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Dr Simon D Smith, School of Engineering, University of Edinburgh

Dr Fred Sherratt, Department of Engineering and the Built Environment, Anglia Ruskin University

THE UNIVERSITY *of* EDINBURGH

Anglia Ruskin University

Cambridge Chelmsford Peterborough

INTRODUCTION

For fifteen years ARCOM has organised and hosted Doctoral Workshops on many subjects within the field of the Built Environment and yet this is the first to be convened on the subject of Health, Safety and Wellbeing. This is perhaps a little surprising considering that construction safety has been a well-researched topic for many years; but the occurrence of the first workshop on the subject in 2015 reflects a growing intensity and awareness of the subject and an increasing intolerance in the construction industry to situations, systems, processes and practices that do not protect the worker.

Research in to safety and risk has been undertaken for decades in many industries, the early works being centred on factories and chemical plants. HW Heinrich, who's works is still cited today, is probably a pioneer of safety research but focussed on 'industry' in general and not in construction. The source of the first construction safety article is difficult to identify. But in trying to do so, interesting insights in to the attitudes and thinking of early researchers is revealed. For instance, an article in *Industrial Engineering and Chemistry* in 1959 suggests that "safety denotes a state of being where no significant distasteful conditions exist" though no definition of distasteful is given nor means of determining significance. More interestingly, in 1969, a paper is revealed where 'Human Factors' is studied, its abstract stating that a focus was on "the workman's attitude toward himself, his fellow workers, his bosses, and the world."

It is not until the 1980s that regular research articles on construction safety appear. In ARCOM, whose archives go back to 1997, we can perform a crude analysis of the proportion of papers on the subject of safety. The trend is clear, as Figure 1 shows,

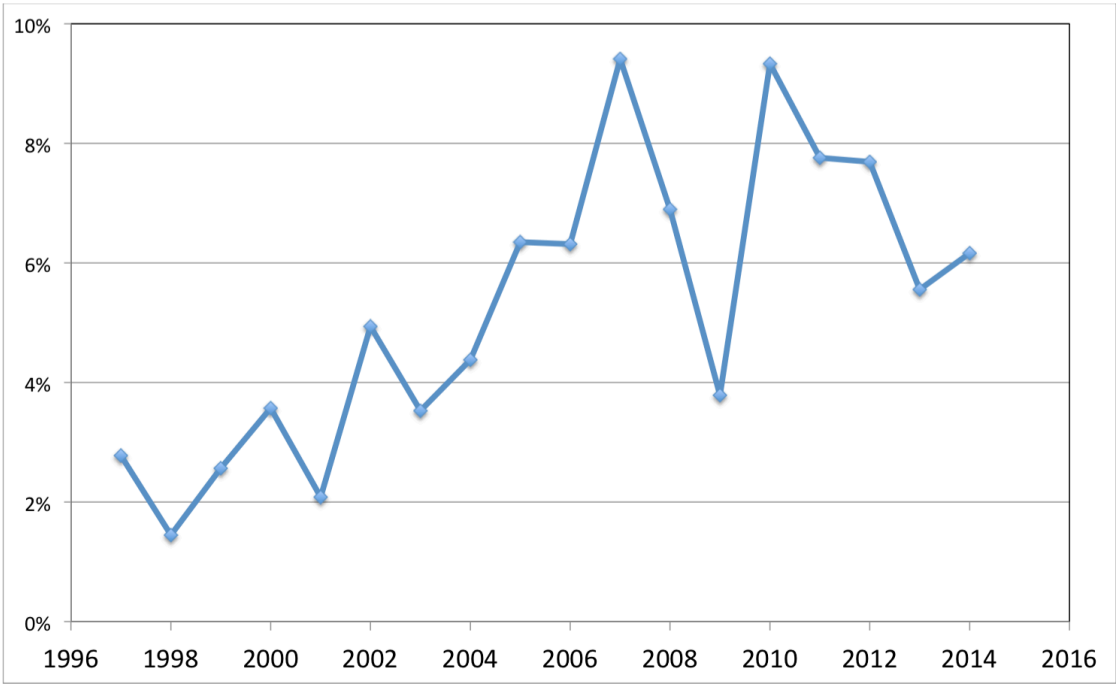

Figure 1 Proportion of papers in the ARCOM conference proceedings on Safety, from 1997 to 2014

though I make no attempt to analyse or explain the drop between 2007 and 2010, nor the further drop between 2011 and 2013. What is less certain, however, is how many articles in ARCOM and in the broader built environment literature consider the *health*

of the worker or even more specifically their *wellbeing*. These two sub-areas are nevertheless becoming more and more the focus of attention as the recognition of the long-term health of the worker is not only affected by construction but in turn affects the effectiveness and prosperity of the construction industry.

And so Fred Sherratt and myself proposed the idea of a Doctoral Workshop on matters of Health, Safety and Wellbeing. Fourteen abstracts were submitted, eight full papers received for review and six selected for presentation at the Doctoral Workshop. The selection process is not the same as for an ARCOM conference, the purpose of the events being very dissimilar, the workshop papers being accepted if in scope and review feedback intended to be formative and developmental to allow the doctoral researcher an opportunity to fine tune their work on the road to PhD completion.

In these proceedings are the six final papers selected, in their final form after review. ***Talabi, Edum-Fotwe and Gibb*** takes the position that a majority of accidents occur because of behaviour and their paper considers the antecedents of workers' behaviour. Theoretically well grounded, the work argues that behaviour modification be considered for improved safety performance, and concludes that there is a misalignment between perceived and actual behaviours.

Hayne, Kumar and Hare consider the potential of Building Information Modelling in improving construction health and safety. It focuses on the providing knowledge to designers to allow better decisions to be made during the design process. They argue that changes in the composition of design teams and a general shift of the industry towards digital technologies means fresh thinking on how designers perceive and recognise hazards is needed. They commence their research with interviews with engineers with experience of the pre-digital era to elicit opinions on the impact of digital technologies.

Near-misses in construction have not been sufficiently researched, argue ***Raviv, Shapira and Fishbain***, and research that has been undertaken has missed the opportunity to connect reported incidents with the tendency for major accidents to occur. The theory is interesting and compelling, that near-misses are the antecedents of problematic situations, and their work has started to consider a database of 241 tower-crane safety incidents.

The construction industry in the UK is quite heavily regulated but one sector that receives less attention than it could is that of volunteer workers. ***Baughan and Crapper*** consider the UK's Heritage Railway industry, staffed primarily by volunteers, where little formal training and safety regulation takes place. Competence and the management of competence is a major concern. Their early work highlights major differences in the recruitment of staff to the voluntary sector to that in the mainline railway industry, with competence being inadequately considered. Their work hopes to bring a change in attitudes as well as management practices in the heritage railway sector.

The majority of the papers in these proceedings focus on safety in general, whether the development of skills and competencies or its management. It is therefore particularly welcome that ***Cheung*** has presented a piece of work that investigates how an individual's wellbeing and psychological capital can affect safety leadership behaviour which in turn can affect safety and safety climate in organisations. She puts forward a series of postulates that relate wellbeing, psychological capital and safety leadership and proposes a conceptual model to test these relationships via qualitative analysis.

To conclude these proceedings, ***Danso, Badu, Ahadzie, Nani and Manu*** focus their attention on adaptive retrofit projects in Ghana, their position being that there is insufficient guidance to the safe execution of such projects. Their early-stage paper provides the background to this problem and suggests a suitable research programme of first identification of factors associated with the problem followed by a Delphi analysis with construction professionals in order to develop a framework to support and facilitate the management of H&D on ARPs in Ghana.

The ultimate aim of the ARCOM Doctoral Workshops is the nurturing of research excellence in the built environment by aiding the doctoral researcher to completion and, possibly, to an academic career and beyond. We wish our paper authors and presenters every success in their path to this achievement.

Simon Smith and Fred Sherratt, February 2015

CONTENTS

CONSTRUCTION ACTOR SAFETY BEHAVIOUR: ANTECEDENTS, CURRENT THINKING AND DIRECTIONS

Babajide Talabi [1], Francis Edum-Fotwe and Alistair Gibb

[1] *School of Civil and Building Engineering, Loughborough University, Leicestershire, UK*

Procedures, regulations, and safety management systems (SMS) have reduced the incidence of occupational accidents, but they still occur. Current methods have enjoyed some success however these methods mostly address aspects of safety that are not behaviour-related. Researchers have argued that construction actors' behaviours account for most accidents and so understanding and being able to modify behaviour should be crucial to improving the occupational safety and health (OSH) performance of the industry. In reference to behaviour, antecedents precede behaviours whilst consequences succeed behaviours and researchers argue that both direct construction actors' behaviour. It is therefore important to study and use them strategically to increase and decrease the frequency of safe and unsafe behaviours respectively. Some antecedents (e.g. training and ergonomics) and some consequences (e.g. saving time and convenience) of construction actors' safety behaviours are discussed. Further, modification techniques (e.g. classical and operant conditioning) that can improve these behaviours are also examined. Researchers have also argued that safety culture and safety climate influence construction actor's safety behaviours and the relationship between the two are discussed as well. According to the theory of planned behaviour and the theory of reasoned action, there seems to a misalignment between perceived and actual behaviours; this paves way for further research. This paper summarises the findings of a literature review on behavioural safety and discusses several techniques to modify behaviours and potential areas for further research.

Keywords: behaviour modification, climate, culture, safety behaviour, safety performance.

INTRODUCTION

Ample opportunities exist to improve safety performance in the construction industry. Over the last five years, the construction industry has been responsible for an average of 53 fatal injuries to workers (Health and Safety Executive (HSE) 2013), with an increase being recorded last year (2013/14) in comparison with the previous year (2012/13) from 39 to 42. Although the current rate of accidents in construction shows a marginal reduction compared to the rate in previous years, the problem of unacceptable occupational safety and health (OSH) performance persists and appears to be plateauing and not reducing fast enough. It is clear that OSH management needs to be more effective. Perhaps a different way to look at safety, to reduce accidents further in the construction industry, is required.

This paper therefore discusses methods to further reduce accidents that cause harm and incidents that do not cause harm and also sustain and improve this reduction so

[1] B.O.Talabi@lboro.ac.uk

that the chances of relapse are reduced. Pybus (1996) developed a model that categorises safety management into three phases: traditional phase, transitional phase and innovative phase; this model is adapted for this paper. Causes of accidents are placed into three broad classes – systems, people and force majeure. 'Systems' broadly cover the aspects of safety that deal with rules, processes, procedures, regulations, technology and engineering, and this parallels the traditional and transitional phases of the Pybus model. 'People' broadly covers human behaviours, and this parallels the innovative phase of the Pybus model where safety and health is integrated into all the decisions that people make. Lastly, force majeure deals with occurrences beyond human control such as adverse weather conditions. This paper focuses on the 'people' aspect of OSH management and makes links with the systems aspect as their interaction is inevitable; one does not work properly without the other (Anderson 2005; Hopkins 2006; Reason 2009; HSE 2009). Also, the safety aspect of OSH management is given more attention than the health aspect.

The current UK safety legislation proposes minimum standards that organisations must adhere to but perhaps ought to tackle safety behaviour specifically. In complex problem solving where people and systems interact, there is no one size fits all approach (DeJoy 2005). Sherratt (2014) argues that the problem with the construction industry lies with the people that operate within it. Accordingly, it appears that some of the current systems can be revised to take account of factors that affect safety behaviour. The argument for behaviour-based safety (BBS) is too important to be ignored or taken with a pinch of salt (see Sulzer-Azaroff and Austin 2000).

Behaviour-based safety (BBS) has been instrumental in reducing accidents and increasing the overall safety performance in several industries (Sulzer-Azaroff and Austin 2000; Geller 2011) and it can also have a positive impact on productivity (Geller 2011). Cooper (2010) argues that the benefits of BBS outweigh its costs, which would suggest that there should be no reason why all UK construction companies do not employ this strategy of reducing accidents.

At this juncture, clarification will be made between people-based safety (PBS) and behaviour-based safety (BBS). Geller (2011) states that PBS emanates from BBS and includes "cognition, perception and person states". In this paper, BBS and PBS are considered to be the same as behaviours are viewed with the theoretical lens that considers internal and external influences, which PBS purports to incorporate.

SAFETY BEHAVIOUR

Behaviour, and by extension, safety behaviour, is influenced by activators/antecedents and consequences (Miltenberger 2012). Figure 1 presents the ABC model of behaviour, which shows relationship between activators (referred to as antecedents in the rest of the paper), behaviours and consequences; antecedents precede and direct behaviour while consequences result from the behaviour and can motivate the behaviour (Geller 2011).

Antecedents and consequences have varying impacts on safety behaviour and some authors (e.g. Jankiewicz and Horne 2000) argue that consequences are stronger influencers of behaviour than antecedents. Reliance on antecedents is traditionally the norm however; it may be more beneficial to pay closer attention to consequences more often because positive consequences drive the reoccurrence of behaviours (Geller 2011). Jankiewicz and Horne (2000) discuss three factors that determine the strength of consequences – its positivity or negativity, the time that lapses before it occurs (after the behaviour) and the certainty or uncertainty of its occurrence. They

claim that consequences which are more positive, sure to occur and manifest quicker yield the best results; this is in contrast with the blame culture that Baiden et al. (2006) claim that the construction industry traditionally has. Bolt et al. (2012) argue that experience from the London 2012 Olympic Park construction showed that a culture of trust was needed to change from the blame culture prevalent in the industry.

Figure 1: ABC of Behaviour

To change behaviour, barriers like poor communication, which hinder construction actors from engaging with safe behaviours, have to be weakened and overcome (Garlapati et al. 2013). Garlapati et al. (2013) argue that natural consequences such as 'saving time' and 'convenience' reinforce unsafe behaviours and are often too strong; therefore they have to be altered and re-directed to favour safe behaviours. For example, one of the consequences of successfully using an unsecure ladder is likely to be the time saved. On the other hand, a different consequence may be an accident. To an experienced operative who has done this for many years, complacency becomes a valid factor that can creep in (HSE 2009). In contrast, Fernández-Muñiz et al. (2012) argue, based on their study of 606 OHSAS (Occupational Health and Safety Assessment Series) 18001-certified organisations, that work pressures do not affect safety behaviours in OHSAS 18001-certified organisations as the work pressures in such organisations are ostensibly lower and their managers are more devoted to and prioritise safety.

Additionally, Peltzer and Renner (2003) argue that overconfidence correlates positively with at-risk or risky behaviours. This overconfident characteristic comes from carrying out an activity repeatedly therefore becoming experienced at it (HSE, 2009). HSE (2009) explain that overconfidence can reduce an individual's perception of a risk, which is critical to reducing the amount of incidents or accidents that occur because people who assess and view activities as 'low risk' tasks tend to have greater rates of accidents. According to HSE (2009), it is common for people to view the risks involved with their jobs as lower than that of others and therefore frequently assess the risk wrongly thereby underestimating it; an approach to improve risk perception is by education (HSE 2009).

Antecedents like training and ergonomics (McDermott et al. 2007) play a huge part in materialising more frequent safe behaviours; training equips people with the right skills to successfully execute their tasks and ergonomics (e.g. correct height of a worktop) makes people feel more comfortable carrying out their tasks. Leading indicators (e.g. training) proactively deal with safety management as opposed to lagging indicators (e.g. lost time injuries), which are reactive. Leading indicators are as valuable as, and arguably more valuable than lagging indicators of safety (Zwetsloot et al. 2014). Waiting for a dangerous occurrence is a reactive way of dealing with occupational safety and as such, unsafe behaviours need to be changed prior to the manifestation of such occurrences.

Zin and Ismail (2012) highlight the need to enforce antecedents sometimes, which can aid compliance and ultimately reduce incidents and accidents. Some authors (e.g.

Jankiewicz and Horne 2000; Daniels 2000; Geller 2005) argue that getting employees to *want to* engage in safe behaviours is better and more valuable than *forcing* employees to comply. For this change from compliance to self-ownership to occur, Geller (2005) claims that people have to be more responsible and Jankiewicz and Horne (2000) claim that their needs have to be met.

Zin and Ismail (2012) further explain that factors such as safety leadership, management commitment and good communication can help to achieve higher compliance rates. Fernando et al. (2008) adds that employee involvement and effective safety feedback improves safety compliance as well. Further, skills, specifically non-technical skills (NTS), which can be considered to be antecedents, have been found to reduce accidents (Reader and O'Connor 2013). These skills deal with individuals' cognitive and social abilities that support safe performance in high-risk environments (Flin et al. 2008).

Situational awareness, which can be said to be an NTS, has also been linked heavily with abating accidents (Stanton et al. 2001). This concept is still increasing in popularity (Patrick and Morgan 2010) and is defined by the HSE (2012) as "being aware of what is happening around you in terms of where you are, where you are supposed to be, and whether anyone or anything around you is a threat to your health and safety". In short, it is 'knowing what you are doing, what you should be doing, what should be happening as you are doing it and what should eventually happen when it is done'.

Resilience, another antecedent, is considered to be the ability to successfully adapt to a change in circumstances. Resilient organisations have the ability to predict, monitor, learn and react to challenges (Praetorius et al. 2012). Further, Hollnagel (2008) argues that managers should regard people and their dynamic ability as assets rather than liabilities. Perhaps, being resilient tackles the latent condition pathways to accidents that Reason (2009) refers to in his accident causation model to an extent, in that, if an organisation is resilient, it should be better equipped to predict and mitigate unplanned developments.

Safety capability, which Griffin et al. (2014) define as the "capability to maintain the safety of complex systems operating in uncertain and interdependent environments", is also important in preventing accidents. In order to achieve this capability, employees need to understand the intricacies of work processes rather than follow rules or instructions blindly (Woods and Hollnagel 2006).

The next section explores various behaviour modification techniques that researchers have suggested can be used to alter behaviours.

BEHAVIOUR MODIFICATION

The psychologist Bandura (1977) claims that behaviours are learned and McAfee and Winn (1989) explain that improvements in safety behaviour and performance have occurred through the use of psychologically based methods known as "Applied Behaviour Analysis" (APA), which involves using various behaviour modification techniques (BMTs) to change behaviour.

Locke (1974) argues that when a baby is born, his/her mind is totally blank, a state commonly known as *tabula rasa*, and the baby's mind begins to acquire knowledge from experiences and or learning. To this end, Bandura (1977) argues that it follows that if human beings are exposed to unsafe behaviours, they are likely to emulate

them; this is commonly known as the social learning theory. On the contrary, some researchers have argued that Locke's tabula rasa is flawed (Duschinsky 2012).

Classical conditioning

The psychologist Thorndike (1898) introduced the 'Law of effect' theory. This theory explains that any behaviour that is accompanied by pleasant consequences will probably be repeated and any behaviour that is accompanied by negative consequences will probably reduce or stop. For example, if an untrained person operates a dumper without having an accident or any negative repercussion and perhaps saves time (pleasant consequence), this person is likely to operate the machine again without training in future.

Pavlov (1902) developed classical conditioning and it involves the association of a neutral stimulus (NS) to an unconditioned response (UR); this technique has been and is still being successfully applied to modify behaviours. Table 1 shows the four key terms associated with this BMT namely, unconditioned stimulus (US), unconditioned response (UR), conditioned stimulus (CS) and conditioned response (CR) and are explained.

Pavlov (1902) shows that this technique applied to animals and Watson and Rayner (2000) later show that it can be applied to humans as well when they conducted the 'Little Albert' experiment.

