photos were representative and provided sufficient information for her to make judgements. She was also comfortable about the time duration for performing the Q-sorting task.

Table 4-6 show the sorting results of the three "test" participants. It is observed that the participants share very similar OSH judgements for some photos (for example, F01, F09, R01, R05, B10, S06, etc.), yet have substantially different OSH judgements for some other photos (for example, F02, F05, R03, S01, S07, etc.) The results indicate that the Q-sort instrument discriminates between participants' perceptions of high and low risk situations and will be able to collect data to compare the similarity/difference between stakeholders' OSH risk perceptions.

Table 4: Sorting result given by participant 1

Likelihood of accidental injury					**Severity of consequence of accidental injury**				
Rare	Unlikely	Moderate	Likely	Almost certain	Insignificant	Minor	Moderate	Major	Catastrophic
Façade					Façade				
F05	F06	F07	F01	F08		F10	F03	F01	F08
		F10	F03	F02			F04	F02	
		F04	F09				F05	F06	
							F07	F09	
Roof					Roof				
R10	R02	R07	R01	R03	R02	R10	R07	R01	R03
		R09	R04	R05			R08	R04	
			R06				R09	R06	
			R08					R05	
Building Services					Building Services				
B10	B06	B01	B05			B09		B01	B05
	B09	B08				B06		B08	
						B10			
Structure					Structure				
	S01	S02	S05	S08		S09	S02	S01	S03
		S03	S06					S04	S05
		S04	S07					S06	S07
		S09						S08	

* Participant 1 didn't sort the deficient photos in the building service category and structure category

Table 5: Sorting result given by participant 2

Likelihood of accidental injury					**Severity of consequence of accidental injury**				
Rare	Unlikely	Moderate	Likely	Almost certain	Insignificant	Minor	Moderate	Major	Catastrophic
Façade					**Façade**				
	F02	F05	F10	F08	F02	F03	F06	F09	F08
	F03	F07	F06	F09	F05	F04	F10	F01	
		F01					F07		
		F04							
Roof					**Roof**				
R02	R03	R04	R01	R08	R02	R03	R04	R01	R08
R10	R07		R05	R06	R10	R07		R05	R06
	R09					R09			
Building Service					**Building Service**				
B10	B08	B05	B07		B10	B08	B02	B07	B03
B09		B01	B03		B09	B05		B06	B04
		B02	B06			B01			
			B04						
Structure					**Structure**				
S02	S08	S09	S06	S05	S01	S08	S09	S03	S05
S01		S10		S07	S04	S02	S06	S10	S07
S04				S03					

Table 6: Sorting result given by participant 3

Likelihood of accidental injury					**Severity of consequence of accidental injury**				
Rare	Unlikely	Moderate	Likely	Almost certain	Insignificant	Minor	Moderate	Major	Catastrophic
		Façade					**Façade**		
	F04	F02	F01	F09		F04	F03	F01	F02
		F03	F05			F10	F05	F09	
		F10	F06				F06		
		Roof					**Roof**		
	R02	R09	R01	R06	R02	R03	R09	R01	R06
		R10	R03				R10	R04	
			R04					R05	
			R05						
		Building service					**Building service**		
	B01	B02	B03			B01	B02		
	B09	B08	B04			B08	B03		
	B10		B07			B09	B04		
						B10	B07		
		Structure					**Structure**		
	S04	S03	S02	S01		S07	S02	S01	
	S07	S05	S06			S09	S04	S03	
		S09						S05	
								S06	

* Eight photos have been removed

Summary

This paper depicted the process of developing and validating a Q-set for exploring construction stakeholders' judgements of OSH risks. An innovative Q-sort method will be used in large scale testing using photographs as stimuli. Photographs ensure that richness and accuracy of information can be conveyed in describing a scenario. Through a pilot study, the instruction of condition has been modified, and the sets of photos have been refined. The validated Q-set together with the condition of instruction will be used for collecting data from different construction stakeholders to compare the similarity/difference between stakeholders' perceptions of OSH risk. The researchers hope this paper provides guidance for future researchers to conduct research in the construction management or OSH areas using Q-methodology.

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