AN INVESTIGATION OF THE VIABILITY OF ASSESSMENT OF SAFETY RISKS AT DESIGN OF BUILDING FACILITIES IN AUSTRALIA

Patrick X.W. Zou, Faculty of the Built Environment, The University of New South Wales, Sydney Australia

Wilson Y.X. Yu, Faculty of the Built Environment, The University of New South Wales, Sydney Australia

Adam C.S. Sun, Faculty of the Built Environment, The University of New South Wales, Sydney Australia

ABSTRACT

Previous research has identified the design aspect of building facilities as being a significant contributing factor to construction site accidents. The aim of this research is to understand the perception, current practices, barriers and impacts of identifying, assessing and mitigating safety risks at design of building projects. Postal surveys were conducted in Sydney Australia. The research results showed that identifying, assessing and mitigating safety risks at design stage of building facilities is a viable, valuable and beneficial concept. However, the majority of designers (architects and engineers) lacked knowledge of and had not implemented such concept/process. Impacts such as extended time and increased cost were discovered as main concerns faced by designers. Although many respondents were willing to take up the responsibility of addressing safety risks during design, it is evident that there is lack of formal training to address the issue. It was identified that the barriers of lack of understanding potential benefits, and inadequate skills and resources were the major factors precluding designers from carrying out assessment of safety risk at design stage, while liability exposure and the nature of subcontracting was not deemed a significant barrier in implementing the concept, as identified by other researchers.

Keywords: Safety risk, Design evaluation, Building facility, Designing for safety

INTRODUCTION AND RESEARCH AIMS

The construction industries have unacceptably high rates of injuries and fatalities. For example, the workers' compensation statistics indicated that the Australian construction industry's incidence rate was 28.6 per 1000 employees in 2003-4 which was almost twice of the overall industry average of 16.4 per 1000 employees (ASCC 2006a). It also experienced a high fatality rate of 6.5 fatalities per 100,000 employees in 2003-4, which was almost three times higher than the national average for all industries of 2.3 fatalities per 100,000 employees (ASCC 2005). The US experienced similar statistics while situation in China was even worse (Zou et al 2007, and Zou and Zhang 2009). These recent empirical evidences suggest that the construction industries are more unsafe than other industries; and that it is an area needing significant reform if injuries and fatalities are to be mitigated.

The design phase is an important stage in building project procurement. It has an important influence on how the building is constructed. Research (Hadikusumo and Rowlinson 2002, NOHSC 2003 and 2005, HSE 2004, BLL 2004, Wienstein et al 2005, Gambatese et al 2005, and ASCC 2006) has shown that in construction project management, many safety risks may be eliminated or mitigated and opportunities seized at the design stage if proper analysis and assessment is carried out. UK's HSE (Health and Safety Executive 2004) shows 47% of injuries/accidents could have been prevented if proper checks were provided during design stage. The Australia NOSHC's report highlighted the importance of minimising safety risks and maximising opportunities at design stage (NOSHC 2005); Hinze (2005) suggests that consideration of construction workers' safety and practice should be salient at design stage.

According to ASCC (2006), “safe design (aka designing for safety)” is a process defined as the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimize the risks of injury throughout the life of the product being designed (ASCC 2006). It aims at eliminating health and safety hazards and minimizing potential health and safety risks by involving all decision makers that will be involved in the life cycle of the designed product. In particular, it considers design implications in the full life cycle of the designed product and begins at the conceptual and planning phases with an emphasis on making choices about the design, methods of construction and materials to be used which enhance the safety of the designed product. The Australia Safety and Compensation Council (2006) issued “Guidance on the Principles of Safe Design for Work” and the NSW State Government Workcover Authority also provided “CHAIR (Construction Hazard Assessment Implication Review) Safety in Design Tool” in 2001. But the actual implementation of these guidelines and toolkits remains unknown.

Why consider safety risks at design stage?

In addition to the reasons mentioned in the Introduction section, there are four main reasons why safety risks should be assessed and mitigated at design stage of building projects, which are discussed as follows:

Firstly it is a requirement established by Acts and Regulations in many countries. For example, the United Kingdom’s Construction (Design and Management) Regulations (HMSO 1994) requires designers and clients in the UK construction industry to eliminate hazards in design phase in order to make buildings safer to construct, clean, maintain and demolish; the American Society of Civil Engineers (ASCE) states “engineers shall have responsibility for recognising that safety and constructability are important considerations when preparing construction plans and specifications”; in Australia, several states, including Queensland, South Australia, Western Australia and New South Wales, place similar responsibilities on designers (Bluff 2003), such as *Occupational Health and Safety Act* 2000 (NSW) and *Work, Health and Safety Act* 1995 (QLD).

