WHO IS 'THE DESIGNER' IN CONSTRUCTION OCCUPATIONAL HEALTH AND SAFETY?

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In countries of the European Union, and now in Australia, OHS legislation establishes specific responsibilities for construction design professionals. Accordingly OHS duties are established for 'The Designer.' The ascription of responsibility to the occupant of an abstract socio-technical role is problematic. In reality, construction design is a complex iterative process that is influenced by human and non-human agents extending well beyond the project architect and engineer. This paper analyses definitional problems associated with the term 'The Designer' in the context of modern building design. A socio-technical systems analysis is presented for one case study construction project. This case study is used to illustrate that simplistic ascriptions of OHS responsibility are unhelpful and likely to be counter-productive to advancing the Construction Hazard Prevention through Design concept.

Keywords: construction hazard prevention, design, occupational health and safety, socio-technical system.

INTRODUCTION

Occupational health and safety in construction

The Australian construction industry accounts for 9% of the Australian workforce but, in 2008–09, accounted for 11% of all serious workers' compensation claims, equating to 40 workers per day requiring one or more week off work due to injury or illness. In 2008-09 construction recorded more fatalities than any other industry and the fatality rate (5.9 per 100,000 employees) was more than twice the rate for all industries (SafeWork Australia, 2011). The potential for OHS improvement to be achieved by considering OHS impacts early in the lifecycle of construction projects, particularly in the design stage, has been empirically demonstrated and is now a well established feature of industry policy and OHS legislation (Manuele, 2008; Creaser, 2008). In Australia, the National OHS Strategy 2003 – 2012 identifies "eliminating hazards at the design stage" as one of five national OHS priority areas. OHS responsibilities for construction design professionals are included in the Safe Work Act 2009 (Model Safe Work Provisions), which underpins the current push towards national harmonisation of Australian OHS legislation.

Designers make choices (either implicitly or explicitly) which can significantly impact upon the OHS of those who build, occupy, maintain, clean, renovate, refurbish or eventually demolish a building/structure (Gambatese *et al.*, 2008). The adoption of

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'Construction Hazard Prevention through Design' (CHPtD) principles into government and industry policy is founded upon a substantial body of research linking design in the construction industry with OHS outcomes. Gibb *et al.* (2004) estimated that OHS risk could be reduced by a change in the permanent design of a building/structure in 49% of construction injuries. Behm (2005) identified design as a cause in 42% of construction workplace deaths. Using data recorded in the Australian National Coronial Information System, Driscoll (2005) analysed work-related deaths in Australia between 1 July 2000 and 30 June 2002, concluding that 18 (44%) of deaths in the construction industry were 'design-related'.

Critics of the CHPtD concept argue that research fails to distinguish between different 'design' activities involved in the building industry, confusing design of the building/structure for its intended end use with design of the site layout, the process of construction or an item of plant/equipment being used or installed (AIA, 2008). The appropriateness of ascribing responsibility for construction OHS to the occupant of an abstract socio-technical role, i.e., 'the designer' has also been questioned. For example, Lingard *et al.* (2007) suggest that ascribing responsibility in this way fails to reflect the structure of the construction industry and/or the complexity inherent in the design process. Specifically, these failures concern: 1) the structure of work (collaborating parties); 2) the structure of information (knowledge transactions); and 3) the structure of governance (contractual arrangements) actually in place within projects.

1) The structure of work

Construction design work is characterised by a complex web of inter-organizational relationships. Inherent in the structure of design work is a division of labour in which different parties work in a highly interdependent manner. Design decision-making is iterative and the design decisions relating to each sub-system of a building/structure are not independent, but inter-related in complex ways. Arguably, simplistic ascriptions of responsibility for OHS do not adequately distinguish between design functions (i.e, what is being designed) and do not acknowledge project-level variations in the degree of practical influence of the multiple parties involved in design decision-making.