Operant conditioning

Skinner (1938) agrees that human beings do indeed have minds, however he believed that it is more practical and valuable to study their behaviours rather than their internal minds because this is more tangible and observable. Skinner believed that the principal way to study behaviour is by observing the causes of an action and its consequences. This, he called "Operant Conditioning". Accordingly, he alleges that the study of behaviours is scientific and not abstract and believes that behaviours are affected by consequences and can therefore be derived. Hollnagel (2008) alludes to the importance of learning from successes and failures (consequences) in order to increase good behaviours and reduce bad behaviours. Table 1 shows 3 elements (reinforcement, punishment and extinction) that have varying effects on behaviour under this conditioning technique. Reinforcement and punishment can be positive and negative however, in any case, reinforcement aims to increase the frequency of behaviour and punishment aims to decrease the frequency of behaviour.

Garlapati et al. (2013) argue that positive reinforcement, such as praise, is more effective in the long term than rewards. They further explain that incentives like money may be good, however, satisfaction from feeling highly regarded is more likely to lead to positive behaviours that are long lasting and natural. Positive reinforcement encourages people to go over and beyond their job duties as well as take reasonable care of their safety and the safety of others. Positive reinforcement ensures people are working towards good ideals as opposed to trying to avoid negative repercussions. Skinner (1972) advises that extra caution must be taken when using punishment because this technique can be construed to limit freedom and choice and can therefore backfire and propel people to carry out more unsafe behaviours or in worse scenarios lead to theft and vandalism. *Extinction burst*, which is the initial increase in frequency, duration and intensity, may occur when previously reinforced behaviours are being extinguished (Miltenberger 2012).

Table 1: Classical and Operant Conditioning

Classical Conditioning			
US – Stimulus that automatically provokes a response. For example, arrival of a boss.	UR – Response that is triggered automatically when the US is present. For example, carpenter begins to work.	CS – Initially neutral stimulus (NS), which later triggers a response when paired with the US. For example, buzzer that sounds when the boss arrives.	CR – Response that is triggered by association with the CR over time. For example, carpenter begins to work when the buzzer is heard, even without seeing the boss.
Operant Conditioning			
Reinforcement – Increases the frequency of behaviour; it can be positive or negative. In other words, positive reinforcement (addition) and negative reinforcement (removal). For example, increasing a workers bonus after he/she engages in safe behaviours can increase the frequency of the safe behaviour.	Punishment – Decreases the frequency of behaviour; it can be positive of negative. In other words, positive punishment (addition) and negative punishment (removal). For example, reducing a workers bonus after he/she engages in unsafe behaviours can reduce the frequency of the safe behaviour.	Extinction – Decreases the frequency of a previously reinforced behaviour. For example, if working without steel-toe cap boots on site was previously reinforced, enforcing a strict compulsory steel-toe cap boots policy is likely to reduce the behaviour of wearing regular boots without steel-toe caps.	

Social conditioning

Social conditioning is a BMT that relates to the sociological influences that urge people to behave in certain ways. Two main theories that support this are 'The Theory of Reasoned Action' (Fishbein and Ajzen 1975) and 'The Theory of Planned Behaviour' (Ajzen 1991). The latter, which is more recent and somewhat supersedes the former, purports that behaviour is influenced by intention, which is influenced by attitudes, social norms and perceived behavioural controls; it is also argued that perceived behavioural control can have direct impact on behaviour.

Dijksterhuis and Bargh (2001) explain that the "perception – behaviour" connection leads to a default proclivity to act in the same way as those around. For example, a bricklayer who is used to stacking bricks on scaffolding without a brickguard gets a new job with another organisation and soon realises that every other bricklayer in the new establishment uses a brickguard. The bricklayer is likely to adapt and start using brickguards. This form of conditioning is aided by peer pressure and positive safety culture. HSE (2009) argue that the things people see around them are major influences of behaviour. Other social influences such as leadership style and culture are believed to change thoughts, beliefs and values, and many researchers constantly have the *nature vs. nurture* debate, in the belief that either one or sometimes both define how human beings develop (Duschinsky 2012). Another type of reinforcement, known as *vicarious reinforcement,* is worthy of mention under this category (Miltenberger 2012); this reinforcement type is less direct. For example, if the bricklayer realises that people who do not use brickguards get fired, he/she is likely start using a brickguard provided that the job is important.

Thus far, the internal aspects of a human being have not being considered. It is possible that the carpenter in Table 1 does not begin to work when the boss arrives because he/she is not happy with the work conditions. This leads to the cognitive aspect of behaviour. In contrast to Thorndike and Skinner who focus on external factors, Neisser (1967) argues that human behaviour is affected by both external

factors like reinforcement and internal factors like beliefs and feelings. Figure 2 shows external (outside circle) and internal (inside circle) arrows, which indicate external and internal influences respectively on human behaviour, which is represented by the circle.

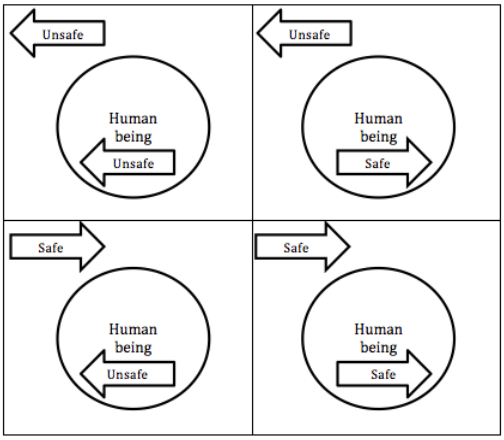

Figure 2: Internal and external influences on human behaviour

From Figure 2, it is logical for senior management to aim to move all their employees to the bottom-right quadrant, where the external and internal influences encourage safe behaviours. Safety climate and safety culture are two key external factors, amongst others like work pressures, work resources and education, which influence behaviours.

SAFETY CLIMATE AND SAFETY CULTURE

In recent times, one of the debates about safety has been related to climate and culture; safety climate vs. safety culture, both of which influence safety behaviour (HSE 2009).

Safety climate

Safety climate has been linked to psychological attributes of employees (i.e. the way people feel, their values, attitudes and perceptions) with regards to safety within an organisation (Human Engineering, 2005). In a sense, it is the way employees appreciate safety in the workplace. It is common for organisations to boast a good safety climate at the corporate level, however if their employees feel that safety is not treated with utmost regard, the organisation's safety climate is considered to be poor (Cooper and Phillips 2004). Signs of poor safety climate are high staff turnover rates, high absenteeism or sickness rates, high direct human-related accidents, low levels of obedience to safety rules and high levels of protests from staff about working conditions (HSE 2009).

Geller (2011) argues that BBS imbibes a reporting climate into an organisation and this can lead to reduced incidents and accidents. It is only logical that reducing the number of incidents will leads to a reduction in the number of accidents, hence it is imperative to instil a 'reporting' climate to encourage employees to report any issues or incidents that occur so that learning can transpire.

Safety culture

Safety culture has become a common tool used to ameliorate safety performance (Finneran and Gibb 2013) and a core part of behaviour-based safety is the culture in which it is bred. The Advisory Committee for Safety in Nuclear Installations (ACSNI)

Human Factors Study Group (1993) provide the following definition for the phrase, perhaps the most widely accepted: "The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of an organisation's health and safety management". They go further to state that "organisations with a positive safety culture are characterised by communications founded on mutual trust, shared perceptions of the importance of safety and confidence in the efficacy of preventive measures."

Cooper (2002) explains that safety culture is a subcomponent of corporate culture that relates to the job, organisation and individual (JOI) elements that affect and influence safety. According to Reason (2009), culture determines the efficiency and effectiveness of safety management systems (SMS). Positive safety behaviour will only thrive in an organisation where the culture permits hence, organisational culture, more specifically, safety culture has to be properly considered and investigated to ensure it is appropriate for positive safe behaviours to grow and be sustained. Good safety culture can therefore help to reduce accidents, ensure that adequate attention is given to safety and increase commitment to safety (Cooper 2002).

According to Reason (2009), culture can be socially engineered and it takes deliberate efforts to achieve good culture; senior management is responsible for ensuring that a good safety culture is ingrained within the organisation (Fernández-Muñiz et al. 2012; National Oil Spill Commission 2011; Hopkins 2006). A safe culture must be an informed one (Reason 2009) and Borys et al. (2009) apprise that an informed culture is made up of four interrelated subcultures: reporting culture, learning culture, just culture and flexible culture. Some critical factors required to achieve a safer culture are trust, accountability and information (Hudson 2007).

LINK BETWEEN SAFETY CLIMATE AND SAFETY CULTURE

Figure 3 shows the distinction and link between safety climate and safety culture.

Figure 3: Relationship between safety climate and safety culture

From Figure 3, safety culture is decided at the corporate level by senior management whilst the 'heads' of the individual constituting departments decide the safety climate for their departments. For example, a construction company may have 6 sites as in Figure 3. The company's senior management will generally influence the safety culture and it should be fairly constant at any point in time, whilst the sites will have different safety climates, which will depend on various factors, such as safety

management systems, technology and people. These people such as clients, project managers and employees are the construction actors affiliated with the site.

To achieve excellent safety performance on a site, the safety climate, which underpins the site's core functioning ability and the safety culture from the corporate level, have to be at the maximum. The culture is the underpinning factor, which sets the potential for climate; good culture should lead to good climate, ceteris paribus, and vice versa. Safety culture is the true value and intention of the organisation towards safety, whilst safety climate can be explained to be the perceived values of an organisation towards safety; 'perceived' is not always the same as 'true' (Sherratt 2014).

Sustaining safety behaviour

Trying to change behaviours can prove challenging especially when the safe behaviour to be engaged in is not known. Geller (2005) places behaviour into three classes: behaviours that are directed by others, behaviours that are directed by one's self and behaviours that are not directed consciously but based on reflex. In theory, people have to be taught and educated on the correct safe behaviour to engage in and with repetition (Stanley 2010), the new behaviour should move from being directed by others through to self-directed and eventually automatic. Once the behaviour is automatic, it is likely to be sustained. Geller (2011) argues that it is sometimes good for behaviours to occur out of habit, however it is better to engage in most safety related behaviours after some form of cognitive reasoning because situations vary and therefore solutions may have to be adapted. Garlapati et al. (2013) highlight the effect that climate has on performance stating that good climate is the medium that allows for the best performance.

DISCUSSION

This paper is the first stage in a study that explores the relationship between what people in the construction industry perceive and what they actually do. It is envisaged that the understanding of this perception versus actual behaviour relationship will shed more light on the barriers that prevent people from engaging in safe behaviours.

It appears that a 'one fits all' approach to safety will not work as people vary vastly based on factors such as their beliefs, experience, knowledge and perception of risk. To this end, it is critical to explore reasons why people do what they know is wrong. The second stage of this research investigates the perceived and actual value systems of construction actors as well as examines the barriers that prevent the alignment of safety culture and safety climate. Crucial to this study is the understanding of 'The Theory of Reasoned Action' and 'The Theory of Planned Behaviour', which can shed some light on the attitude-behaviour relationship. The next phase of this study will involve observing construction actors in their natural work environments; interviews will then follow to understand the reasoning behind their actions.

CONCLUSIONS

It appears that if the 'people' problem is solved, many, if not most occupational accidents can be eliminated. Behaviour modification techniques ought to be more frequently employed to nudge people to engage in safe behaviours. A key to ensuring more frequent safe behaviours lies within the safety culture and safety climate of an organisation. It is known that the safety culture and the safety climate are not always in alignment and resolving this disparity may be the solution to achieving better safety performance. Once the barriers that prevent this gap from being closed are realised

and resolved, the ‘people’ issue becomes yet smaller therefore fewer accidents will occur because more people will engage more frequently in safer behaviours.

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THE DEVELOPMENT OF A FRAMEWORK FOR A DESIGN FOR SAFETY BUILDING INFORMATION MODEL (BIM) TOOL

Graham Hayne, Bimal Kumar and Billy Hare,

School of Engineering and the Built Environment, Glasgow Caledonian University, Cowcaddens Road, Glasgow, G4 0BA, UK

At present, there is a considerable amount of research being undertaken into building information modelling (BIM) and its potential benefits to health and safety. The majority of the research is focused on the site construction process with little emphasis of the design stages of the project. This paper describes the initial findings of research to develop a framework for a 'design for safety' BIM tool, focused on providing knowledge and information to designers, thereby allowing them to make informed decisions regarding the health and safety implications of their designs. The character of building design offices has changed dramatically following the widespread adoption of digital design, drawing and modelling. By revisiting the philosophy of engineering, the radical impact the digital world has upon the traditional working practices of consulting engineers is explored. Consideration is given to the consequences of these changes upon the training, knowledge acquisition and effectiveness of engineers to deliver designs that are, as far as possible, free from hazards. It is suggested that the potential reduction in experiences, including site experience, of engineers, raises questions about their ability to understand digital images and their ability to discern the pertinent issues. A series of interviews were carried out with a purposive sample of seven practitioners who have witnessed these changes to the industry in order to formulate a deeper understanding of the impact the changes are having on the delivery of building designs. This was followed by hazard perception tests on final year building engineering students to ascertain their ability to identify hazards at their entry point to the industry. The results of the interviews and tests will inform the development of a framework for a design for safety tool that will exploit the attributes of BIM technologies.

Keywords: BIM, Education, Design for Safety.

INTRODUCTION

It is widely accepted that construction sites are dangerous work environments. The cause of accidents can be wide reaching and multi-faceted. However, research has shown that there is often a contributory link with design (Behm,2005; Gambatese et al. 2008; Haslam, et al. 2005).

The nature of building design offices is also changing with emphasis being placed solely on academic qualifications and the opportunity to progress through the traditional route of day release and night classes being made increasingly difficult. The advent of the digital world is altering the way engineers work with a limited number of researchers questioning the effectiveness of new working practices (Weick,1985;Zhou et al,2012). Additionally, the Institutions of Civil and Structural Engineers no longer require design engineers to spend prolonged periods of time on site en-route to becoming chartered.

This research questions if these fundamental changes to the industry are impacting the ability of structural engineers to produce designs that are, as far as possible, free from hazards.

The results of a literature review which sets out a detailed perspective of the changing working practices together with their potential impacts on the industry were explored. Empirical research finding in the form of interviews and hazard perception tests will be presented which supports the hypothesis that changing practices may be having a detrimental impact upon the development of design engineers.

BACKGROUND

UK Construction related injuries and fatalities

It is clear that construction sites are proportionally high risk places to work. Construction in the UK accounts for 5% of the working population but experienced 32% or fatal work related injuries with 42 workers losing their lives and 76 000 cases of work-related ill in the year 2013/2014(HSE, 2014).

The Construction (Design and Management) Regulations 1994 (HMSO, 1994), updated in 2007 (HMSO, 2007), were introduced by the UK Government as a specific response to the European Union directive 92/57/EEC which attributed a significant responsibility to designers for causes of construction accidents

Cameron and Hare (2008) citing Blaxendale and Jones (2000) noted that the perception of many within the industry was that the regulations were failing in their objectives and simply creating another level of bureaucracy and superfluous amounts of paperwork. This view is supported by practitioners writing in the Proceedings of the Institution of Civil Engineers (Beal, 2007)

Construction accidents and design

In the USA Behm (2005) took advantage of the fatal accident data available through the NIOSH FACE program and established that 42.0% of the fatalities had a link to the design. Gambatese, et al (2008) availed themselves of an expert panel to test the results produced by Behm and found agreement in 71% of the cases. Interestingly, they suggested that the relatively low instances of agreement could be *'due to the fact that some of these respondents are not able to recognize how the potential of a design change could assist them in working safer.'* (Gambatese, et al., 2008, pp.687)

Research undertaken in the UK has found that up to half of the 100 accidents examined could have been mitigated through a design change (Haslam, et al. 2005). It should be noted however, that these figures include a link to the design of tools and equipment as well as the artefact itself.

Unlike the UK, designers in the USA have no explicit legislative requirement to consider health and safety issues in their design. Notwithstanding this important difference researchers have identified that designers are often not aware of their impact on site safety and lack the knowledge and ability to modify their designs to improve safety (Gambatese and Hinze, 1999; Qie et al,2011)

History and development of engineering

Modern building engineering is founded on a base of craft knowledge and rules of thumb together with the application of science (Blockley, 1980). Early builders were often proficient in the mathematics and science of their time as well as the crafts associated with building. Indeed the Roman, Marcus Vitruvius, stated *'...Architects*

who have aimed at acquiring manual skill without scholarship have never been able to reach a position of authority to correspond to their pains, while those who relied only upon theories and scholarship were obviously hunting the shadow, not the substance. But those with a thorough knowledge of both, like men armed at all points, have the sooner attained their object and carried authority with them' (Blockley, 1980).

The training and development of structural design engineers has changed with the advent of computerised analysis and design software packages. Previously, engineers entering design offices gained a feel for the building by carrying out repetitive calculations by hand, number crunching, under the direction of experienced engineers (Blockley, 1980). Whilst acknowledging the positive benefits and opportunities that computing has brought to structural engineering, Dr David Brohn questions, *'how are the skills of structural modelling, hard won by designers before computers existed, to be transferred to the new generation of young engineers in training?'* (Brohn,2006).

In order to gain chartered status of the Institute of Civil (ICE,2013) or Structural Engineers (IStruct E, nd), graduates historically needed to spend a minimum of six months working on site. Both institutions have reduced the mandatory site experience allowing candidates to accumulate site experience through visits rather than a continuous period. It could be argued that these changes are leading the profession away from the traditional roots of being based upon a sound working knowledge of construction and academic education (Blockley, 1980).

A generation ago design offices were populated with chartered engineers who had graduated from universities as well as those who had progressed through apprenticeships and day release courses. This diverse mix of backgrounds brought a practical approach to the office which is being lost due to today's requirement to have a masters degree in order to become chartered.

The impact of the digital era

Digital technologies have profoundly affected the way we work. Karl Weick (1985) questions the effectiveness of people using computers. *'People using information technologies are susceptible to cosmology episodes because they act less, compare less, socialize less, pause less, and consolidate less…As a result, the incidence of senselessness increases'* (Weick,1985).

Researchers have identified that *'digital systems do not encourage the active challenging of assumptions'* (Zhou et al,2012). For young engineers, this can lead to a feeling of omniscience (Weick, 1985) and subsequently to *'mindlessness'* (Zhou et al, 2012) This phenomenon can be compounded by a lack of underlying knowledge by the operator, a characteristic commonly recognised in designers when considering the process of design for safety (DfS). (Gambatese & Hinze, 1999; Gambatese, 2008; Qi et al, 2011).

The problem of consolidating is identified by Whyte (2013), where designers being studied, commented that errors were usually identified when a new engineer joined the team and saw the project with a *'fresh set of eyes'* (Whyte, 2013, p51). This is analogous to the discovery of new scientific paradigms by scientists new to the field (Kuhn, 2012) and is particularly dangerous when inexperienced engineers working in isolation lack the opportunity, or inclination, to discuss their work with colleagues.

Visualisation and visual imagination

Improved visualisation is often propounded as being one of the major benefits of the BIM process (Eastman et al, 2011; 2010; Kiviniemi et al, 2011). A serious weakness with this argument, however, is that it fails to acknowledge that the interpretation and understanding of visual images is largely dependent upon our own experiences.