Secondly, in construction project management, many risks could be eliminated (and opportunities created) if proper analysis is carried out at the design stage (ASCC 2006b). According to Australian NOHSC (2003), 42% of the 210 identified workplace deaths definitely or probably had design related issues involved. Likewise, WorkCover NSW indicated that 63% of all fatalities and injuries can be attributed to design decisions or lack of planning (NSW WorkCover 2001). The report by Health and Safety Executive (HSE 2004) shows 47% of the safety injury/accidents could have been prevented if proper checks were provided during the design stage. Zou *et al* (2006 and 2007) claimed that designers should carry out comprehensive investigation of site conditions, articulate the clients’ needs in a technically competent way and within the limitation of the clients’ resource, work collaboratively to develop sound program schedule and cost planning and minimize defective designs

Thirdly identifying and eliminating risks at design stage is a key to effective cost and managerial control (Andres 2002) and many benefits may be achieved, such as improved productivity, avoidance of expensive retrofitting to correct design shortcomings, and significant reduction in environmental damage, and attendant costs (ISTD 2003).

Finally, as claimed by ASCC (2006b), ‘assessing safety risk at design’ provides a number of benefits, including prevention of injury and disease, improving usability of products, systems and facilities, improving productivity and reducing costs.

Current methods in designing for safety (assessing safety risk at design)

A number of different approaches and tools have been identified in the literature review that allows for safety risks to be identified either during the designing process or via a design review process. These processes include design reviews and checklists used to identify safety risks in a design. Designers and engineers in charge of designing should include safety as one of the key tasks during design along with aesthetics, and functionality as the brief (Hinze and Wiegand 1992). Clients also impact on construction safety through their involvement. Gambatese (2000) found

various ways which owners can actively address safety and positively influence project safety performances through: (1) Ensuring that safety is addressed in project planning and design, (2) Assigning safety responsibility during construction, (3) The project characteristics, (4) addressing the selection of safe contractors, (5) inclusion of safety requirements in the contract, and (6) owner's active participation in safety during project execution. Gambatese (2000) further suggested, that to the extent possible, owners through their project representatives, should participate with the contractors in all project safety activities, including but not limited to, new employee orientation, safety meetings, jobsite safety audits and accident investigations, training, and incentive program and other safety related programs.

Barriers for assessing safety risk at design

Despite the importance and benefits of safety design, there are still many barriers for considering safety risks at design stage. According to Hinze and Wiegand (1992), Gambatese (1998), Gambatese (2003), Hecker, Gambatese & Weinstein (2004), and Toole (2004), barriers to implementing "designing for safety" include:

- Weak or absent regulatory requirements for architects and engineers to design for the safety of the construction workers
- Occupational Safety and Health Administration's placement of safety responsibility on the employer (typically the constructor)
- Liability concerns among architects and engineers
- Narrow specialization of construction and design
- Limited availability of safety-in-design tools, guidelines, and procedures
- Limited pre-construction collaboration between the designer and constructor due to the traditional contracting structure of construction industry
- Limited education architects and engineers receive on issues of construction worker safety and on how to design for safety

Research aims

The aims set out in this research are to:

1. Establish the liability and benefits of safety risk identification and assessment tools and processes during design of building projects.
2. Identify current methods, practices, perception and barriers of systematic safety risk management processes used by architects and engineers during design in Australia.

RESEARCH METHOD

Literature review and survey questionnaires are used to achieve the research aims. The method of sampling selection employed in the survey questionnaire was based on Area Sampling and the Random Sampling methods, which is cost effective and easy to implement. 200 samples were chosen to represent the population of concern. The sample size was split in to 6 mutually exclusive segments. In this case, location was used to segment the sample population. The number of samples given to the segments is derived by the assumption that architectural firms are more densely populated in the Sydney CBD area and is less populated as it moves out from the Sydney Metropolitan area. The sample given to each segment is shown in Table 1.

Areas	*Number Sent Out*
Sydney Metropolitan	40
Sydney North	30
Sydney East	30
Sydney West	30
Outer West	20
Sydney South-West	20
Total	200

Table 1: Locations of surveys sent.

The questionnaire was designed to be efficient in conveying the question to the participant and recording data. Relevant literature was referred to when developing the questionnaire, for example, the questions used by Gambatese et al (2005a) was included in this survey. This will allow cross nation comparisons. It is separated into 4 parts: Section 1 aims to identify characteristics of the population of concern, experience and involvement with the concept, and barriers affecting their involvement in assessment of safety risk at design. Section 2 provides participants 6 statements, which relates to the perception of safety risks and changes to design during the design stage to improve overall safety (Questions 1 to 6), and how they perceive each statement. A 5-point Likert Scale ranging between 'strongly agree' and 'strongly disagree' is used to determine the respondent's perception towards the statement. In Section 3, participants were asked a series of 'yes' or 'no' (Questions 7 to 20) questions, which relates to the participant's involvement in identifying risks and modifying designs to improve safety. In Section 4 (ie Question 21), participants were given a list of barriers to assessment of safety risk at design and were asked how they perceive each item by indicating on a 5-point Likert Scale ranging between 'strongly agree' and 'strongly disagree'. While in Question 22, a list of performance characteristics of assessment of safety risk at design were given and respondents were asked how they perceive each item by indicating on a Likert Scale ranging between 'very positive and 'very negative'.