2) The structure of information

Construction design work is characterised by multiple information exchanges, information dependencies and 'feedback loops.' Frequent interactions between different specialists are necessary to ensure that the components of a building/structure are compatible and exchanges of information between multiple contributors to the design of a building/structure play a critical role in shaping decisions that are eventually made. The extent of information exchange, evidenced by the analysis of four typical building designs, revealed that the building design process comprised between seven and ten iterative loops each comprising between five and 30 interrelated loops. The number of design tasks was around 350-400 and the number of information dependencies was over 2400 (Austin *et al.* 2000).

3) The structure of governance

The role played by different contributors to the design of a building/structure is influenced by the project delivery mechanism selected and the contractual roles and relationships established between the parties. For example, the ‘design and build’ approach provides a natural opportunity to address OHS in design, while the ‘construction management’ approach arguably allows the client/owner to play a more aggressive role in project decision-making (Gambatese *et al.* 2005). Thus, from a practical perspective, the extent to which project participants are able to influence CHPtD outcomes will vary from project to project on the basis of the delivery mechanism and structure of contractual relationships governing the project.

Defining 'the designer'

Legislation establishing responsibilities for CHPtD attempts to define 'the designer' in fairly broad terms. For example, according to the UK Construction (Design and Management) Regulations (2007), a "designer" means any person (including a client, contractor or other person referred to in the Regulations) who:

(a) prepares or modifies a design; or

(b) arranges for or instructs any person under his control to do so.

Any person who in the course of their work engages in either of these activities must attempt to reduce the level of foreseeable risk to people who will carry out the construction work. Under the CDM Regulations (2007) designers are also required to provide sufficient information about aspects of the design of the structure or its construction or maintenance to clients, other designers and contractors. In Australia, WorkSafe Victoria defines construction designers in inclusive terms, stating that designers may include:

(i) architects or building designers or draftspersons who undertake the design on behalf of the clients, including conducting a feasibility study, producing a schematic design or preparing construction documentation or tendering, depending on the contractual arrangement; and/or

(ii) other designers who participate in the design or make decisions during any of the project phases. These may include: engineers; interior designers; industrial designers; and contractors who design parts of the building or structure.

The difficulty with the definitions of the designer embodied in OHS legislation and guidance material is that they do not adequately reflect the fact that construction design is a complex socio-technical system.

In the context of design work in the construction industry, attempts to specify OHS responsibilities for different professional contributors to design decisions have proven difficult. Further, attempts to superimpose a linear and structured CHPtD risk management process on construction design decision-making have also been problematic (see, for example, the Guide to Best Practice for Safer Construction). This is arguably because the traditional 'decomposition' approach that underpins most OHS and risk management methodologies is not a suitable model for the management of decision-making in complex, nonlinear, dynamic socio-technical systems.

Pavard and Dugdale (2006) suggest that complex systems have a dynamic structure and limited functional decomposability. This means that it is difficult to study the properties of a complex system by decomposing it into its functional parts. In the case of design work in construction it is difficult (if not impossible) to decompose system elements into design functions, professional contributions or logical 'steps' in the design process because these are in permanent interaction with one another and facets of the external environment. It is this interaction that enables self-organisation, which creates emergent properties that an understanding of individual component parts may not permit one to identify or anticipate.

Given the difficulties experienced in the practical implementation of CHPtD within projects, a case can be made for CHPtD research to explore more sophisticated explanatory models for the way in which decisions with the potential to impact upon construction workers' OHS are made by designers (as well as other parties whose decisions influence design outcomes). A socio-technical systems approach to investigating CHPtD in construction projects may help to inform the development of CHPtD tools that are based upon a closer connection between industry practice and theory.

Aim

The aim of this research is to explore the way in which design decisions 'unfold' in a construction project situation to produce OHS outcomes for construction workers. The research analyses design decision-making as a socio-technical system to identify the multiplicity of influences and interactions between project participants that impacted upon CHPtD outcomes in relation to one aspect of building design. The purpose of this analysis is to: (i) describe and analyse how CHPtD outcomes are actively influenced and shaped by the interactions between multiple project stakeholders; and (ii) to critically consider the implications of complexity for industry policy and practice relating to CHPtD.