Hanson (2010) demonstrates this anomaly efficaciously by suggesting two 16th century astrologers who are asked what they see when they witness the dawn. Tycho Brahe, followed the religious dogma of the day, believed that the earth formed the centre of the universe and everything revolved around the earth. His observation was that the sun was rising above the horizon as it did every day. When asked the same question, Johannes Kepler, who accepted Copernicus's understanding of the cosmos, would simply see the horizon dipping below the sun. If asked to draw what they saw, both astrologers' drawings would be identical indicating that what they 'saw' was more than an implant on their retina but an interpretation based on previous experiences and understanding. Helmholtz (1867) suggests that *'The [visual] sensations are signs to our consciousness, and it is the task of our intelligence to learn to understand their meaning'.*

When a designer sees a 3D BIM model of a structure, advocates of the medium may suggest that he is having the design effectively and efficiently communicated to him. However, all too often the model is simply a representation of the design and arguably does not promote or encourage visual imagination or perception, which are required to facilitate the discovery of knowledge (Jessop,2008) and meaning (Schon & Wiggins, 1992). This issue is particularly pertinent for younger engineers who perhaps lack the foresight to predict events (Bronowski,1978).

BIM

At the present time there are many definitions of BIM within the AEC industry. Some authors seek to clarify the matter by describing what BIM is not, namely 3D digital models that do not contain attributes or intelligence and have only geometry and rendering (Eastman et al, 2011).

'BIM is essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them'(BIM Task Group, 2013). This definition encapsulates the true essence of BIM as a source of intelligent information that is usable throughout the entire life of the project. The 3D model is constructed from parametric data with elements having the ability to contain supplementary attributes such as; weight, cost, and safety information (Eastman et al, 2011). It is this facility that enables BIM to be used in digital checking tools. For instance the model is aware that a slab has an exposed edge and there is nothing below the edge for, say, 3m.

HEALTH AND SAFETY APPLICATIONS OF DIGITAL DESIGN AND BIM

The following section gives an overview of the main areas of research being undertaken in BIM and health and safety, particularly relating to design for safety and rule checking applications.

Rule checking systems

Research undertaken by Benjaoran & Bhokha (2010) in Thailand was based upon developing a rule checking tool incorporating: hazard identification, safety measure

planning and control. The tool uses rule based algorithms to identify areas of the project where falls from height may occur. When identified, safety measures such as edge protection will be automatically inserted from a database of safe operating procedures (SOP). Importantly, the time schedule will be adjusted to allow the installation of any protective measure and a bill of quantities produced. Whilst this tool could, undoubtedly, be adjusted to operate in a true BIM environment the tool was not specifically designed for BIM and may, therefore, not be utilising BIM's full capability.

Qi et al (2011) considered how BIM could be used to assist designers to identify hazards during the design process. The development of the research tool was focused on the prevention of falls from height and falling objects and utilises best practice provisions identified by Gambatese et al(1997). The developed tool allows designers to access the text version of the design for safety suggestions. The second function of the tool is to check the prescriptive rules such as roof pitches or heights of windowsills. Elements that fail the checks are highlighted and recommended actions are suggested.

A major difficulty with automatic model checking is that they are only effective for yes/no questions (Qi et al, 2011). Whilst the tool is helpful for simple checks it does little to advance the dissemination of tacit knowledge to an inexperienced designer and the presentation of text based rules is little more than an electronic database of rules.

A further study of rule based checking of models to identify potential falls from height was carried out by Zhang et al (2013). Rule based algorithms were established to identify holes in slabs and walls and unprotected edges of slabs. Occupational Safety and Health Administration (OSHA) safety rules were applied and protective measures of edge protection, window guardrails or the covering of holes in slabs were automatically added to the model. The developed tool was found to operate accurately but similar limitations to those found by Qi et al (2011) were also encountered.

Design for safety (DfS)

A potential of BIM explored by a smaller group of researchers (Ku & Mills, nd: Zhou et al, 2012) is that of DFS. Interestingly, it is suggested that there is a dearth of research on this subject and that a digital approach to safety in the design phase is much less developed than in the construction phase (Zhou et al, 2012). Both research teams identified that the parametric BIM model should be able to be checked against automated rules that could improve design quality in respect of health and safety.

Researchers in America studied four aspects of DfS with the aim of establishing timescales for the mainstream adoption and implementation of the processes within the AEC sector (Toole & Gambatese, 2008 The four strands of DfS considered were: prefabrication, material selection, construction engineering (designers input during construction) and spatial considerations. Unexpectedly, the authors established that it could take up to ten years for these aspects of the process to be common practice.

Several issues should be considered when reviewing the conclusions of this paper; The paper was published in 2008 suggesting the research and background investigation was conducted in 2007 or earlier, at the time when the use of BIM was only starting to gain momentum. BIM delivers a significant increase in potential of automation of processes over non-parametric digital design that was prevalent pre 2007. Although the paper was written by acknowledged experts in the field, no

research was carried out with design practitioners. The outcomes were established from a historic literature review and the researcher's personal views.

DISCUSSION

The preceding sections highlight five separate areas of concern:

1. There has been a marked change in the composition of engineering design offices.
2. The engineering profession is moving away from its historical roots and is being changed by the wholesale use of digital technologies.
3. There is growing evidence that design can significantly impact site safety whilst engineers are lacking the experience to remove hazards from their designs.
4. Advocates of BIM are extolling the virtues of 3D visualisation whilst ignoring the need of experience to interpret visual images.
5. Much of the research in BIM is driven by the capabilities of the software and not necessarily the needs of the industry.

It is suggested that the industry should be concerned that minimal research is being undertaken into the first two points. Additionally, if the research being undertaken in utilising new technologies is being driven by software capabilities, it is unlikely that the underlying root causes of problems in the industry are going to be resolved in the near future. Likewise, over reliance on automated, self-correcting tools will have little effect on the lack of experience of younger designers to produce designs, as far as possible, free from hazards.

In order to assess the accuracy of these statements interviews were undertaken with practising consulting engineers who have witnessed the change to the digital world.

Secondly, tests were carried out on final year MSc civil engineering students to gain a greater understanding of their ability to identify hazards within designs, using both 2 and 3D mediums. It is proposed to carry out similar tests on office based graduates who are working towards chartered status in order to understand if they are gaining an ability to identify hazards in the work environment

RESEARCH METHODS

Interviews

The research needed to understand the perceptions of practicing engineers of the changing industry. Therefore, three styles of interview were considered: Structured, un-structured and semi-structured (Bryman & Bell, 2007; Blaxter et al, 2010). This research required specific questions to be asked that related to the impacts of digital technologies and it was considered important that these questions were asked to the entire sample population. However, it was also acknowledged that supplementary questions would be required in order to achieve the depth of detail required. It was, therefore, decided that a semi-structured form of interview would be utilised.

A purposive sample made up of practising consulting engineers who began their careers in the pre-digital era was identified. The sample consisted of six engineers as set out in table 1. The initial analysis of the interviews indicated that saturation had been achieved and additional interviews were not considered necessary.

The locations of the interviewees were geographically disparate requiring five of the interviews to be conducted using Skype as telephone interviews do not give the opportunity to observe body language or facial expressions (Bryman & Bell, 2007).

The interviews were sound recorded and later transcribed before being coded using Nvivo software. The common themes were drawn together in memos (Miles & Huberman, 1994: Dey, 1993) which facilitated a subjective, inductive analysis of the data.

Table1. Details of interview sample.

PSEUDONYM	ROLE / POSITION	YEARS IN INDUSTRY	ROUTE INTO INDUSTRY
John	Experience in consulting engineering in UK, North America and Gulf states.	24	HND in Civil Engineering, BSc Civil Engineering
Alan	Experience in consulting engineering in the UK but with some time in Gulf States.	40	BSc Civil Engineering
Phil	Experience in consulting engineering in the UK prior to last 3 years in China	27	BSc Civil Engineering
Paul	Experience in consulting engineering in the UK.	27	BSc Civil Engineering
Adam	Experience in consulting engineering in the UK with some time in KSA and USA.	33	BSc Civil Engineering
Richard	Experience in consulting engineering in the UK.	29	BSc Civil Engineering
Glen	All work experience in steel fabricators in the UK	30	Practice based apprenticeship and ONC

Hazard perception tests

The following criteria were used to select the University to be used as the research site for the hazard perception tests of final year undergraduate students:

- Recognised within the top ten universities for civil engineering
- One of the leading universities based upon the number of civil engineering students graduating each year.
- A balanced curriculum between theoretical engineering science and practical engineering
- Has a sandwich course where students spend their third year in industry

The tests were partially being carried out to understand the students ability to discern germane information in 2 and 3D formats. However, it was noted that the student's ability to use appropriate software may produce unreliable data. It was, therefore,

decided that the tests would be carried out using 2D paper plots with the students being given blue pens to note any hazards they could identify. When no more hazards could be found, drawings showing 3D images of the building would be provided and their blue pens exchanged for red. This approach was considered to be the most effective and manageable format.

A small pilot test was carried out using final year Construction Management students at Glasgow Caledonian University and the test format was found to be satisfactory.

INTERVIEWS

The problems with computers

Most graduate engineers were over-reliant upon the use of computers was a point raised by several of the engineers. As one participant put it: '*In the olden days you would have liked to rationalise the structure…but now they just tend to put it straight into the computer and believe the results*' (Alan). This sentiment was echoed by others who stated: *'Their natural instinct is always to go to the computer'* (Richard). '…*because they can use it [the computer], and need to on some of the stuff, they tend to use it on everything but they don't necessarily need to'* (Phil).

Several of the engineers had concerns that graduates were feeding designs into computers with little understanding of what the expected output would be (John2), One respondent suggested that*: '…people put it in the computer, don't really know what's going on and then believe the output'* (Alan). This is not a view shared by all the engineers as Adam believes such concerns are now outdated. He emphasised his belief that: *'the computer is the tool that helps you understand it …Modern technology allows you to challenge the structure more easily and I think that can give you a better understanding of structural behaviour rather than the old fashioned would...'* (Adam). Paradoxically, this is not a view shared by Richard who explains that, *'it is quite difficult to try and get younger graduate engineers to actually interrogate what comes out of the computer because they don't know how to interrogate it'* (Richard).

The persistent use of computers can also affect the graduate's ability to understand the underlying engineering principals within their designs. One participant pointed out that: *'You see evidence of this with jobs that come out of the office designed by young guys and you wonder how much raw engineering has gone into it'* (Alan). Alan goes on to note that in the pre-digital world engineers would have rationalised a structure using engineering judgement (Alan). This is a view echoed by Phil who recalls that complex structures were previously broken down into smaller more manageable sections allowing engineers to understand the structure. By analysing the entire structure digitally he suggests that *'you might be losing the ability to see what's going on.'* (Phil). This is often lost on some younger engineers who *'feel that they are good engineers because they can do the software analysis…rather than taking responsibility for the solution'* (John 8)

The importance of good mentoring, to overcome the problems noted above, was raised by several of the interviewees (John, Paul, Richard). Richard was quite clear in his belief that *'it is important for experienced engineers to pass on their knowledge and experience'* (Richard). Repeatedly, Paul highlighted the potential problem that *'inexperienced engineers could work for too long without the input of more experienced engineers'* (Paul). It was interesting that he also stated that the nature of the questions asked by graduates has changed as they are *'… about how to fly the machine which aren't about engineering. In the days of hand calcs I suppose it was more about engineering'* (Paul).

Precision and accuracy

Issues relating to precision and accuracy were raised by four of the consulting engineers, three of whom suggested that it was a potential problem for inexperienced engineers (Alan, Adam, Richard).

Three arguments are put forward by the engineers to explain why the level of accuracy sought by graduates is not appropriate; 1. Site conditions, 2. Buildability and tolerances, 3. Design assumptions.

Alan, who is working as the site team leader for the design team on a large complex project in the Middle East, raises the issue of site conditions stating that the computer generated accuracy is inappropriate *'...particularly when you see the work carried out on site'* (Alan).

The issue of buildability and tolerances is raised by Richard who highlights the issue that technicians constructing 3D models often have *'...a lack of understanding of tolerances. A lack of understanding of how things fit together.'* (Richard). He contends that a lack of understanding also leads to the creation of details that, whilst buildable in a digital world, are impossible to construct in the real world.

However, a view put forward that contradicts the previous thoughts is that a computer must be accurate *'It can only be accurate; it cannot give you a vague answer.'* (Phil). The interviewee goes on to argue that checks to ensure the sum of the resultants must equal the loads applied and must be accurate as any discrepancy, however small, could be a symptom of a much larger problem with the analysis model which must be explored and resolved. Whilst requiring accuracy it is interesting that this point does not contradict the three main points raised above.

Positive aspects of computers

There was an overwhelming belief that computer technology has brought some distinct advantages to the industry (John, Phil, Adam, Richard,). The general view was that much more complex structures were now being designed than would have been impossible to design in a pre-digital world. *'The likes of Gehry buildings and Zaha's buildings and that is purely enabled by technology'* (Adam). This view was echoed by Phil who interestingly provided the caveat that *'it's very hard to always bring it back to something that's real'.*

The ability of computers to remove the drudgery of hand calculations was seen as an improvement in the design process (Phil). Similarly, the ability to understand the spatial interactions of buildings in a 3D environment was seen as an advantage, not only for the engineers but also to explain the engineering principals to the architects (Richard).

Good engineer practice / Engineering philosophy

There was widespread recognition that the fulcrum of engineering is the ability to solve problems (Phil, Alan, Adam). Phil went on to state that the ability to complete a structural analysis using a piece of software was not, in his mind, problem solving. Indeed, the use of computers in such a way, linked with BIM modellers who were experts in IT technology as opposed to construction was perceived to be a potentially dangerous situation (Richard). It is therefore important to recognise the role that experienced engineers have in mentoring and teaching younger engineers (Richard).

The essence of problem solving would be using an engineering mind (Alan) to identify what should be analysed, how and using what software (Phil).

Adams position was somewhat between these views as he suggested that engineers must be able to break down complex structures into more manageable pieces or simplify the structures using approximations. By undertaking this process it should be possible to produce analysis models that could be constructed in reasonable time frames but would give solutions of an acceptable accuracy considering the approximate nature of building design (Adam).

Experience and feel

Not surprisingly experience was raised by all the engineers. Whilst experience is the generally understood phenomena of gaining knowledge through witnessing or undertaking specific actions, feel is somewhat more subjective. Feel was raised by four of the engineers several times in the context that designers have an, almost innate, ability to understand the structural actions of a system and /or the magnitudes of elements within detailed designs. *'...you still get that gut feel if they are the right…in some respects its feel more than anything else'* (Adam) *'...have lost a sense of feel for it'* (Alan) *'...gave me a very good feel for what works'*(John).

Not only was the experience relating to structural analysis and design questioned, the ability of younger engineers to relate a 3D model to reality was also questioned (Richard, Phil, John). The 3D visualisation of models provides a benefit in understanding how buildings fit together (Paul). This alone was not considered sufficient for other engineers. Phil questioned the engineer's ability to truly understand what the model represents if you are lacking experience. *'...if you don't have the grounding of the nuts and bolts of how it all fit together it must be quite hard because it all so abstract. So how can you relate that back to a piece of concrete? Or steel?'* Richard, questioning the lack of experience stated that '… you need the experience behind it. You still have to relate that 3D model to reality' (Richard). He went on to highlight that '*Even though you have a 3D model you wouldn't necessarily perceive that risk unless you have that experience'* (Richard). This view was echoed by others who argued that if you did not have explicit experience of how elements should be connected in theory and on site issues were going to be missed (John).

Site experience

It is evident that site experience is considered as an integral part of the development of design engineers. All of the consulting engineers and the steel fabricator extolled the virtues of a significant period of site experience. *'I think going out on site is vitally important'* (Paul).

Likewise, all the engineers expressed concern that the Institutions of Civil and Structural engineers were now accepting an accumulation of separate visits to attend site meetings or inspections in lieu prolonged periods of continuous site experience. *'People are now cobbling together through site meetings enough days to qualify'* (Alan). *'Well, it's a cop out really isn't it. Because it's easy to visit site, look at things, write a report and go home'* (Phil). *'... attending site meetings and doing an inspection and a walk round site just doesn't do it. You don't learn the same things and you're not as equipped as if you've done that fuller experience'* (John). These views are particularly concerning bearing in mind that all the statements are from engineers who, or have previously, acted as Supervising Engineers guiding and managing graduate trainees on Company Approved Training schemes.

STUDENT TESTS

Only the initial analysis of the student tests has been completed. However, already there are a number of significant traits becoming evident that support the earlier discussions:

The drawings contained numerous examples of construction processes that could endanger workers. However, apart from a very few exceptions, the students were unable to identify them with the majority of hazards noted being generic. For example, the foundation detail shown in figure 1 requires workers to place blinding concrete, formwork, reinforcement, foundation concrete and dense concrete blockwork whilst working in the excavation. The common hazards identified were that the trench may be unstable and that exclusion barriers or trench supports should be provided. The students were unable to identify that the construction process would not be possible if trench supports were provided nor that the actual operation of construction including the delivery of materials would be almost impossible and extremely dangerous if attempted.

A student, whose industrial placement had been office based commented that placing the blinding concrete could cause concrete burns and PPE must be worn. This shows an appreciation of generic health and safety issues but a clear lack of knowledge and understanding of construction processes and their associated hazards.

The students who had an industrial placement working on site occasionally showed a greater knowledge of the hazards associated with construction processes. For example, suggesting precast stairs are used as opposed to insitu concrete. Where these students differed noticeably from the students with no site experience was that they exhibited a deeper understanding of safety processes used on site; permit to work, exclusion zones, safe lifting practices, etc.

The initial analysis of the test results cannot be deemed to show any conclusive evidence that site experience increases hazards awareness. However, there are indications that such experience can assist in gaining a better understanding of safety issues.

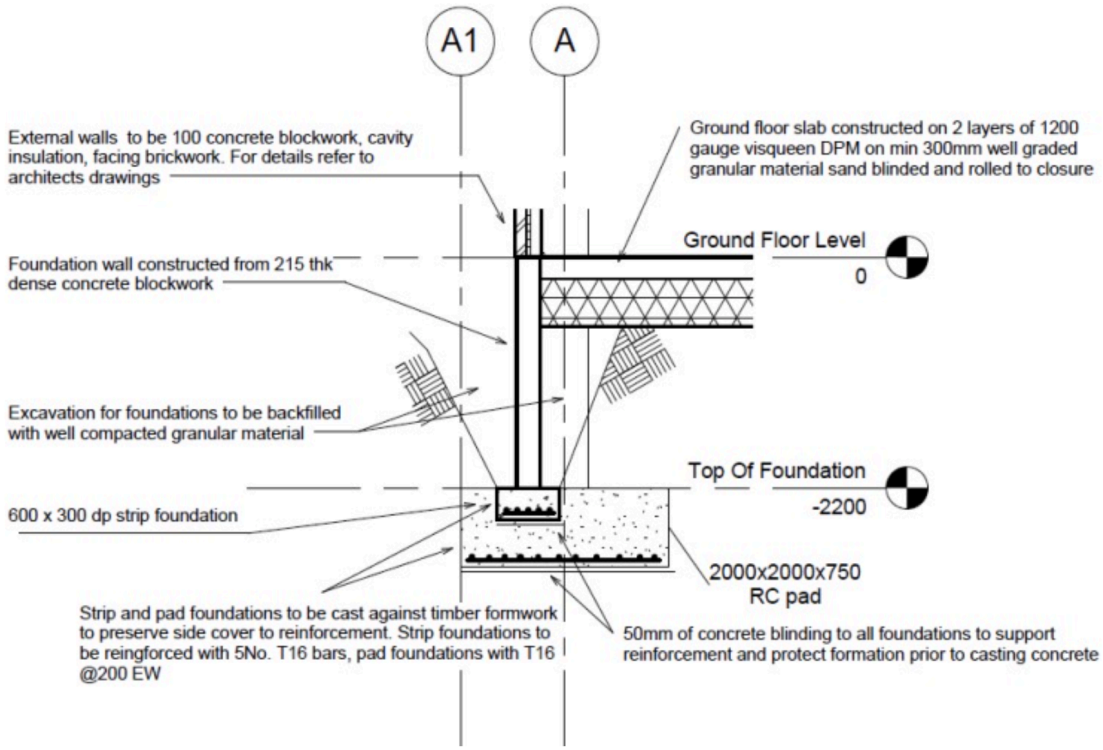

Figure 1, Hazard test foundation section

FRAMEWORK OF A DIGITAL DESIGN FOR SAFETY TOOL

The preceding sections of this paper have highlighted deficiencies within the development and working practices of engineers employed in design offices. It is, therefore, important that the proposed framework of the tool helps rectify the failings that are at the root cause of the problem to enable engineers to be better equipped to produce well-reasoned and buildable designs.