METHODS

Case study approach

The research adopts a case study approach, favoured for the rich causal data that it produces. It encouraged a highly descriptive, in-depth investigation of complexity and the relationships between concepts (Orum *et al.*, 1991; Eisenhardt, 1989; Fellows and Liu, 1997; Yin, 1994). Substantive evidence of the reasons why design decisions were made and how they influenced OHS outcomes on site were collected and 'chains of evidence' constructed within the context of the case.

The research context

Data were collected at a food processing plant located in the outer suburbs of Melbourne, Australia. The plant had been partially destroyed by a fire in January 2010. Originally the client decided that the plant would not be rebuilt. It had been in operation since 1919 and, despite many upgrades and extensions, the plant was of an old design and the client organization had newer, more efficient sites in other locations. However, to prevent the loss of employment in the area, the State Government of Victoria offered substantial monetary assistance to the client to support the re-construction of plant and fast-tracked the planning process to facilitate this. As a consequence of this support, the client decided to re-build the plant and appointed a contractor under a 'design and build' contract to undertake the project. To combat the risk of losing business to competitors during the reconstruction period, the client set an ambitious date for the re-opening of the plant, compressing the design and construction work into a ten month period.

Data collection

Gorse and Emmitt (2007) identify the need to investigate social interaction and communication in 'live' construction projects. In-keeping with this recommendation, the data collection approach adopted involved a number of different methods including: (i) direct observation of project team interactions; (ii) interviews with project actors; and (iii) inspection of artefacts, such as aspects of the physical worksite and project documentation. The ability to observe and record activities as they occur is a valuable tool in the study of human activity in which there may be a difference between ideal and manifest behaviour. For example, Larsson (2007) reports that when asked to describe their behaviour, people tend to give an account closer to the ideal than the manifest.

The researcher attended fortnightly design team meetings at the project site between 27th May 2010 and 13th October 2010 and weekly meetings until 15th December 2010. Direct observation of project participants was followed by a series of interviews designed to explore the meaning that participants attributed to decision-making observed by the researcher during design team meetings. In total 18 project participants were interviewed, including some 'external stakeholders.' Interviews were conducted with, representatives of the 'Design and Build' contractor, the structural engineer, the hydraulic engineer, the project architects, the structural steel subcontractor, the plumbing subcontractor, the concrete subcontractor, the Country Fire Authority (CFA), the specialist fire engineer, the building surveyor and the client. The interviews explored project stakeholders' expectations, motivation and reasoning relevant to design decisions. For the purposes of brevity, only one design aspect is described in this paper. However, for the purposes of demonstrating socio-technical complexity, a single case is acceptable.

The CHPtD 'vignette' described in the next section of the paper provides a rich description of the way in which decision-making was constituted through interactions between the various project stakeholders (i.e, the social subsystem) and technological aspects of the project design and construction (i.e, the technical subsystem).

RESULTS

Fire rating the boning and packing building

Once construction work on the boning and packing building had commenced, following a review by a registered building surveyor, it became apparent that the size of the building exceeded the requirements of the Building Code of Australia (BCA). To satisfy the BCA requirements, as well as the client's preference that a sprinkler system not be installed, it was necessary to 'design in' a fire-rated wall to reduce the size of building compartments. This decision was made once the primary structure was already erected. As the 'Design and Build' contractor's project manager commented: "We were literally putting up a building when we found that our areas were over what we thought they were. Whereas normally you would be in a conceptual design you would see it and stop and evaluate it, whereas having been committed to a building out there, we had to make the decision to put a blockwork wall in."

The original plan was to erect the fire-rated wall using a 'tilt-up' panel method of construction. However the method of constructing the wall was changed to blockwork to allow for penetrations to be more easily made when the building's equipment and services design was finalised. In addition to the building surveyor's concerns about the fire rating of the building, an external stakeholder, the Country Fire Authority (CFA) also became involved. A number of aspects of the building design deviated from the specification standards contained in the BCA, necessitating approval of these design aspects by the CFA prior to granting a building permit. Notwithstanding the designers' decision to construct the building using fire retardant panels, the CFA advised that they would not support the original building design because the design did not provide full perimeter access for their fire appliances.