Initial thoughts on the framework are that it's primary function should be as an educational tool providing engineers with experience, information and knowledge enabling them to make reasoned judgements about safe systems when producing designs. It is also acknowledged that the parametric attributes of BIM software will allow bespoke algorithms as well as proprietary rule checking sets to be utilised to identify potential hazards within designs.

Links to multimedia video, audio, and augmented reality files could be exploited to provide descriptions of construction processes, show why some processes are hazardous and offer suggested alternatives. Notwithstanding the fact that potential hazards will be automatically highlighted, it is imperative that no changes to the design are actioned without full input from the designer. This will ensure that the designer remains fully accountable and responsible for the design.

A preliminary outline of the framework is suggested as follows:

- The identification of hazardous operations or processes
- The explanation of the hazards
- Suggested alternatives
- Advice on the information required to mitigate residual risks

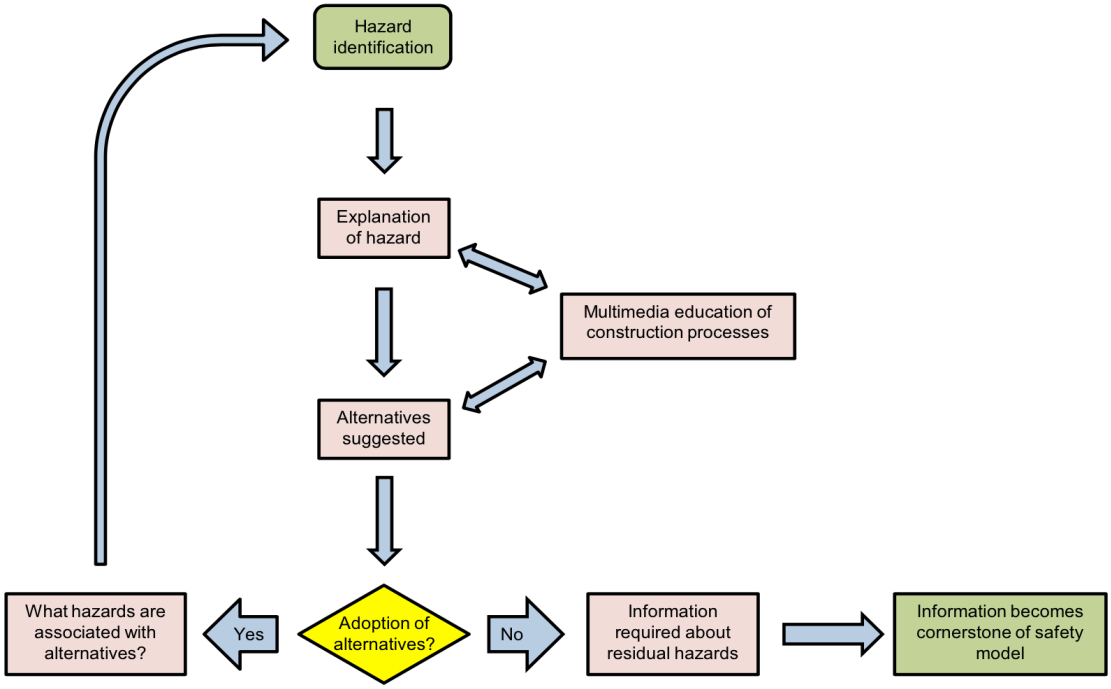

Figure 2. Proposed framework for development of the DfS tool.

CONCLUSION

It is evident that problems have occurred with the training and development of building engineering graduates following the widespread adoption of computer design and modelling software. This issue has also been compounded by the reduced site experience that office based engineers are exposed to.

The vogue for automated safety programmes constructed on the architecture of modern software packages has the potential to cure the symptoms of the problem, but not the problem itself. It is believed that the framework of a tool suggested in section 8.0 may go some way to solving the root problem as it educates and provides missing experiences to the engineers.

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ANALYSING AND MODELING NEAR MISSES IN CRANE-WORK ENVIRONMENTS

Gabriel Raviv[2], Aviad Shapira and Barak Fishbain

Faculty of Civil and Environmental Engineering, Technion–Israel Institute of Technology, Haifa 32000, Israel

The use of the term "near miss" in construction is relatively new, it has not yet been fully explored or understood, and all the while near-miss incidents suffer from underreporting. No effort appears to have been made to investigate near misses in a systematic perspective or to propose a model that enables to analyse a given set of reported incidents and draw due conclusions. In the current study, tower-crane related near-miss events were analysed due to the centrality of tower cranes in present-day construction, on the one hand, and the potential of tower cranes as hazard generators on the site, on the other hand. An extensive effort was invested in collecting the stories of safety events, including near misses and full-scale accidents. These were collected by establishing industry connections and interviewing site managers, superintendents, and safety managers in leading Israeli construction companies. Exploratory research methods are now being implemented in the development of a comprehensive database of crane related accidents and near-miss events. The database is classified under a set of encoded variables that disclose event definition, crane status, crane activity, crane failure mode, and more. The current phase of the study demonstrates the use of the database in extracting systematic conclusions concerning the causes of a set of multiple incidents. In the next phase of the work, advanced statistical analysis methods will be implemented to classify near-miss events within the database according to their potential to develop into severe accidents. We envision the possibility of automatically analysing future near-miss reports, including warnings concerning their risk potential.

Keywords: accidents, exploratory research, health and safety, near misses, tower cranes.

INTRODUCTION

There is much evidence that near-miss reporting and analyses have been proved efficient in different industries such as the process industry (Jones et al. 1999; Seveso II 1997), civil aviation (ICAO 2010), and railway transportation (Wright and van der Shaaf 2004), yet in construction the term "near miss" is relatively new (Cambraia 2010), and data on near misses and accidents suffer from gross underreporting (Shapira et al. 2012). The issue of near misses in construction has drawn some attention in recent years. Cambraia et al. (2010) studied the implementation of a near-miss reporting system as a part of a safety planning and control model, and suggested expanding a near-miss database to include also construction technologies. Wu et al. (2010b) described an investigative tool to obtain information from accident databases and suggested analysing near-miss events using a database of "precursors and immediate factors (PaIfs)" derived from the analysis of historical records. Wu et al. (2010a) studied the implementation of a radio frequency identification (RFID) device

[2] gabi.raviv@gmail.com

in the identification of near-miss situations on construction sites. Similarly, Cheng and Teizer (2013) suggested real-time location data collection, using tracking sensors to detect dangerous situations and increase situational awareness for construction site hazards. Hallowell et al. (2013) recognized near-miss reporting as a measure of a construction site proactive safety management indicator. Nevertheless, no effort appears to have been made to investigate near misses in a systematic perspective, presumably due to the inherent difficulty in establishing a set of technical attributes and relating it to variable definitions within the numerous near-miss or accident aspects. The study reported here proposes the use of a structured categorisation approach to form a comprehensive tower-crane related safety incident database. Implementing the database definitions in various quantitative analyses can lead to conclusions regarding issues such as identifying accident barriers and drivers, noticing recurring causes leading to the implementation of due corrective actions, and more. Further quantitative analyses can also reveal the risk potential embedded in a single or a given set of near-miss occurrences, and thus point at high-risk situations and other prevailing conditions. Consequently, the enhanced understanding of near miss occurrences can lead to better safety perception and stimulate the undertaking of corrective actions as needed.

The first objective of the current study was to establish a comprehensive database of safety incidents (near misses and full-scale accidents) to serve as a starting point for further analyses. Leading construction companies in Israel revealed data on near misses and accidents taken from existing files, and also provided the research team with the opportunity to proactively elicit incident stories during field interviews. Exploratory research methods were implemented to categorize these data. The main purpose of the categorisation was to specify all relevant incident information under a concise set of definitions to serve as a tool for further analyses, with respect to both an individual incident and multiple incidents. The final database is organised into categories with variables within each of the categories. The defined categories (and variables) are event definition (e.g., near miss, slight damage, major injury), crane status (e.g., routine work, idling time), crane activity during the incident (e.g., rigging, hoisting, jumping), failure mode (e.g., signalling error, inattention, fatigue), and several others. The resulting database also enables to identify future events as identical or similar to previous ones, and to draw conclusions according to the analyses established earlier in the study.

The categorized database proved effective in a multi-data analysis, which emphasized potential areas for corrective action. A pilot run was demonstrated on incident data received from two of the leading companies that supplied data, revealing a flaw in the technical state of equipment for one and ground crew (riggers and signallers) problems for the second.

An ongoing effort is currently in progress using statistical classification methods to segment construction near misses and accidents to clusters according to their risk potential. This procedure is intended to indicate the risk potential identified for near-miss events within the database as well as for future events.

LITERATURE REVIEW

Near Misses – Historic Background and Current Practice

It is common thinking to attribute the first appearance of the term “near miss” to the seminal work of H. W. Heinrich (1886-1962), first published in the early 1930s. Heinrich et al. (1980) stated that for every instance of “major injury” there are 29

"minor injury" accidents and 300 "no-injury" accidents. Underlying and causing all 330 events are an unknown number of unsafe practices or conditions, possibly running into thousands. This work established the well-known "Heinrich triangle", which was later followed by similar triangles (i.e. Bird and Germain 1966; Phimister et al. 2003; Masimore 2007) that suggested different definitions of and ratios between the different incident levels. Nevertheless, the basic idea remains the same: for every case of injury, we can find a large number of no-injury accidents (later termed "near misses"), in which there was a narrow escape from injury. The data extracted from these occurrences provide useful lessons for preventing both major and minor injuries.

Heinrich et al. (1980) claimed that accident prevention is too frequently based upon the analysis of the causes leading to major injury, mostly because of a misunderstanding what an accident really is. They defined an accident as an event that results "in a personal injury or the probability thereof", meaning that the importance of the individual accident lies in its potential to cause injury and not wholly in the fact that the injury actually happened. Thus, the investigation of accidents must also include the no-injury accidents. Wright and Van der Shaaf (2004) claimed that Heinrich (1931) did not intend to convince the reader as to the commonality of causes between different accident outcomes, but rather to illustrate the fact that prevention need not wait until an accident occurs, and that prevention should not focus only on the most severe consequences but also on events at the lower level of the triangle. They also stated that the similarities in the pathways leading to minor and major incidents are a vital argument that should be used to motivate employees to report near misses. Thus, they recommended studying the communality of causes (the "common cause hypothesis") between the different incident levels for different domains, and claimed to have provided qualified support for the common cause hypothesis in the UK railways causal taxonomy. Alamgir et al. (2009) studied the causal pathways of near misses and minor occupational injuries and concluded that the relative distributions of causes and activities involved in musculoskeletal injuries were similar. Moreover, they claimed that their findings support the use of near-miss and minor injury data in injury prevention programs. Lander et al. (2011) used a different methodology to examine the utility of a near-miss reporting system in a mid-size electrical plant, regardless of the causal pathways of the reported incidents. They concluded that the implementation of the system was associated with a decrease in injury rates, proving its value in injury prevention in a manufacturing setting. These studies, among others (i.e. Davis 2000; Wright 2000; Konstandinidou et al. 2011), support the usefulness of collecting, studying, and drawing conclusions from near-miss as well as actual-accident data.

Definitions of Near Misses

Van der Shaaf (1991) defined near misses as "any situation in which an ongoing sequence of events was prevented from developing further and hence preventing the occurrence of potentially serious (safety related) consequences". This definition, which concerns undefined serious consequences, differs from that of Heinrich (1980), who focused only on whether or not injury occurred. Jones et al. (1999) found the fixation of the definitions of accident and near miss to be essential for a consistent understanding of undesired events. They suggested the term "major near miss" to describe an event that could reasonably be expected to lead to a "major accident" (as defined by the Seveso II Directive) and "near miss" as one that could have caused an accident. Phimister et al. (2003) stated that in order to have an effective near-miss management system a definition must be adopted that will be easily understood by all

employees. They suggested a new definition: “An opportunity to improve environmental, health and safety practice based on a condition or an incident with potential for more serious consequence”, and added two further restrictions to the definition: (1) a near miss must entail an “event”, or (2) it must involve a “last barrier challenged”. Cambraia et al. (2010) adopted the concept of a near miss as an instantaneous event, which involves the sudden release of energy and has the potential to generate an accident. They further emphasised that, according to their point of view, near misses do not result in material damage, which is assumed to belong to the full-accident definition. Gnoni et al. (2013) stated that one of the main problems affecting the identification of near-miss events is the need to define features that characterise events as near misses. They suggested separate definitions for unsafe acts and conditions, and defined a near miss as the closest event to an accident that has the intrinsic potential to cause injury or adverse health effects.

It is thus possible to identify several perspectives on the definition of near misses: (1) range of incident, or is property damage included or not? (2) definition of the lower limit of near misses in order to differentiate them from unsafe acts or conditions; and (3) the need to rank near misses according to their risk potential.

Tower-crane related risk factors

The current research focuses on tower-crane related near-miss events due to the centrality of tower cranes in present-day construction, on the one hand, and the potential of tower cranes as hazard generators on the site, on the other hand (Shapira et al. 2007). This combination renders the tower crane’s environment fertile ground for the occurrence of numerous near-miss events. Crane related risk factors have been studied extensively (Häkkinen 1978; Häkkinen 1993; Suruda et al. 1999; Shepherd et al. 2000; Beavers et al. 2006; Aneziris et al. 2008), and studies have covered all types of cranes, namely mobile cranes, tower cranes and derricks. Shepherd et al. (2000) studied 500 crane fatality narratives for the years 1985–1995, of which only 6% were related to tower cranes. Since other studies used similar databases, one can assume that the percentage of tower cranes does not vary significantly among them. Furthermore, these studies use different sets of variable and category definitions: Häkkinen (1993) specified “situations” of serious accidents, (i.e. falling of loads, dismantling of cranes) and categorised accidents according to the phase of work in which they occurred (i.e. handling of lifting gear, descent of load, maintenance and repair). Suruda et al. (1993) adopted their “common failure modes” from MacCollum (1993), (i.e. overloading, killer hooks, and upset\overturn), while Shepherd et al. (2000) classified crane fatalities according to the damaging energy involved: electrical (i.e. overhead power lines), gravitational (i.e. falls of objects, falls of people), or mechanical (i.e. caught in between). Beavers et al. (2006) examined crane fatality data to determine proximal causes (i.e. struck by load) and contributing factors (i.e. rigging failure, unbalanced load). Moreover, they challenged definitions used in other studies that identified crane failure modes as proximal causes, claiming that unlike proximal causes, the contributing physical factors (e.g. “improper rigging” that led to the proximal cause “struck by load”) are not mutually exclusive. Aneziris et al. (2008) addressed the crane accidents reported by the National Institute of Occupational Safety and Research (NIOSH), and focused on collapsing, overturning, and falling of loads from cranes.

Due to the versatility of definitions, a distinct set of variables and categories must be decided on before starting to establish and analyse any database of incidents. The study thus adopted the nomenclature from the literature, with adaptation to its goals,

and the under the caveat that the employment pattern of tower cranes, which varies significantly from that of mobile cranes (Shapira and Glascock 1996), may produce different kinds of hazards and risk factors. Thus, a tower-crane related set of risk factors and categories was developed to be used in further analyses, as will be explained later on.

METHODOLOGY

The integration of data on near misses and accidents forms a comprehensive database that will be useful in drawing conclusions based on several phases of qualitative and quantitative analyses. Creswell and Plano Clark (2011) described the exploratory sequential research design approach within the framework of mixed method research. This approach begins with the collection and analysis of qualitative data, reflecting and analysing codes, themes and concerns that arise during the observation. Then a second step takes place, building on top of the exploratory results, using quantitative methods to generalise or append the initial findings. Accordingly, this chapter describes the process of data collection and the establishment of the database using a qualitative exploratory approach, and further chapters will describe the database structure and the quantitative approach implemented in the ongoing phase of the study.

Research on near-miss incidents necessitates adopting a precise definition of the term and setting boundaries between the different levels to ensure consistency in collecting the data and defining the different incidents. Therefore, the research adopted the following definitions:

1. Upper boundary definition – between accidents and near misses. An event will be defined as a near miss if:
    a. No lost-time injury was recorded; and
    b. No damage occurred, except for damages below the threshold of "acceptable damage".
2. Lower boundary definition – between near misses and unsafe acts and conditions:
    a. A near miss is an "event"; it has a beginning, a development phase, and an end.
    b. Following Cambraia et al. (2010), a near miss has to involve the release of energy.

This definition led to the six-point incident severity scale, which was identified and implemented in the database definitions to be explained later. Nevertheless, it is worth mentioning here that the resulting database differentiates between two levels of near misses: (1) no injury and no damage and (2) slight property damage only. Moreover, four accident levels were introduced: (1) severe damage only, (2) minor injury, (3) major injury, and (4) fatality.

Data collection

Any safety information system depends crucially on the willingness of people in direct contact with the hazard to report their errors and near misses. To achieve this it is necessary to engineer a safety culture (Reason 1997). Yet it may not be easy to persuade people to file reports. Indeed, the ability to provide meaningful statistics on construction accidents and near misses from reports is limited due to gross underreporting (Shapira et al. 2012). Yet Cambraia et al. (2010) achieved a dramatic increase in both number and quality of reports after systematically encouraging the

workforce to report. This idea was adopted in the current research, in the collection of safety incident data for analysis, which turned out to be a time-consuming and labour-intensive effort due to the aforementioned tendency for underreporting and the reluctance of several construction companies to reveal safety incident data. Finally, personal professional contacts with leading construction companies in Israel were utilized, enabling the researchers to interview site managers, superintendents, and safety officers. The interaction with each construction company began with a forty-minute lecture given to a wide forum of site managers, portraying the basic ideas of near-miss definitions, near-miss reporting and analysis, and the essential idea of providing near-miss reports in a non-punitive environment. The main goal of the lectures, besides introducing terms and definitions, was to be acquainted with the site managers and gain their confidence in preparation for the subsequent research stages. It turned out that, indeed, some of the companies had safety event records, which were revealed and provided the first incident stories. The next stage consisted of one-hour-long site interviews with the local management forum (project manager, project engineers, and superintendents). The interviews, which were recorded and later transcribed, uncovered a considerable number of near-miss stories that had not been reported earlier. This entire procedure was possible under a commitment to confidentiality that included signing strict confidentiality contracts. Further stories were acquired from the literature (King 2012; Shapira and Lyachin 2004) and internet sources (Craneaccidents.com; Vertikal.net). Consequently, a large bulk of stories was created, representing various context conditions such as different companies, methods of data collection, and levels of detail. The stories were then classified according to basic common themes that define full-record events of tower-crane related incidents, accidents, or near misses. The current database includes 241 tower-crane safety incidents, of which 162 are near misses and 79 are full-scale accidents.