The project manager was aware that penetrations would need to be made in the blockwork wall at the time of its construction. However, the number, size and location of these penetrations were not known and depended upon information being provided by the equipment suppliers and installation contractors. The project manager commented: "The equipment contractors were direct to [the client] and they were hard to pin down. So we always knew that product had to come through…so this issue has see-sawed back and forth with the issues that we have had with the openings." When the information was provided, the penetrations required were considerably larger than the 600mm² allowed for in the blockwork wall. Not only would this impact on the rework requirements, but it would also impact on the fire integrity of the wall. Work commenced to enlarge the penetrations, presenting specific occupational health and safety risks to workers required to undertake this demolition work. Once the plant was installed, the plant installation contractor advised that the openings in the blockwork wall could have been reduced by 40%. To maintain the integrity of the firewall, the penetrations were in-filled to the recalculated sizing. However, this reconstruction had to take place after the plant was installed and operational, presenting additional OHS risk to construction workers engaged to undertake this work. The construction of the penetrations required that the block work needed to be cut and then flashed with stainless steel to adhere to the food safety regulator's requirements. Whilst the openings where not high in the wall, scaffolding was required to provide access to the area in which the work was being undertaken.

The openings remained a "subject of contention with the fire authorities," who maintained that the blockwork wall could no longer act as a firewall. In the CFA's opinion the building was an oversize single building that required a sprinkler system to comply with the BCA. An assessment was commissioned from a fire engineer who advised that 'fire tunnels' would be required either side of the wall to stop the spread of fire, smoke and heat. The size (or length) of the tunnels needed to be proportional to the size of the openings - the larger the opening the longer the tunnel. However, given the plant that had already been installed, limited space was available for the construction of fire tunnels. The original design for the tunnel required a 2.5 metres length, for which there was insufficient space. A reduction in the size of the openings permitted a reduction in length of the tunnel to 1.8 metres. The construction of the fire tunnel commenced to maintain the project programme in relation to the required date for commencement of production. However, the CFA had not yet approved the design of the fire tunnel. In the event, the CFA did not approve this design, insisting on the installation of a full sprinkler system to the boning and packing building. In order to obtain approval for the building design, the client had to agree to retro-fitting the building with a sprinkler system within a specified period after the start-up of production.

The project manager expressed his frustration: "It was quite difficult to explain to the CFA what the site does and how it works and therefore what the risks are and what the issues are…They don't really understand the operations of the plant in that they see a factory, they think warehouse, they think mounds and mounds of cardboard. That's the perception that I get. In a food processing environment it's mostly stainless steel and mostly non-combustible. It's like there are whole sections of the plant that are at sub zero, or zero…. If we had a lot of time on our hands, if we had had another 12 months then we might have said fine we will take our line and you take yours, because we disagree we go to building appeals. Obviously that would have been a way to resolve that, but we couldn't afford [the delays]."

The late inclusion of a sprinkler system into the design meant that the installation will be retrofitted into what is essentially a finished building. This will present unique OHS challenges as the workers undertaking the installation will need to negotiate existing plant and services located in the ceiling, a confined space. Another area of OHS concern is access to the underside of the ceiling to install the sprinkler heads. Fixed plant and equipment has already been installed in the building, which cannot be easily moved to provide space for access equipment. Further, the production plant is operational, providing only a short window of opportunity to carry out the installation work for the sprinkler system.

DISCUSSION

Multiple stakeholders

The results of this analysis reveal the interplay of influences that impacted upon the design decisions that were made in relation to the food processing facility and CHPtD performance of this design. Design decisions 'unfolded' as project participants and stakeholders interacted with one another. Further, the project participants' interactions with material objects (e.g. the physical aspects of the processing plant and fire protection technologies available to them) also contributed substantially to decisions that were ultimately made. These decisions were instrumental to determining the degree of OHS risk to which construction workers engaged in the construction of the processing plant and the retro-fitting of the sprinkler system that they would ultimately be exposed to.

The quality of CHPtD outcomes in the case was not only influenced by the dynamic interaction of relevant stakeholders 'within' the project, but was also influenced significantly by agencies external to the project, specifically the Country Fire Authority (CFA). The decision process was characterised by considerable uncertainty concerning decisions relating to the fire rating of the boning and packing room. The end product of lengthy interactions between the suppliers of specialist plant and equipment, the project engineer, the CFA, a specialist fire engineer and the 'Design and Build' contractor was a decision to retrofit a sprinkler system into the building once production had commenced. This decision illustrates the way in which OHS hazards can emerge from the complex interaction and articulation of stakeholders' interests and technological artefacts, even after the commissioning and handover of a facility.

These findings are consistent with the argument of Tryggestad *et al.* (2010) who suggest that design decisions should be understood and viewed as the output of collective action. They suggest that design goals should not be viewed as invariant inputs that are established at the commencement of a project and remain unchanged. Rather, design is better understood as a flexible process of engaging in 'trade-offs' to achieve workable solutions to emergent problems. This contingent view of design raises questions about the practical implementation of CHPtD as it is inconsistent with the traditional approach to OHS risk management. In the traditional approach to OHS risk management, OHS hazards are identified at the beginning of a linear process which proceeds through a series of steps including risk assessment and subsequent risk control and review (see, for example, a description of this process provided in Lingard and Rowlinson, 2005). The assumption of this process is that hazards are all clearly identifiable at the beginning of the linear process. Any hazards that are not identified at this step will be excluded from subsequent analysis. Thus, the linear process of OHS risk management is not sufficiently flexible to cope with adaptive decision-making and emergent hazards.

Further, the fact that design decisions (and OHS impacts) arise as a result of the interactions between stakeholders (internal and external), material artefacts and technologies makes it very difficult to ascribe professional responsibility for OHS to the occupant of an abstract socio-technical role. While, at a superficial level it might seem to be quite clear who is responsible for a particular design component based on a formal job description or contractual provision, in practice it is much more difficult to pinpoint responsibility for the OHS consequences of a particular decision. This is because design decisions emerge in a dynamic process as a result of the interaction between multiple social, material and technological inputs.

Implications for CHPtD policy and practice

The importance of the role and influence of external stakeholders suggests that the implementation of CHPtD processes within a single design organization and/or construction project is likely to be of limited effectiveness. Our results also suggest that many of the protocols, procedures and tools available to support the implementation of CHPtD may be unable to cope with the dynamic and contingent nature of design work in the construction context. For example, advocates of BIM, assume that detailed building information models can be constructed at an early design stage and that these models can be used to undertake a comprehensive analysis of the OHS risks presented by a particular design solution. However, this proposed use of BIM technology assumes that highly detailed and stable information about building components is available at a particular assessment point (Toole and Gambatese 2008; Sulankivi *et al.* 2010; Kamardeen, 2010). Although intuitively appealing, there are very real practical difficulties associated with this assumption. The research presented in this paper suggests that design is a dynamic, complex and reflexive process of collective negotiation. In this context, uncertainty prevails and design goals are subject to change. It is imperative that the development of CHPtD management processes or tools take the reflexive nature of design work into consideration and address the issue of how their processes and/or tools ‘fit’ within design work.

CONCLUSIONS

The research highlights the complexity inherent in integrating CHPtD into construction design. The case study reveals complex structures of work, with design decisions 'unfolding' as a result of a dynamic and collective process of negotiation between multiple stakeholders. Thus design solutions emerged as a result of a network of inter-related decisions and outcomes resulting from repeated interactions between multiple stakeholders. Further, social and technological components of the project interacted to shape the design decisions that were eventually made. The case study also reflects complex structures of information, with multiple information exchanges necessary to support decision-making and information 'bottlenecks' arguably preventing the optimisation of CHPtD in relation to the design of the fire protection system. Structures of governance reflecting the roles, authority and and power relations between project participants are also revealed as an important determinant of CHPtD outcomes in this case study. Indeed, issues relating to structures of governance extended beyond 'internal' project stakeholders. The case reveals, for example, the key role played by external parties in shaping CHPtD outcomes through their regulatory authority. Given the socio-technical complexity surrounding construction design, it is arguably problematic to ascribe responsibility for CHPtD to an abstract socio-technical role, i.e., 'the designer.' It is important that policy initiatives and legislation are informed by an improved theoretical understanding of the nature of design practice in construction projects.

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