Exploratory approach

As explained earlier, several sources were explored to reveal near misses as well as accident stories. The stories were analysed to explore the conditions, contexts, and components that constitute tower-crane related safety incidents. An open-ended observation was implemented, revealing new sets of data each time a new source of stories was encountered and additional incident stories entered the database. Fellows and Lieu (2008) stated that the categorisation of qualitative data (as appeared in the event stories) may rely on the researcher's opinion, based on expertise and experience. To avoid bias, they recommended starting with initial guidelines and confirming or amending them on a first pass of the data. The second pass has to include the complete categorisation consistently. Accordingly, each piece of data in the current study (the incident stories) was carefully examined to identify data categories and variables within the categories. The incident analyses included several vital questions, such as "what is the shortest way of defining the incident", "what is the most prominent failure mode" and more. Variables were defined primarily by giving priority to terms embedded in the text itself (i.e. the variable "inattention" was defined when the word was a part of the text, like "the operator did not pay attention to…"). Thus, maximum rigor and objectiveness were assured. The collection of data continued until no new categories or variables were found when additional stories were analysed. This state of saturation occurred after examining about 200 crane related safety incidents. Following this stage, a second, more structured stage took place in which all accumulated near-miss stories were analysed again, using the updated set of categories and variables. The definitions of the variables within the categories were obtained through continuous comparison with definitions set out in the literature and

subsequent adjustments as well as additional definitions that arose, which were not found in the literature. Ongoing research is being performed, implementing advanced statistical analysis methods, to classify near-miss events within the database according to their potential to develop into severe accidents.

THE DATABASE

The aforementioned iterative process established a set of definitions that systematically covers most issues involved in each tower-crane related safety incident, so as not to miss any relevant detail. The final database consists of several categories, some of which are strictly contextual information, such as date, day of the week, crane work status, etc. Another category measures the severity of the incident using a six-point scale (1 = near miss with no injury or property damage to 6 = fatal injury). The three most important categories that reveal substantial information about the incident answer three questions: (1) "when?" – the type of activity the crane was performing when the incident occurred, (2) "what?" – the definition of the incident, and (3) "why?" – a description of the failure mode that caused the incident. As the first two definitions are straightforward and arise directly from the texts, the third one, namely the "why" definition, is more elusive and has to rely on a predetermined method for providing the exact definitions. This method has been studied in various disciplines. Reason (1991) described the General Failure Type (GFT) approach adopted in the North Sea oil exploration and production domain. The GFT indicators are derived empirically from close observations of the company's activities. The Failure State Profile (FSP), which describes the percentage of occurrence for each failure type within the company, can reveal its health and safety state. Since several failure types may be attributed to one incident, the overall percentage might exceed 100%. Davis et al. (2000) described the Confidential Incident Reporting and Analysis System (CIRAS) within the UK railway domain. They proposed a system that identifies error on three levels: the proximal ('sharp-end'), intermediate, and distal. Among the proximal causes, they identified codes such as attention and perception. At the aforementioned crane domain, Beavers et al. (2006) challenged definitions used in other studies that identified crane failure modes as proximal causes, claiming that unlike proximal causes, the contributing physical factors are not mutually exclusive. Thus, the current research adopted the GFT approach reported by Reason (1991), whereas the technical definitions were adopted mainly from among proximal causes and contributing factors offered by crane related studies (Häkkinen 1978; Häkkinen 1993; Suruda et al. 1999; Shepherd et al. 2000; Beavers et al. 2006; Aneziris et al. 2008). Moreover, while examining the event stories, some of the proximal causes described by Davis et al. (2000) were adopted as well. It is important to note that the database is modular and further categories may emerge and be added as required. One example is an indication of whether or not the lift was a blind lift.

Figure 1 presents a full description of the variable definition comparison for the category "the incident" (the "what" category). The right hand frame presents the resulting variables while the others specify definitions adopted by other studies, as mentioned. All bold-font definitions represent variables adopted from literature under the category, while the numbers in brackets represent similar or identical meanings for the different variables [for example, no. (05) "struck by moving load" and "struck by moving object" are parallel, while (06) "electrocution" is identical in all cases]. The resulting database, including its categories and variables, was meant to serve further quantitative analyses of trends and context conditions.

The safety incident coding and categorization enables the identification of future incidents according to an identity number that describes its relevant "building blocks". One simple example describes a typical recurring case of a concrete bucket falling due to a technical failure in the hoisting mechanism, or in the reporter's own words: "While casting a wall using a concrete bucket attached to the tower crane, the bucket suddenly accelerated towards the lobby floor. The bucket was still attached when it reached the ground, hitting a worker. The worker was sent to the hospital in an ambulance, suffering from a fractured leg". The main incident coding is as follows: 04 (minor injury), 01 (routine work), 01 (crane carries load), 02 (activity during incident – lifting), 11 (failure type – technical failure in crane), 02 (no blind lift).

IMPLEMENTING THE DATABASE

The main goal of collecting tower-crane related safety incidents was to compile an initial set to study and to create a database. Nevertheless, the first beneficiaries of the research were the companies' safety officers and safety status in general. As the number of incidents increased and the initial database definitions were completed, two sets of incidents given by two construction companies were analysed as a pilot run, implementing a multi-case analysis. The two construction companies in question are well known and are among Israel's top 10 in terms of revenue. The results were interesting and encouraged the companies to take actions. Figure 2 depicts the comparative histogram of the "failure state profiles" (Reason 1991) of the accident and near-miss data given by the two companies. It is evident that company A (the black bars) suffers from two main drawbacks regarding crane safety: (1) recurring incidents involving technical failures (no.11) attest to the poor technical state of their tower crane fleet as well as to maintenance problems, and (2) failures involving human factor issues (no. 06 and 07) and a distinct violation of regulations (no. 16) emphasize the need for a comprehensive training effort as well as discipline measures. Company B, on the other hand, suffers from a noticeable flaw concerning the training of their ground crew (riggers and signallers, no. 03 and 04), as is evident also by the significant portion of load problems (no. 12). This comparison emphasizes the efficiency of relating the various near-miss stories to a set of simple codes that enable various crosschecks that lead to the drawing of initial conclusions from the raw data. This systematic coding also opens up the possibility of matching future incidents to corresponding incidents already in the database and analysing them automatically according to predefined risk potentials or other conclusions.

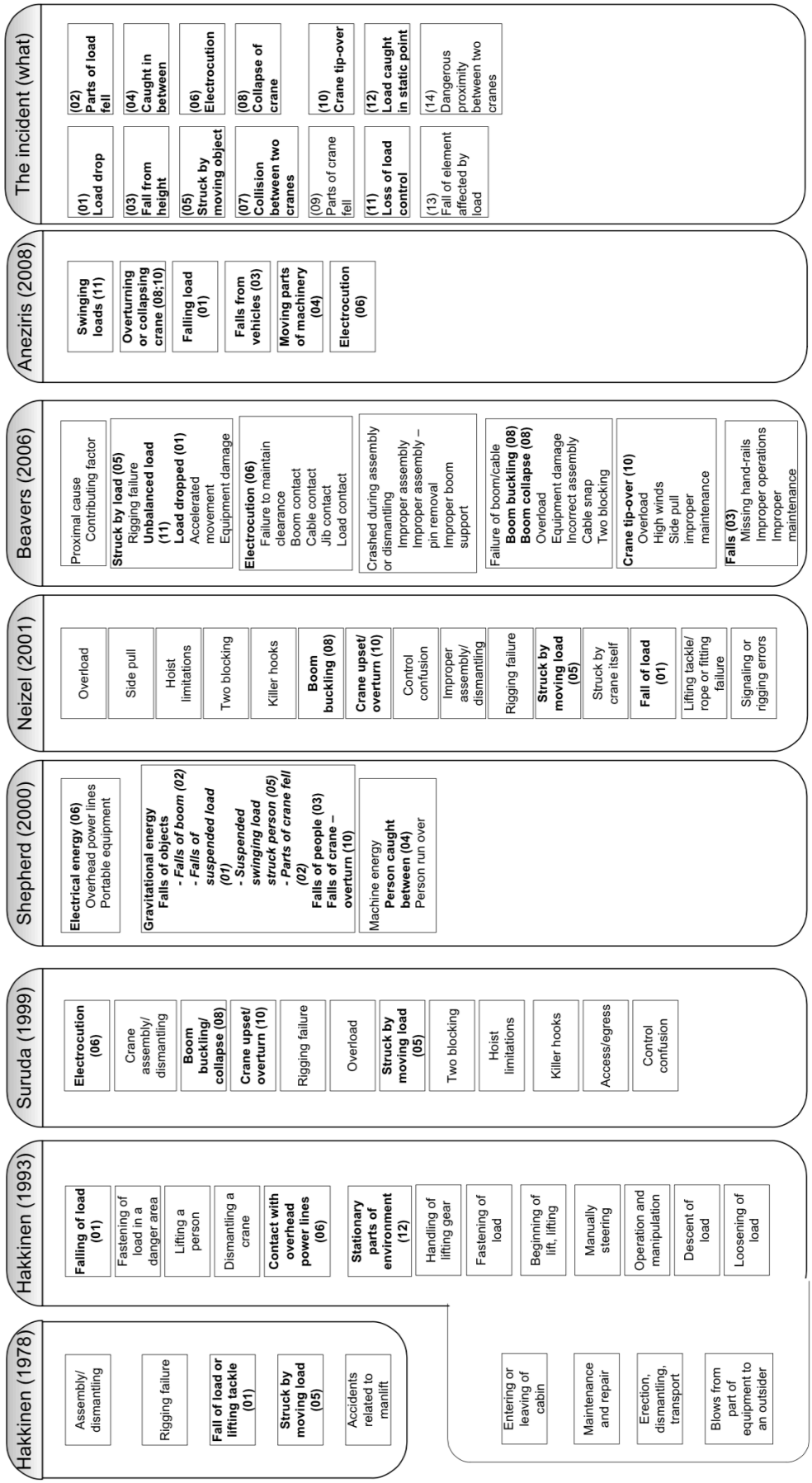

Figure 1: Various definitions of the "incident" category

THE WAY FORWARD

In addition to the definition of basic categories and variables that guide the analysis of causes and corrective actions, the goal of the quantitative analysis is to specify the risk potential embedded in near-miss events. This evaluation is intended to be performed with respect to both single events and multiple incidents, as was done in the first part of the study. Segmentation of large crush dataset and the analysis of clusters, which are designed to find subtle trends and significant causes, are common practices in transportation accident research (Fishbain and Grembek 2014), and seem to be applicable also to construction near-miss and accident data. The database will, therefore, be segmented according to the above-described categories and variables, in an attempt to obtain groups that represent similar risk potentials. Thus, the severity category will be defined as the dependent variable in the analysis, reflecting the severity of the incident outcome on the aforementioned six-point scale. A pilot run was performed on the first 66 incidents, which included eight fatal accidents, implementing the K-Means clustering method (Norušis 2011). The run resulted in three clusters of 28, 26, and 12 incidents. It is worth mentioning that the smallest cluster (12 incidents) contains four of the eight fatal accidents. This result strongly indicates that this line of investigation for risk potential is valid and that this cluster represents high-risk incidents. This small cluster also contains three near misses. Thus, the concept suggested here regards these near misses as having a high-risk potential. Future near misses that are identified as similar to these according to the database definitions will be evaluated accordingly. The concept presented here, while showing great potential, has not yet matured, and several additional classification methods are being investigated as well. Further validation of the method on a larger scale dataset is also called for.

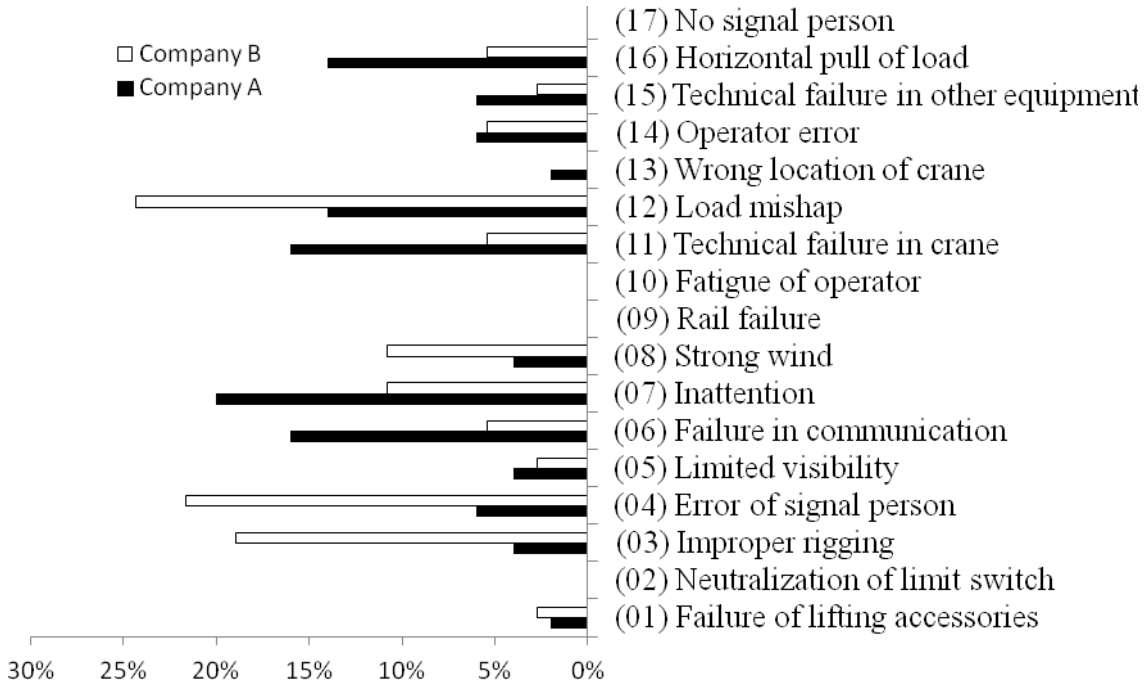

Figure 2: Failure state profiles of two construction companies

CONCLUSION

Collecting data on accidents and near misses in a system that can barely handle this information on a regular basis posed the first challenge of the study. Persuading leading construction companies to cooperate and reveal their data, as well as providing them with our initial findings, gave both sides the opportunity to launch a new procedure within existing organizations and granted the researchers access to important data for analysis. The comprehensive database, which includes incidents acquired so far and future incidents to be collected, will enable structured analyses of tower-crane related incidents as demonstrated above, and more. This first step of the study established a basis for implementing quantitative analysis methods to draw further conclusions from near-miss data. The quantitative analysis of multi-case data according to the set of basic standard definitions enabled drawing useful conclusions directly from the data without the need for complicated investigations, and further application of statistical analyses will help improve the profound understanding of near-miss and accident occurrences at construction sites, in relation to tower cranes. These analysis methods will provide construction companies with the means of implementing preventive steps according to their findings and conclusions. Although the study focuses on tower-crane related incidents, the suggested methods can produce similar results in other domains or regarding safety incidents at construction sites in general.

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COMPETENCE MANAGEMENT IN THE UK HERITAGE RAILWAY INDUSTRY

Robert Baughan[1], **Martin Crapper** [2]

[1] *PhD Research Student, School of Engineering, The University of Edinburgh, EH9 3JL, UK*
[2] *Senior Lecturer in Civil and Environmental Engineering, School of Engineering, The University of Edinburgh, EH9 3JL, UK*

There are over 100 heritage railways in the UK, running vintage trains for leisure and tourism and operated primarily by volunteers. Factors such as the volunteer culture, the prevailing language, the diversity of skills, qualifications and learning abilities, are all key factors to be addressed in managing competence effectively.

Safety is a key issue in the heritage railway industry. Recent accidents, including a fatality in 2012 on the North Yorkshire Moors Railway, have led to competence management being highlighted by the Rail Accident Investigation Branch as a key issue to be addressed by the industry, reinforcing standards and guidance already published by the Office of Rail Regulation.

The research aims to study this issue in four specific sub-areas of the heritage railway industry: infrastructure, operations, managing change and responsibilities of directors. The intention is to identify and recommend an approach to competence management that is appropriate to the specific needs of the UK heritage railway industry.

In terms of research methods, it is envisaged that firstly a detailed understanding will be developed of the competency requirements through the application of engineering safety management approaches. Secondly, in order to understand the particular issues associated with a largely volunteer workforce drawn from a variety of backgrounds, and often working on an informal or "ad-hoc" basis, sociological research methods will be applied as interviews are conducted with a representative selection of UK heritage railway personnel.

Initial research has identified a significant difference to the approach adopted when recruiting and inducting staff for safety critical roles. Selection criteria in the heritage railway sector is generally limited to age and physical limitations, contrasting with competency based assessment and pre-employment medicals in the mainline rail sector. Heritage railway induction processes are limited and have to address mixed backgrounds and capabilities, whereas in the mainline industry these are tailored to known abilities and formally assessed.

The PhD research is ongoing and it is anticipated that the results will contribute to more effective volunteer selection and will inform future heritage railway guidance on competence management.

Keywords: heritage railway, safety, competence, volunteer

INTRODUCTION

There are over 100 heritage railways in the UK, running vintage trains for leisure and tourism and operated primarily by volunteers. All require to be managed and operated in a safe manner, subject to the same overall regard for the safety of travelling public, staff and third parties as are the mainline networks.

Safety is thus a key issue in the heritage railway industry, and recent incidents, including a serious injury in 2010 on the Foxfield Light Railway (RAIB 2011) and a fatality in 2012 on the North Yorkshire Moors Railway (RAIB 2012), have led to competence management being highlighted by the Rail Accident Investigation Branch (RAIB) as a key issue to be addressed by the industry, reinforcing standards and guidance already published by the industry.

The Office of Rail Regulation (ORR) has published a number of documents to address competence management, including a Guide to Developing and Maintaining Staff Competence (ORR 2007). The Railways and Other Guided Transport Systems (Safety) Regulations 2006, which are enforced by the ORR, apply to the UK heritage railway industry as well as the UK mainline railway. The regulations include the need for a Safety Management System, and to ensure that all staff, including volunteers, are adequately trained and possess necessary skills (ROGS 2006). In addition, the Rail Safety and Standards Board (RSSB) has recently published a Good Practice Guide on Competence Development (RSSB 2013), whilst the Heritage Railway Association have published a series of Guidance Notes including one on General Competence in Relation to Safety Critical Work (HRA 2013).

Competence management within the UK heritage railway sector affects all aspects of the industry including engineering of infrastructure and rolling stock, train operations, corporate management and governance and the overall project management and delivery of change. The heritage railway working environment poses particular challenges with respect to the implementation of an effective competence management system, with a largely part time volunteer workforce overseen in most cases by a small full time paid staff.

There has been no systematic analysis of this subject matter carried out to date and it is intended that the research to be undertaken will contribute significant new and interesting knowledge of this subject area by taking into account the perspectives of the largely voluntary workforce as well as the relevant standards and processes.

CONTEXT – A LARGELY VOLUNTEER WORKFORCE

A key aspect to effective implementation of a competence management system in the UK heritage railway sector is the need to understand the issues associated with a largely volunteer workforce drawn from a variety of backgrounds and often working on an informal or “ad-hoc” basis. Factors such as the volunteer culture, the prevailing jargon, the diversity of skills, qualifications and learning abilities are all potential limitations or constraints that need to be taken into account for the effective application of any competency management system.

With its origins in the early narrow gauge preservation schemes of the 1950s, the evolution of the UK heritage railway industry gathered pace in the 1960s as a wholly volunteer run endeavour, as groups of railway enthusiasts sought to preserve branch lines that were being closed by British Railways (Beeching 1963). These enthusiasts came from a variety of backgrounds, with a diversity of reasons underpinning their desire to be involved, and their numbers have grown consistently since then. In 2013,

there were 18,528 individuals recorded as volunteers on UK heritage railways (HRA 2013). As the industry has matured and grown into a multi-million pound (GBP) business, carrying ever increasing numbers of customers (Heath 2013), so the need for a small full time paid staff at each heritage railway has also become the norm.

It is against this unique backdrop, of a volunteer part-time workforce with a myriad of capabilities and motivations complemented by a small full time permanent staff, that competence management systems have to be developed for and applied to the UK heritage railway industry. The objective of this research is to identify and recommend an approach to competence management that is appropriate to the specific needs of the UK heritage railway industry.

METHODOLOGY

It is envisaged that the research will adopt both a practical and theoretical approach.

Background Research

The initial stage of the research has sought to develop an understanding of the UK heritage railway sector and the particular issues relating to a largely volunteer workforce drawn from diverse backgrounds and why competency management is required today.

Associated with this, early engagement has been made with the Heritage Railway Association (HRA), the body representing the majority of the heritage and tourist railways, railway museums, steam centres and railway preservation groups in the UK and Ireland. HRA has acknowledged that the proposed project scope and see the research as potentially of great benefit to the HRA and the industry. One new area that this early engagement brought to light was that of *corporate memory fade* - how to replace the competencies belonging to the founding generation of volunteers.

The background research also comprises a review of published works with respect to the various types of competency management systems, their applications in various industry sectors and why they are required. This includes a review of freely published information, available on the internet and from other sources as well as a structured review of relevant peer reviewed research through relevant academic search engines.

Finally, the various potential research methods available will be reviewed to ensure that the appropriate qualitative or quantitative methods are selected to address the proposed areas of research.

Anticipated Research Methods

In carrying out the research into the four proposed sub-areas of competency management within the UK heritage railway sector (infrastructure maintenance and renewal, operations, managing change [effective project management] and the responsibilities of directors), it is envisaged that firstly a detailed understanding will be developed of the competency requirements through the application of engineering safety management (iESM 2014) approaches. This research will be undertaken through examining published documentation, obtaining access to unpublished information within the UK heritage rail sector and through detailed analysis and observation of these issues as applied in reality at a representative sample of UK heritage railways. As part of this research, and as a necessary “benchmarking” exercise, competency management systems / issues within the UK mainline rail industry will also be investigated.

The second key area of research will be to understand the particular issues associated with a largely volunteer workforce drawn from a variety of backgrounds and often working on an informal or "ad-hoc" basis. It is anticipated that this research will involve the application of qualitative research methods involving sociological research as interviews (Potter and Hepburn, 2005) are conducted with a comprehensive variety of UK heritage railway personnel at a sufficient sample of levels and locations to be truly representative of the industry. Through discursive analysis, analysing the linguistic exchange (Sherratt et al 2012) resulting from these interviews, factors such as the volunteer culture, the prevailing language, the diversity of skills, qualifications and learning abilities will all be analysed in detail. The results of this analysis will be used to determine the limitations or constraints that will need to be taken into account for the effective application of any competency management system.

During the course of the project, it is our intention to develop a detailed understanding of appropriate sociological research methods, and the specific language and constructs associated with their application, in order to elicit the most relevant and pertinent data to support the research being undertaken.

FINDINGS AND DISCUSSION

As a starting point for the research, the authors have been able to reflect on their own direct experience with different heritage railways, together with the established recruitment procedures of various contractors working for Network Rail (NR).

It has thus been possible to record some initial observations with respect to the different applications of competency management systems within these two environments. Although both entities are involved in the maintenance and renewal of UK standard gauge[3] railway infrastructure, due to the inherent operating and staffing differences of these two environments the approach to, and the application of, competency management systems is quite different.

Initial observations have identified a significant difference to the approach adopted when recruiting and inducting staff for roles, including those that are safety critical. Selection criteria in the heritage railway sector is generally limited to age and physical limitations, contrasting with competency based assessment and pre-employment medicals in the mainline rail sector.

For example, at a typical UK heritage railway, the start of the recruitment process for volunteer roles can take the form of an open day where interested candidates are asked to attend an introduction to the railway and to the various disciplines and departments seeking resources. With a limited introduction to the various (often safety critical) voluntary roles on offer and no assessment of competences or medical condition undertaken, candidates are asked to indicate their preference for specific volunteer roles. Candidates are then contacted by the railway at a later date to attend an induction for their chosen volunteer role, with competence assessment and certification coming only later at various stages of advancement within the role (for example the transition from cleaner to fireman and then to driver on steam locomotives). This is generally limited to technical skills and knowledge with no formal assessment of aptitude for any given role.

[3] 4' 8 ½" (1,435 mm) is the standard gauge for UK railways

By contrast, in the UK mainline rail industry candidates for specific roles are required to attend a formal, usually competency based, interview as part of the selection process. For some roles, psychometric testing (RSSB, 2013) will also be carried out to determine that candidates possess the necessary attributes to carry out the role successfully. Prospective candidates will also typically be required (always for a safety critical role) to attend a pre-employment medical and this will include, as part of the Network Rail Sentinel scheme, screening for drugs and alcohol usage (NR 2014). It is only after successful completion of all of these stages in the recruitment process that a candidate may be offered a position of employment.

As a result of the recruitment process, heritage railway induction processes have to address new recruits with mixed backgrounds and capabilities, whereas in the mainline industry these are tailored to defined minimum standards of competence and aptitude.

A typical UK heritage railway induction will be undertaken by a volunteer who is not necessarily trained in instruction and in an uncontrolled, often workplace, environment. Whilst valuable and relevant information is imparted during the induction, there is not necessarily a structured syllabus for the induction, or a subsequent assessment, requiring a minimum standard to be attained before a new recruit is able to commence their role.

Induction processes in the UK mainline rail industry are highly structured and typically carried out in dedicated environments. Instructing staff are qualified and competent to carry out the induction with new entrants being assessed to ensure that minimum standards are attained. For most roles, the induction process will be a precursor to more job specific training that is tailored to the role to be undertaken.

It should be noted that whilst the approach to competence management within the mainline rail industry is necessarily rigorous, this is not generally the case within the UK construction industry where competence management is often determine by a Construction Skills Certificate Scheme (CSCS) card or by word of mouth.

It is clear from these initial observations that there are significant differences with respect to the application of competency management systems within the UK mainline railway and UK heritage railway environments.

Of course the two industries, although sharing a common base form of infrastructure and operations, are different. The UK heritage railway industry is primarily serving a leisure based market by operating vintage trains at 25 miles per hour or less, with a mainly volunteer workforce. By contrast, the UK mainline rail industry is serving both business and leisure customers, operating predominately “state of the art” rolling stock at high speed and where journey times and reliability are a significant factor for clients.

It could therefore be interpreted as reasonable that the approach to competence management within the heritage rail sector should reflect the generally lower risks of this industry and the need to address and maintain a motivated volunteer workforce. However, it could equally be argued that there are some minimum standards of competence management that have to be applied in any rail environment, due to the inherent risk of rail operations and the potential consequences of any incident, and it is defining this “balance” that is the prime objective of this research project. Competency management systems for the UK heritage railway industry should be tailored to and address the specific risks of each railway, must take into account the

predominately volunteer workforce and cannot be detrimental to the overall viability of the industry.

The research activities still to undertaken as part of this project will seek to build upon these initial observations in order to determine how competency management can be effectively applied to the largely volunteer workforce within the UK Heritage Rail industry.

CONCLUSIONS

The research is still in the background research stage and hence it is currently too early to draw any significant conclusions from the research activities undertaken to date.

However, some initial observations have identified a significant difference to the approach adopted, when recruiting and inducting staff for safety critical roles, when comparing the UK heritage railway sector with the UK mainline rail equivalent.

Selection criteria in the UK heritage railway sector is generally limited to age and physical limitations, contrasting with competency based assessment and pre-employment medicals in the UK mainline rail sector. UK heritage railway induction processes are limited and have to address mixed backgrounds and capabilities, whereas in the mainline rail industry these are tailored to known abilities and formally assessed.

It is clear from these initial observations that there are significant differences with respect to the application of competency management systems within the UK mainline railway and UK heritage railway environments. However there are different drivers and risks associated with each industry and the challenge is therefore to determine an appropriate approach to competence management within the UK heritage railway environment that addresses the specific risks of each railway, takes into account the predominately volunteer workforce and is not detrimental to the overall viability of the industry.

It is anticipated that the results of the research will contribute to more effective volunteer selection and will inform future heritage railway guidance on competence management across all the relevant sub-areas. Indeed, the HRA has already indicated that it would like to see a new Guidance Note on Competency Management in due course as an outcome of this research project.

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THE DETERMINANTS OF SAFETY CLIMATE: A CONCEPTUAL MODEL TO EXPLORE HOW PSYCHOLOGICAL CAPITAL AND WELL-BEING AFFECT SAFETY LEADERSHIP BEHAVIOURS

Clara Man Cheung[4]

[1] *Department of Civil and Environmental Engineering, University of Maryland, USA*

Safety in the construction industry is a major issue in the United Kingdom and the United States, representing about 20% and 31% of all fatal injuries respectively in 2013. Research suggests a strong predictor of safety performance is safety climate, while safety climate is mainly cultivated by safety leadership behaviours. Although psychological constructs is an important factor influencing behaviours, there has been scant attention to which positive psychological constructs might drive the positive safety leadership behaviours. To narrow such a research gap, we examined how positive psychological constructs studied in positive organisational behaviour (POB) theory may inform our understanding of human mechanisms that affect safety leadership. Specifically, we looked into how psychological capital and well-being may be associated with safety leadership behaviours which in turn affect safety climate in construction organisations. We accomplish these objectives by putting forth a conceptual model and methodological suggestion with related limitations.

Keywords: positive organisational behaviour, psychological capital, safety leadership, safety climate, well-being.

[4] cmcheung@umd.edu

INTRODUCTION

Construction is a high-risk industry. It has accounted for the highest number of fatal work injuries of any industry section in the United States and the United Kingdom. According to the U.S. Bureau of Labor Statistics, the industry hired 4 % of the employees in the United States in 2013, but it accounted for about 20% of total fatal injuries. Statistics from the U.K. Health and Safety Executive indicated that although the construction industry accounted for only 5% of employees in Britain, it accounted for 31% of total fatal injuries in 2013. Given this disproportionate safety performance, construction organisations (e.g., contractors) have devoted considerable efforts to improve safety and prevent accidents, while researchers have supported these efforts by investigating what leading factors are associated with safety performance. Many of these studies suggested that safety performance can be predicted by safety climate (e.g., Neal & Griffin, 2006; Zohar, 2010). Safety climate is generally accepted as a 'snapshot' of employees' perceptions about safety (Mearns, 1999). In other words, to improve safety performance, organisations need to enhance their safety climate.

Although researchers found that safety leadership behaviour is a critical factor linked to safety climate (e.g., Yule, 2003; Flin et al., 2004; Hystad et al., 2014), little is known about the antecedents of positive safety leadership behaviours. In particular, scant attention has been paid to which positive psychological constructs could drive the positive safety leadership behaviours. This aspect of psychological factors, however, is important because psychological constructs are recognised as effective predictors of behavioural outcomes (Harms & Luthans, 2012). Hence, there is a need to explore this new dimension in the management of safety climate from the psychological perspective.

The studies of positive psychological constructs are grounded in the emerging research of positive organisational behaviour (POB) theory which has found that psychological capital (hope, self-efficacy, optimism, and resilience) and well-being are the two most important positive psychological constructs leading to positive work behaviours (e.g., employee engagement and organisational citizenship) Donaldson & Ko, 2010; Russell, 2008). Therefore, we posit that psychological capital (PsyCap) and well-being are possible underlying mechanisms leading to positive safety leadership behaviours; this, in turn, helps to sustain a positive safety climate in construction organisations.

In this paper, we first identify the literature gap in studying safety leadership behaviours; delineate positive psychological constructs, safety leadership behaviours and safety climate in a concept-by-concept manner; and synthesise these concepts into a conceptual model as shown in figure 1. We conclude by suggesting a methodological approach in pursuing this exploration, and revealing limitations of the approach.

LITERATURE GAP

Since the notion of 'safety climate' was introduced by Zohar (1980), numerous research found that it is highly related to 'management commitment to safety' (Dedobbeleer & Béland, 1991; Flin, 2003;; Glendon & Litherland, 2001; Michael, Evans, Jansen, & Haight, 2005); however, the term has been used rather vaguely to include a broad range of managerial activities and roles (O'Dea & Flin, 2001). Recent studies attempted to operationalise 'management commitment to safety' in terms of a

range of leadership behaviours that are consistently related to good safety performance. Bryden (2002) found that there were a number of critical mangers' behaviours related to safety outcomes in an oil company: articulating an attainable vision of future safety performance; demonstrating personal commitment to safety symbolically; engaging everyone with relevant experience in decision-making; and being clear and transparent when dealing with safety issues. Yule et al., (2007) identified that leadership behaviours such as intellectual stimulation, idealised consideration and contingent rewards were significantly related to lower accident rates in a power generating company. Wu et al., (2008) reported that safety coaching, safety caring and safety controlling were the leadership behaviours being linked to safety performance in universities' laboratories. Lu & Yang (2010) indicated that leadership behaviours on safety motivation, safety policy and safety concern affected the safety behaviours of container terminals' operators. Hoffmeister et al., (2014) found that leaders who acted as role models on safety issues, clearly articulated safety missions, and asked for new ideas for improving safety performance were critical for cultivating safety climate in construction organizations.

While these works illustrated leaders do play a pivotal role in promoting safety climate through their behaviours, there is a research gap in the existing literature, because it remains unclear what underlying mechanisms help drive these positive leadership behaviours. Psychological constructs are widely regarded as important factors influencing an individual's work behaviours in organisational behavioural research (Harms & Luthans, 2012). As such, we infer that positive psychological constructs could be effective predictors of positive safety leadership behaviours as well. Since positive psychological constructs, which can be measured, developed and effectively managed for improving work performance, are studied in positive organisational behaviour (POB) theory (Luthans, 2002 p.59), we suggest examining how POB constructs may affect safety leadership behaviours, In particular, we call for the attention on psychological capital (PsyCap) and well-being, the two most important psychological constructs emerging in POB, in this study.

PSYCHOLOGICAL CAPITAL

Psychological capital (PsyCap) has emerged as a core construct of positive organisational behaviour (POB). It is a higher-order constellation of four positive psychological constructs: self-efficacy ('having confidence to take on and put it in the necessary effort to succeed at challenging tasks'); hope ('persevering towards goals and when necessary redirecting paths to goals'); optimism ('making a positive attribution about succeeding now and in the future'); resilience ('when beset by problems and adversity, sustaining and bouncing back and even beyond to attain success') (Luthans & Youssef, 2007 p.3). PsyCap yields higher correlations with performance outcomes than its constructs independently (Avolio et al., 2007). In addition, PsyCap can be developed and improved through training (Luthans et al., 2010).

We consider that psychological capital may be a potential antecedent of safety leadership behaviours in several ways. Leaders who are more hopeful tend to set higher standards on safety performance and be role models of safety behaviours. They are highly motivated to make their followers comply with the safety standard through various actions such as establishing a safety responsibility system, acting on safety policies, and recognizing followers' safety behaviours. Furthermore, their efficacious

and optimistic beliefs about succeeding with their objectives on safety improvement lead them to put in the effort and persistence required to succeed. Finally, highly resilient leaders are more able to bounce back from adversity, and stay focused on handling safety issues. As a result, they can find ways around difficulties to achieve better safety performance.

Substantial empirical research has indicated that PsyCap has significant positive relationships with desirable employee attitudes and behaviours (i.e., job satisfaction, organisational commitments, psychological well-being, and organisational citizenship) (Avey, Reichard, Luthans, & Mhatre, 2011; Peterson, 2011; Qadeer & Jaffery, 2014). As regards the impact of leaders' PsyCap specifically, Walumbwa et al. (2010) pointed out that leaders who score higher in PsyCap not only show more positive behaviours and higher performance themselves, but they also serve as role models for followers, and thus lead them to attain similarly positive behavioural outcomes. Considering that positive safety behaviours are part of desirable employee behaviours, we, therefore, infer that leaders' PsyCap could be positively related to safety leadership behaviours. This leads to our first research hypothesis (see figure 1):

H-1: Leaders' psychological capital is positively related to safety leadership behaviours.

WELL-BEING

Well-being is recognized as one of the important psychological constructs in POB (Avey et al., 2010; Linley & Joseph, 2004). It is defined as 'optimal psychological functioning and experience' (Ryan & Deci, 2001, p.142), and can be separated into hedonic, eudaimonic and evaluative well-being (Jeffrey et al., 2014; Ryan & Deci, 2001;).

Hedonic well-being refers to people's emotions or feelings such as happiness and pleasure (Ryan & Deci, 2001). Eudaimonic well-being includes motivational and behavioural aspects (Ryff, 1989; Ryff & Keyes, 1995). From a motivational perspective, eudaimonic well-being refers to seeking self-realization. Behaviourally, it involves optimal positive functioning, and act of striving (Ryff, 1989; Ryff & Singer, 1998). Therefore, eudaimonic well-being leads people to perceive themselves as mentally growing, engaged and productive (Waterman, 1993). Evaluative well-being refers to how people evaluate their lives. It can be a particular aspect of their lives such as job satisfaction (Jeffrey et al., 2014).

Culbertson et al., (2010) concluded that PsyCap and well-being may have some overlap, but these two constructs are theoretically different. We deduce from this conclusion that PsyCap is related to well-being. PsyCap is regarded as personal psychological resources and capabilities, and affects how an individual interprets a life experience, and thus they have an impact on one's emotional status (e.g., wellbeing). In other words, PsyCap could contribute to individual well-being. For instance, leaders with high PsyCap tend to interpret negative experience (e.g. setbacks that occur during a process of improving safety performance) in a positive way. They regard negative events as a temporary one, and do not let them affect too many aspects of their lives (optimism). In addition, they can quickly bounce back from negative emotions aroused by the experience (resilience), generate possible solutions to improve the situation (hope), and are confident to implement those solutions (self-

efficacy). The ability to successfully cope with negative experience makes them more likely to have better well-being status.

While there is little research on the relationships between PsyCap and well-being, studies that have looked into the relation have used limited conceptualisation of well-being. For example, Avey et al., (2010) indicated that employees' PsyCap is related to hedonic well-being. In addition, Culbertson et al., (2010) concluded that there are positive relationships between PsyCap, and employees' hedonic and eudaimonic well-being. Therefore, researchers have called for using a more comprehensive assessment of well-being to study the relationships. This study tries to redress this by investigating the relation between PsyCap and three different dimensions of well-being (hedonic, eudaimonic and evaluative). This leads to our second research hypothesis (see figure 1):

H-2: Leaders' psychological capital is positively related to their well-being.

Although substantial research shows that well-being relates to work performance and outcomes (e.g., job satisfaction, employee retention, workplace accidents, sick days, absenteeism, engagement, quality defects, and profitability), research examining the causal relationships is limited. To bridge this gap, Harter & Agrawal (2012) used a longitudinal sample of 11,500 U.S. Gallup Panel members[5] to explore the causal relationships among a composite of wellbeing antecedents (career, social, financial, physical and community) and a list of work outcomes (e.g. employee engagement and workplace turnover). They found wellbeing is a stronger cause than consequence, and wellbeing at work is most highly predictive of employee engagement. Engagement has been defined as 'a positive attitude held by employees towards the organisation and its values. An engaged employee is aware of business context, and works with colleagues to improve performance within the job for the benefit of the organisation' (Robinson et al., 2004). From this, we infer that leaders higher in well-being are engaging leaders. They are more likely to care about the safety performance which is one of the key performance indicators of construction organisations. Under the circumstances, they are more willing to work with their team members to improve safety performance through showing positive leadership behaviours (e.g., encouraging subordinates to provide safety suggestions). This leads to our third research hypothesis (see figure 1):

H-3: Leaders' well-being is positively related to their safety leadership behaviours.

Based on the hypothesised relation that PsyCap is positively related to well-being and that the hypothesised relation that well-being is positively related to safety leadership behaviours, we expect that well-being will mediate the relationship between PsyCap and the safety leadership behaviours.

In addition, as previously discussed, PsyCap is regarded as personal psychological resources that could affect leaders' interpretation on safety activities, and thus their safety leadership behaviours. Specifically, leaders who have high PsyCap generally possess positive expectation for achieving the safety performance goals, and thus are

[5] The Gallup Panel is one of the few research panels that are representative of the entire U.S. population http://www.gallup.com/services/172364/draft-gallup-panel.aspx.

more likely to be high in well-being at work. Well-being, particularly hedonic well-being is primarily an emotional experience. To be high on well-being is to be simultaneously high on positive emotions and low on negative emotions (Cropanzano et al., 2003; Wright, 2004). According to Fredrickson's broaden-and-build theory (Fredrickson & Losada, 2005), positive emotions broaden one's momentary thought-action repertories through expanding the obtainable array of potential thoughts and actions come to mind. In other words, leaders with high well-being could generate more pathways and actions to achieve safety performance. From this, we infer well-being is a mediating variable that transfers the effect from PsyCap to safety leadership behaviours because it helps convert positive interpretation into actions. This leads to our fourth research hypothesis (see figure 1):

H-4: Leaders' well-being mediates the relationship between psychological capital and safety leadership behaviours.

SAFETY LEADERSHIP BEHAVIOURS

Leaders play an important role in managing safety performance (Flin & Yule, 2004), as they are the ones who take safety policy of their organisations and show them through specific behaviours (Slates, 2008); this, in turn, affects employees' attitudes and behaviours for achieving safety goals(Wu et al., 2008). In particular, safety leadership behaviours are a range of managerial behaviours that are consistently related to safety performance (O'Dea & Flin, 2001). Several previous studies identified a number of critical leadership behaviours for safety (Bryden, 2002; Hoffmeister et al., 2014; Wu et al., 2008; Yule et al., 2007). All these leadership behaviours can generally be grouped into two types: transformational and transactional. Transformational leadership focuses on providing employees with an inspiring vision for safety and supporting them to achieve it rather than depending on formal contingencies such as procedures (Conchie, 2013); Transaction leadership focuses on linking rewards with safety performance (Inness et al., 2010).

Based on the different aspects of transformational and transactional leadership, Lu and Yang (2010) have recently developed a safety leadership scale that categorised safety leadership behaviours into three dimensions: safety motivation, safety policy, and safety concern. Safety motivation and safety concern are facets of transformational leadership; safety policy is closely linked to transactional leadership. Safety motivation refers to the extent to which a leader creates a motivation system to encourage followers' safety behaviours. Such a system may include 'rewarding safety behaviours, praising workers' safety behaviours, setting up a safety incentive system, reporting potential incidents and safety suggestions, and encouraging workers' participation in safety decision'(Lu & Yang, 2010 p.124). Safety policy refers to the extent to which a leader creates a clear mission, goal, and responsibility so as to set standards for employees, and to create a safety system correcting employees' safety behaviours. Safety concern refers to the extent to which a leader is a role model to employees; emphasises the importance of safety equipment; focuses their interest in acting on safety policies; is concerned about safety improvement; and coordinates with other departments to solve safety issues.

SAFETY CLIMATE

Safety climate is widely regarded as a good predictor of safety performance (e.g., accidents and injuries) in both Western and Eastern societies (Vinodkumar & Bhasi,

2010). Although safety climate is generally accepted as a 'snapshot" of employees' perceptions about safety (Cooper & Phillips, 2004; Yule et al., 2007), researchers are in less agreement regarding the composition of safety climate. According to Yule et al., (2007), the main debate is whether the safety climate should be restricted to workforce perceptions on management commitment to safety (a single faceted approach), or whether the role of management is incorporated with other safety issues such as worker involvement, personal accountability, and safety training (a multifaceted approach). In our conceptual model, we use a multifaceted approach to operationalise safety climate so as to maximize the insights that we can gain from the study.

Specifically, three safety climate dimensions are used in our model (see figure 1), namely: management commitment in safety, individual involvement in safety, and safety management system. These dimensions were developed based on 15 safety climate studies published in the past 30 years (Brown & Holmes, 1986; Cheyne et al., 1998; Cox & Cox, 1991; Cox & Flin, 1998; Dedobbeleer & Béland, 1991; Glendon & Litherland, 2001; Lee, 1998; Lin et al., 2008; Mearns et al., 1998; Mearns et al., 2001; Mohamed, 2002; R. Sunindijo & Zou, 2012; Williamson et al., 1997; Zohar, 1980; Zohar & Luria, 2005). Management commitment in safety refers to the workforce perceptions about how management prioritises and supports safety management in an organisation. Individual involvement relates to the perceptions about how an individual is supported to perform his or her job safely, and is encouraged to participate in safety improvement. Safety management system refers to workforce perceptions about whether an organisation obtains systematic and organisation-wide processes to identify safety issues, control associated risks, and continuously improve safety performance.

As previously discussed, management clearly has an important role to play in safety climate. Indeed, Zohar (1980) who first introduced the concept of safety climate suggests that safety climate is highly related to employees' perceptions of the safety attitudes and behaviours of management. Similar propositions have been found in other research across industries (Arboleda, Morrow, Crum, & Shelley II, 2003; Dedobbeleer & Béland, 1991, 1998; Donald & Canter, 1994; Eyssen, Hoffmann, & Spengler, 1980; Flin, 2003; Niskanen, 1994; Ostrom, Wilhelmsen, & Kaplan, 1993; Wu et al., 2008; Wu, Chang, Shu, Chen, & Wang, 2011). Following these suggestions, we propose the last hypothesis (see figure 1):

H-5: Safety leadership behaviours are positively related to safety climate in construction organisations.

PSYCAP, WELL-BEING, SAFETY LEADERSHIP BEHAVIOURS AND SAFETY CLIMATE - A CONCEPTUAL MODEL

Figure 1 summarises the conceptual model, showing the hypothesised relations among PsyCap, well-being, safety leadership behaviours, and safety climate. The model posits that leaders' PsyCap exert a positive influence on safety leadership behaviours, both directly and indirectly through their well-being. The direct influence of leaders' PsyCap on safety leadership behaviours reflects that their positive interpretation on safety performance poses a positive impact on their actions to implement safety measures. The indirect influence of PsyCap on safety leadership behaviours is through the enhancement of leaders' well-being; this, in turn, helps to strengthen the

conversion from positive interpretation to actions. Subsequently, safety leadership behaviours influence on safety climate.

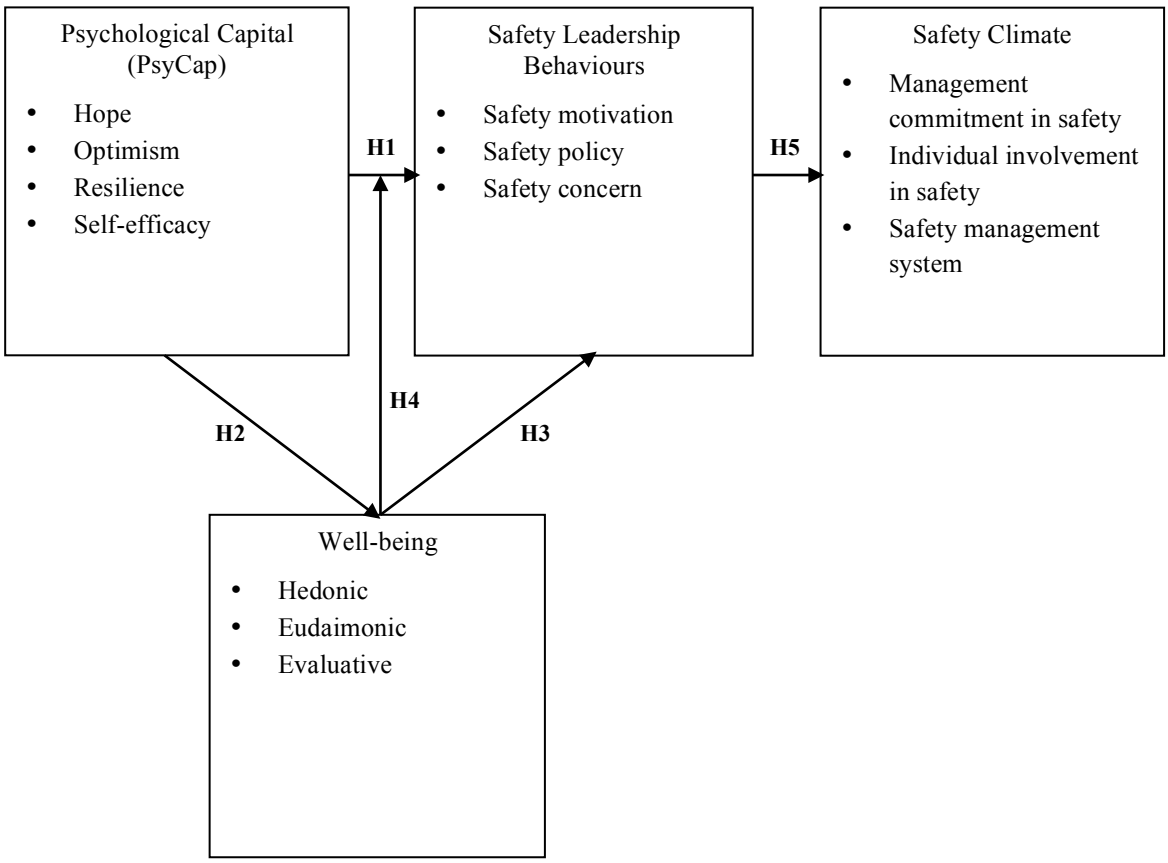

Figure 1: A conceptual model linking PsyCap and well-being to safety leadership behaviours and safety climate.

CONCLUSIONS

Practical implications

This paper explores how psychological constructs could affect safety leadership behaviours that relate to safety climate. The proposed model links the cognitive, emotional and behavioural aspects of leadership to the followers' perceptions on safety climate in construction organisations. This represents a promising new perspective on antecedents of safety climate and leadership behaviours, and in turn provides a new lens to the future research in safety science through looking into psychological factors of management as a source of improving safety climate. In addition, it also offers a new direction to the construction industry on how to effectively select and train their safety leaders based on the assessments and intervention on their PsyCap and well-being status. Last but not least, the propositions and model are also the recognition that in addition to the institutional variables such as safety management system, human variables, specifically their psychological and behavioural aspects, are an equally important dimension in safeguarding construction safety performance.

Methodological suggestion

To examine the relationships among PsyCap, well-being, safety leadership behaviours, and safety climate outlined in the model (figure 1), we propose to use a mixed methods design which combines questionnaire and semi-structured interview. The questionnaire helps to identify what the relationships are among the variables, while the interview is used as a complementary method to the questionnaire because it enables us to take a closer examination on the identified relationships by the questionnaire, and to further investigate the reasons leading to these relationships.

Specifically, the questionnaire contains two parts. The first part includes questions about demographic information and safety climate. The second part of the questionnaire includes questions about the PsyCap, well-being and safety leadership behaviours. The first part of the questionnaire is self-rating; the second part is informant rating which means respondents need to evaluate their direct supervisors' PsyCap, well-being and safety leadership behaviours based on their observations. All questionnaires use a 5- or 7-point Likert scale format ranging from strongly disagree to strongly agree.

Except for the questions of demographic information, all the other questions in the questionnaires are from four established instruments which showed adequate internal reliability (Cronbach's alpha > .80) in previous published studies. Safety climate is assessed with a 20-item Construction Safety Climate questionnaire created by Sunindijo & Zou (2011). The 12-item Psychological Capital Questionnaire is used to measure psychological capital (Luthans et al., 2007; Luthans & Youssef, 2007; Avey, Avolio, & Luthans, 2011). Well-being is measured with the 40-item Happiness at Work survey developed by New Economic Foundation (Jeffrey et al., 2014). The 16-item Safety Leadership Attributes questionnaire developed by Lu & Yang (2010) is used to measure safety leadership behaviours.

A pilot study with the involvement of experts and practitioners in the construction industry will be conducted to ensure that all items in the questionnaire are clear and have adequate content validity. The questionnaire will then be distributed as a web-based online survey. Using a convenience sampling approach, two major construction companies (each has more than 2,000 employees) headquartered in the United States are invited to participate in the questionnaire. Based on the results of the questionnaire, we identify a focus group on which we conduct semi-structural interview.

As all the variables in the model are latent variables which are estimated from several observed variables, we might use structural equation modelling (SEM) to evaluate the appropriateness and fit of the proposed model because it enables to test the structural relations between latent variables. By using SEM, we can first verify the validity of the measurement portion of the model through conducting confirmatory factor analyses which test whether the data fit a hypothesised measurement model.

After confirming a good fit for the measurement model, we can proceed to examine the full structural model, and test the hypothesised relationships. Model fit will be judged by reviewing the magnitude and statistical significance of factor loadings, the chi-square value, and a series of commonly used goodness-of-fit statistics such as the comparative fit index (CFI), the standardized root mean square residual (SRMR), and the root mean square error of approximation (RMSEA), with its 90% confidence interval.

To test for mediation of well-being on the relationships between psychological capital and safety leadership behaviours, we suggest using the Baron and Kenny (1986) four-step procedure through using hierarchical linear modelling followed up with a bootstrapped analysis of indirect effects.

Study Limitations

There are two methodological limitations need to be recognised in this study. First no causal conclusions can be drawn as the study design is neither experimental manipulation nor random assignment. Therefore, causal effects between PsyCap and well-being, between PsyCap and safety leadership behaviours, between well-being and safety leadership behaviours, and between safety leadership behaviours and safety climate cannot be determined. To minimize this limitation, we will conduct post hoc analyses to test several competing theoretical models through utilizing path analysis in SEM. Although model comparison does not demonstrate the 'absolute' causality, it does demonstrate which model provides the optimal fit of the data, and thus it provides us with a better inference for directionality of the tested model at least to some extent.

Second, as both independent and dependent variables will be collected from the same respondent, this is one of the potential sources of common method bias which can lead to inflated relationships (Podsakoff et al., 2003). Thus, this study will follow their recommendation to methodologically separate the measures by having respondents complete the measurement of the predictor variables (PsyCap, well-being and safety leadership behaviours) in informant rating, and complete the measurement of criterion variable (e.g. safety climate) in self-rating. This procedure can help minimize but obviously does not eliminate this limitation. Yet, some organisational research methodologists have recently argued that the threat of common method biases may not be as serious a problem as once expected (Spector, 2006).

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TOWARDS A FRAMEWORK FOR THE MANAGEMENT OF HEALTH, SAFETY AND WELL-BEING ON ADAPTIVE-RETROFIT PROJECTS IN GHANA

Frederick Owusu Danso[6], Edward Badu[7] Divine Kwaku Ahadzie[8], Gabriel Nani[9], Patrick Manu[10]

[1]*Building Technology Department, Takoradi Polytechnic, Takoradi, Ghana*

[2]*Collage of Architecture & Planning, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[3]*Centre for Settlements Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[4]*Building Technology Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[5]*Department of Architecture and the Built Environment, University of the West of England, Bristol, UK*

Adaptive-Retrofit Projects (ARPs) face the challenge of wide-adoption due to health and safety (H&S) issues surrounding ARPs. In developing countries like Ghana, this challenge exists alongside other challenges such as outdated and inadequate H&S legislation which do not provide adequate guidance for the safe execution of new builds let alone ARPs. As ARPs are mostly executed in confined areas, are characterized by: uncertain structural integrity of the buildings or structures concerned; hazardous and toxic substances (which are difficult to observe and evaluate); and highly labour intensive activities, the health, safety and wellbeing of workers on ARPs generally tend to be more difficult to manage. In the context of the Ghanaian construction industry, safe management of ARPs is even more serious given the numerous problems and challenges the industry faces. As ARPs become common in Ghana, fatal and non-fatal accidents are likely to occur and even escalate further. Therefore, providing some guidance to help manage the H&S issues regarding ARPs will help to protect workers from accidents/injuries and thereby also encourage wider adaption of older buildings in Ghana. To this end, this study through a review of H&S literature makes the case for research to be undertaken to develop guidance framework for managing H&S on ARPs in Ghana. The study also proposes the Delphi method as being a suitable method of inquiry to be used in undertaking the research. It is envisaged that embarking on this research would help bridge the gap of the dearth of literature on H&S management on ARPs especially in the context of developing countries.

Keywords: adaptive, health & safety retrofit.

[6] ofreddanso@yahoo.com

INTRODUCTION

The issue of wide adoption of ARPs, under various themes such as economic, social and environmental viabilities, has been championed by many researchers such as Gallant and Blickle (2005), Bullen (2007), Langston et al. (2008), Adeyeye et al. (2010), Bullen and Love (2010), and Bullen and Love (2011) . Notably, one problem confronting wider adoption of ARPs has been the issue of health and safety (H&S). As part of achieving a wider aim of developing health and safety (H&S) guidance for safe execution of ARPs, this paper presents an overview of the research work. It starts with the research background which underscores the need for in-depth study into H&S on ARPs in the Ghanaian context. It then proceeds to argue for the need for a guidance framework to help manage health and safety on ARPs. This is followed by the key objectives of the study and the proposed research method.

RESEARCH BACKGROUND

ARPs is an area within the construction industry with a potentially viable benefit of increasing the functional life, quality and aesthetics of existing buildings, and reduction of pollution, carbon emissions, material use and cost (Balaras et al. 2007; Bullen 2007; Langston, Francis K W Wong, et al. 2008; Ravetz 2008; Bullen & Love 2011; Ma et al. 2012; Roper & Pope 2014). Regardless of these benefits, ARPs face the problem of wide adoption because of health and safety issues surrounding it (Bullen & Love 2010; Bullen & Love 2011).

Typically, ARPs involve old existing buildings being subjected to a range of activities including: partial demolishing and rebuilding; installation of new internal systems to replace outdated ones; introduction of new components, element or services which were not originally part of the existing old building; and extensions of parts or improvement of parts of existing buildings. Adeyeye et al. (2010), and Bullen & Love (2011a) classified those ranges of activities and called them the aggregation of refurbishment, renovation, rehabilitation and repairs and maintenance work (4R+M) being applied to old existing buildings to assume different functions other than their original use. Thus, Adeyeye et al (2010) and Bullen and Loves' (2011a) classification seems to suggest that refurbishment, renovation, rehabilitation and repairs and maintenance works are the key activities of ARPs.

Anumba et al. (2004) mentioned that, refurbishment works alone in the UK construction industry accounts for about 40.6% of the total number of construction fatalities. This huge percentage of fatalities has been linked to the fact that, the hazards during refurbishment are more uncertain and hence difficult to observe and evaluate (cf. Egbu, 1999; Anumba et al., 2006). Like refurbishment work, repairs and maintenance share similar attributes and are also hazardous operations responsible for 43% of construction accidents in the UK (Anumba et al., 2004). Indeed, as indicated by Hon et al. (2010), the accident ratio of 4R+M to the construction of new buildings (NB) has significantly increased from 17.9% in 1998 to 50.1% in 2007 in Hong Kong. Comparatively, fatal cases from 4R+M works in 2010 increased to 66.7%, while non-fatalities accounted for 44.7% in 2011 (Hon et al., 2014). The compelling factors accounting for these huge fatalities could be linked to the numerous constraints faced by ARPs. These include insufficient structural safety data, uncertain condition of

equipments, unknown accumulated gases, and limited time required to convert old existing buildings to another use, and limited competing space within the old buildings during the activities of structural changes and the replacement or the changing of outmoded equipment (Sanvidoet et al 1991; Bullen, 2007; Adeyeye et al, 2010). Due to the large construction fatalities and numerous constrains associated with ARPs, ARPs are clearly more dangerous than new builds and this is partly responsible for the reluctance by some construction professionals, clients and constructors to fully embrace ARPs (Anumba et al 2004; Bullen and Love, 2010&11; Adeyeye et al, 2010; Zhenjun et al, 2012; Ray, 2014).

It is very significant to note the ARPs suffer from a dearth of literature on occupational health and safety (OH&S). In the main, the extant literature appear to only caution and highlight the significance of H&S on ARPs without providing much detailed analysis of key issues and guidelines on H&S for safe execution of ARPs. For example, Xu et al (2012) through fuzzy theory identified eight key performance indicators (including a health and safety indicator) that require consideration when adapting old hotel buildings in China. The performance indicator, comprising of the safety of the structure, construction workers and the occupants, was seen as a major key indicator. In order of importance, the H&S indicator ranked third ahead of other indicators such as energy consumption, resources saving, and stakeholders' satisfaction. A study into barriers to ARPs by Bullen and Love (2011) indicate that, the inherent structural risk and uncertainty are the key elements preventing the adaption of existing old buildings in Australia. Langston et al (2008) in their study on ARPs in Hong Kong investigated how adapted old buildings could comply with current H&S standards and legislations since ARPs sometimes involve heavy structural changes. Langston et al (2008) cautioned the importance of undertaking structural survey and construction quality checks during adaptive-retrofitting of old buildings to ensure the safety of workers, materials and plants on sites. Meanwhile, Hon et al. (2014) has also cautioned the urgent need of practitioners to develop an appropriate safety rules and clear practices for ARPs works to enhance safety performance of ARPs in Hong Kong. From the findings of these researchers, a conclusion can conveniently be drawn that health and safety is vital in ARPs.

Although comprehensive H&S measures exist for safe management of new work/construction, the H&S literature shows that these measures alone are not sufficient enough to safely manage ARPs. For example, Quah, (1988), asked 46 refurbishment contractors to compare the level of risk involved in executing refurbishment projects to new building projects. Quah, (1988) reported that 42 (91.3%) out of the 46 refurbishment contractors, were of the view that works involving refurbishment are of greater risk than new build projects. Following this, Egbu (1999) concludes that, special H&S knowledge and skills are required by refurbishment managers in other to undertake refurbishment work. Special H&S knowledge and skills are important to all managers of refurbishment works because, as noted by Egbu (1999), refurbishment works are dangerous and most often than not, involves demolition work and disposal of hazardous substances such as asbestos and lead which, certainly, are not found in new builds. Recent studies on the H&S impact of construction project features (cf. Manu, 2012; 2014) also provides insight of how demolition, refurbishment and new work potentially influence accident occurrence on construction sites. Manu et al., (2014) report demolition and refurbishment as having a higher potential to cause harm to workers. In terms of the likelihood of occurrence of

harm (i.e. the risk of harm), Manu (2012) also reported that demolition and refurbishment are associated with a higher risk than new builds/works. Given that H&S control measures are supposed to be proportionate to the extent of risks (HSE, 2000; 2007), it is then clear that the H&S control measures that are needed for ARPs cannot simply be exactly the same as the controls used on new works. Rather the controls that are used on ARPs should reflect the kinds of H&S risks/issues that workers are likely to be exposed to and thus ARPs will need some extra H&S guidance to deal with H&S issues.

In Ghana, just like many other countries , a significant number of old buildings exist waiting to be upgraded to assume different functions from their original use and to reduce energy use, pollution, carbon emissions, material use and cost (Farvacque-Vitkovic et al, 2008; Dauda, 2011). ARPs in Ghana is much more seen as inclusion of new buildings or parts of buildings to existing old buildings and the addition of components, elements and new systems to the existing old buildings which were originally not part of the design (Dauda, 2011). However, due to the numerous problems faced by the industry such as poor worksite safety management, the use of labour intensive construction methods, and inadequately trained workforce coupled with the inadequate and outdated health and safety legislation, the industry lacks specific guidance (Oppong & Masahudu, 2014) for the safe management of ARPs.

In Ghana, statistical data on construction injuries (fatal and non-fatal) on ARPs barely exist. However, the reported construction injuries for new buildings/works (NB) are becoming alarming year on year. For example, it is on record that NB recorded 902 accident cases comprising 56 fatalities in 2000 and 846 non-fatal accidents (Laryea et al. 2010, Danso, 2005). According to Danso et al. (2010, 2011, 2012), Kumasi (the regional capital of Ashanti Region, Ghana) alone recorded 160 construction fatalities from 1998 to 2008 (see Figure 1). Judging from this, it is thus not surprising that there is the view that the application of 4R+M to existing old buildings in Ghana is likely to further worsen injury statistics unless adequate safety guidelines are provided. This is an urgent concern as ARPs are likely to become more common in Ghana due to the need for more construction activity in the country in order for it to bridge its longstanding infrastructure and housing deficits (Ahadzie et al., 2004; Bank of Ghana, 2007).

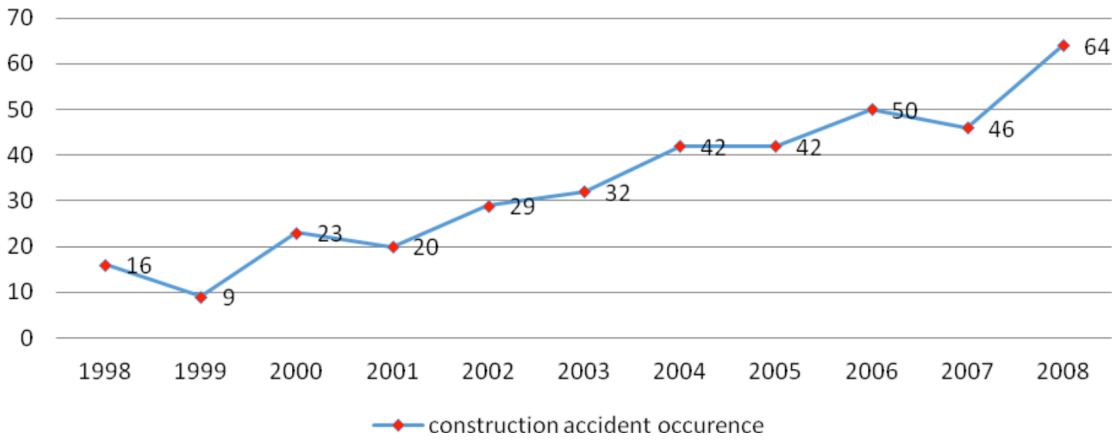

Figure 1: Number of Fatal Injuries in Kumasi (Danso, 2010)

TOWARDS A H&S MANAGEMENT FRAMEWORK FOR ARPS IN GHANA

In Ghana, a large number of old existing buildings are waiting to be upgraded to assume new functions or improve their existing functions. Unlike new builds, where safety guidelines and measures abound in literature, the same can generally not be said for ARPs (Hon et al. 2014; Bullen & Love 2010). This presents serious occupational H&S challenges for the industry as the industry is even struggling to keep up with H&S on new builds. As presented above, the different kinds and levels of H&S issues/risks that are associated with ARPs do not simply enable ARPs to use exactly the same H&S measures that are used on NB (Oloke, 2012; Adeyeye et al., 2010; Bullen & Love, 2010). There is thus the need for customisation or development of safety measures for ARPs to complement the existing measures that are used for NB.

Within the intense need for safe execution of ARPs, Hon et al. (2014) campaign for the development of measures or tools to enable safe management of ARPs. Such measures or tools, rather than being simply copied or transposed from practices in developed countries to the Ghanaian context, they have to be carefully developed or adapted in a joined-up way through research, such that they map unto the project life cycle to provide a coherent and a unified framework that offers guidance for dealing with the H&S issues associated with ARPs. Direct copying or transposing measures or tools from developed contexts will not be the way to go as there are some differences, for instance in the level of technological development between these contexts. As an example, whereas construction operations are highly mechanised in the developed contexts, in developing countries such as Ghana, construction operations are highly labour intensive and hence the degree of exposure of labour to H&S hazards (which are more common on ARPs) is far greater.

Central to developing a H&S management framework for ARPs in Ghana is firstly the identification and categorization of the relevant H&S issues or factors that come into play. Subsequently, the establishment of the relative importance of these issues or factors and the identification of adequate mitigation steps to be undertaken by relevant project parties at various phases of a project is also important. Collectively, these represent the cardinal points to be addressed by this research work. The key questions that need answering are thus:

What are the typical health and safety issues or factors relating to ARPs in Ghana?

What is the relative importance of these issues in terms of the extent of their potential impact on the H&S of workers on ARPs?

How can these issues be resolved throughout the lifecycle phases of ARPs?

To answer the above questions, the following objectives are to be pursued by this research:

- identify, categorize and present health , safety and wellbeing issues or factors that affects workers on ARPs;
- identify potential control or mitigation measures for those factors or issues that influence the safety, health and wellbeing of ARPs workers;

- implement a suitable method for investigating the H&S issues that are relevant to Ghanaian context, their extent of impact and their relevant mitigation measures;
- integrate the findings from the above investigation into a H&S management framework for ARPs in Ghana; and
- evaluate the usefulness of the framework from the perspective of industry practitioners

OUTLINE OF PROPOSED RESEARCH METHOD

To meet the set objectives of this research, two research tasks are planned. The first is to review literature and the second is to apply a Delphi technique. This is diagrammatically presented in Figure 2. The research will begin by reviewing literature (see Figure 2) from academic journals, research reports, theses, etc. with the prime focus of:

- identifying and compiling a comprehensive list of H&S factor/issues that come into play on ARPs;
- identifying and compiling a comprehensive list of control/mitigation measures that correspond to the identified H&S factors/ issues; and
- Mapping the list of factor/issues and their corresponding control/mitigation measures onto the phases of project life cycle with an indication of the various project parties who are/should be concerned with addressing those H&S factor/issues.

The literature review will thus address objectives 1 and 2 of this research work. The third (3) objective will be achieved through the application of a Delphi method. The Delphi method is an iterative process used to collect and distill the judgments of experts using a series of questionnaires interspersed with feedback (Skulmoski et al., 2007). The method can also be used when there is incomplete knowledge about a problem that does not lend itself to precise analytical techniques but rather could benefit from the subjective judgments of individuals who have a wealth of expertise/knowledge about the problem area (Adler and Ziglio, 1996; Delbeq et al., 1975). As ARPs are relatively less common in Ghana compared to NB, fewer construction professionals are expected to have expertise or knowledge about their execution and hence the H&S issues involved. ARP execution in Ghana is thus expected to be characterized by limited knowledge and expertise amongst professionals. In view of this, it is prudent to use a Delphi method as this method enables the use of the collective judgment of experts in investigating such phenomena or problems (that are characterized by limited insight) and coming up with workable solutions (see Adler and Ziglio, 1996; Delbeq et al., 1975). The application of Delphi method in construction management research and more specifically H&S studies is not uncommon (see Chan et al. 2001; Yeung et al., 2007; Hallowell, 2009; Hallowell and Gambatese, 2010). This also reinforces the suitability of the Delphi method for this research.

In applying the Delphi method, a team of construction professional who have expertise regarding execution of ARPs in Ghana will be assembled to participate in two or more rounds of Delphi surveys. This is to obtain the opinion of these experts

towards the development of the framework for the management of health, safety and well-being of workers on ARPs in Ghana. The experts will ascertain the relevance of the H&S factors/issues and their mitigation measures (which will be identified from the literature review) to the Ghanaian context. Beyond that they will also contribute to the research process by identifying H&S factors/issues and mitigation measures which may not be apparent in the extant literature but are applicable to the Ghanaian context.

The Delphi method is thus to be applied in 2 main facets. In the first facet, the experts' judgement will be collected and distilled by the use of questionnaire interspersed with feedback to reach a reliable consensus of opinion on:

- The relevance/applicability of the identified H&S issues/factors to ARPs in the Ghanaian context; and
- The relative importance of the H&S factors/issues in terms of the extent of their H&S impact on workers.

In the second facet, experts will be required to judge the relevance/applicability of the mitigation/control measures identified from the literature to ARPs in Ghana. In both facets 1 and 2, the iterative nature of Delphi technique permits the generation of new information for re-examination and modification of judgments. By this, each expert is encouraged to review the anonymous judgments of the other experts and reconsider the previous response. The purpose during this process is to reduce the level of inconsistencies of responses to attain group consensus of opinion. The process will stop after the most reliable consensus of opinion is met and a statistical aggregation of the responses in the final round will determine the final results (Delbecq and Gustafson 1975; and Skulmoski et al., 2007; Hallowell & Gambatese, 2010).

To achieve the fourth objective, the filtered results of H&S factors/issues and mitigation measures for ARPs in Ghana will then be amalgamated into a framework for the management of the health, safety and wellbeing of workers on ARPs in Ghana. The framework will then be presented to practitioners to obtain an evaluation of its practical usefulness/relevance.

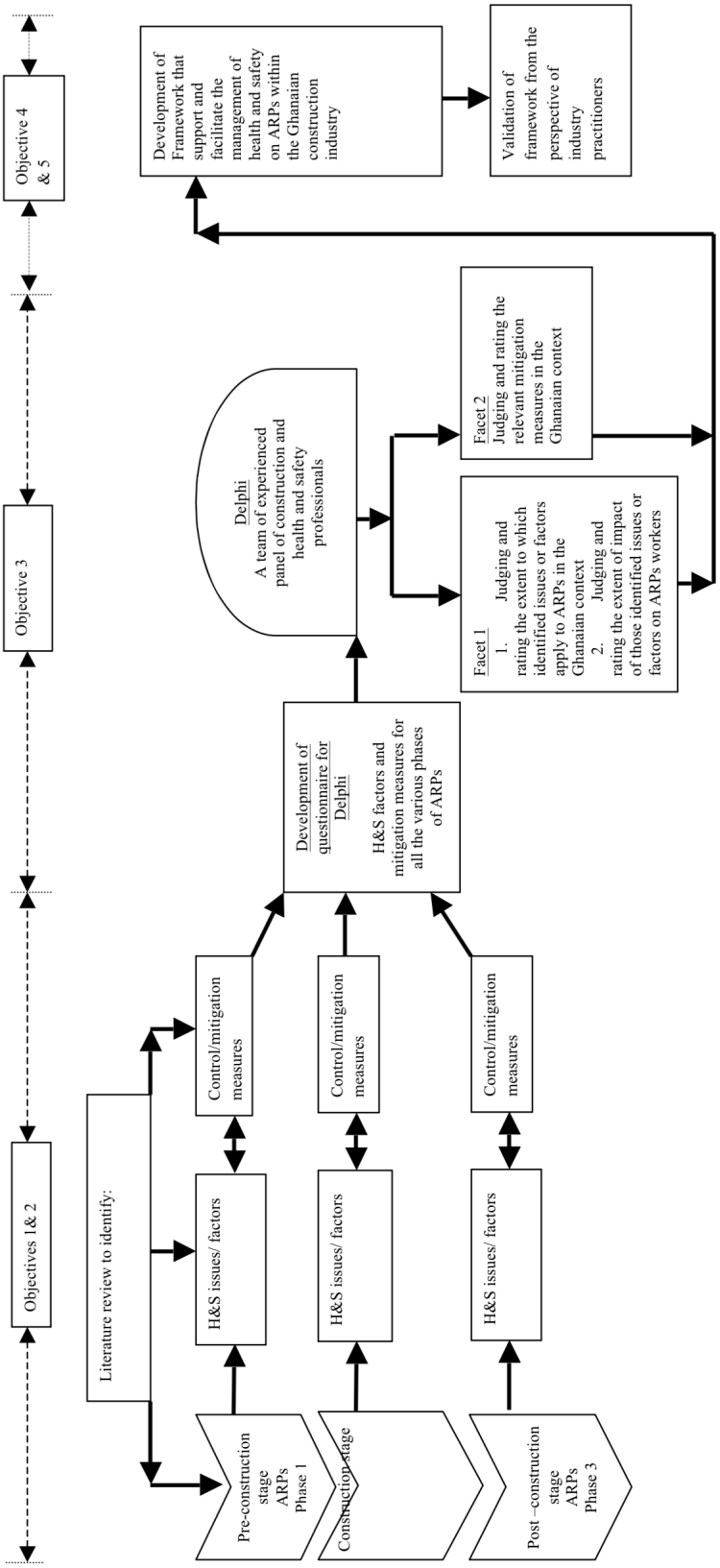

Figure 2 A diagrammatic presentation of a proposed research method

CONCLUSIONS

It is clear that quite apart from the derived benefits, ARPs is challenged with wider adoption. Inference is that the H&S issues surrounding ARPs have not been wholly addressed. In Ghana, just like other developing countries, this challenge is present alongside outdated and inadequate H&S legislation which do not provide adequate guidance for the safe execution of new buildings let alone ARPs. Within the Ghanaian context, the application of 4R+M to existing old building is likely to further aggravate the injury statistics especially when Ghana is bridging its infrastructure and housing deficits. Through research, rather than copying practices from developed contexts, this paper argues for the development and provision of coherent and unified safety guidelines in the form of a framework for the safe execution of ARPs in the Ghanaian construction industry. Delphi method has been proposed as the way to go for such a research. It is envisaged that embarking on this research would help bridge the gap of the dearth of literature on H&S management on ARPs especially in the context of developing countries like Ghana.

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