RESULTS AND DISCUSSIONS

Of the 200 surveys sent out to participants, 49 responses were returned, which equates to a response rate of 24.5%. The participants were from a variety of architectural and building backgrounds. The majority (62%) of respondents were from Architectural Consulting Companies while the remaining is made up of a mix of Engineering (10%), Design & Construction (12%), and Construction (16%) (Refer to Table 2). The participants were categorised as architects (47%), Directors (20%), Engineer (19%), Design Consultant (9%) and Others (5%) (Table 3).

It was also noted that their design experience outweighed construction experience in the 'less than 5 year' experience group and the '5 to 10 year' experience group. But from '10 to 30 years' of respondents' expertise lay in the construction experience outweighs design experience (Figure 1).

Firm Type	*percentage*
Architecture	62%
Engineering	10%
Design and Construct	12%
Construction	16%
Others	0%
Total	100%

Table 3: Types of respondents' organisation.

Position	Percentage
Director	20%
Senior Design Manager	0%
Architect	47%
Engineer	19%
Design Consultant	9%
Others	5%
Total	100%

Table 2: Respondents' position.

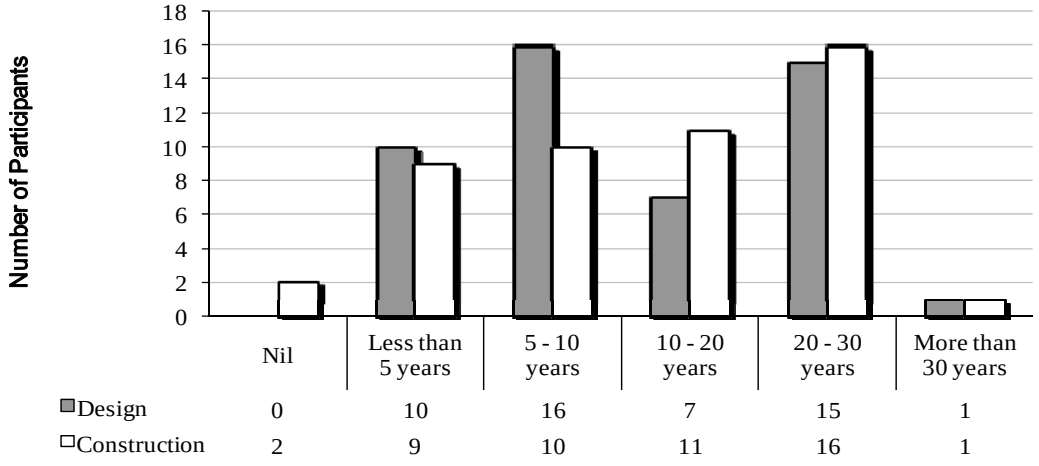

Figure 1: Design/construction experience, years.

Perception on assessment of safety risk at design
The general perception towards assessment of safety risk at design was evaluated using Statements 1 to 6. Table 4 summarises the responses to the perception towards assessment of safety risk at design.

There is a general consensus for participants to understand the concept of assessment of safety risk at design and the associated benefits. A total of 57% of responses agreed that safety issues are easier to identify at the design stage (refer statement 1). In addition, 75% agreed that construction site safety would improve if designs involve the consideration of worker's health and safety (refer statement 2). The data is skewed towards the positive response region, which indicates respondents do acknowledge that site safety can be improved by designing with occupational health and safety in mind. However, it is also of particular concern that 12% of the respondents did not agree with statement 2. It may be due to a number of barriers or limitations that exist when considering designing with safety in mind. We will investigate the barriers of implementing safety risk assessment in later section.

About half (51%) of the respondents perceived the development of appropriate design solutions to be a feasible option in addressing safety risks and potential hazards of a project (statement 6). There was a tendency for respondents to select the neutral category (35%). Design changes made during design stage are perceived to be easier (statement 3, 74%), less time consuming (statement 4, 53%) and more cost effective (statement 5, 63%). This reiterates the benefits of applying safety risk identification and mitigation by making appropriate design changes in the design stage. It also underlines the common perception that changes are more feasible in the preliminary stage where designers have more control over design changes and influence on safety. Statements 4 and 5 also relate to impacts of implementing design changes at design which will be discussed in later section.

Statements	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Statement 1 - "Issues relating to site safety are easier to be identified in the design stage as opposed to the later stage of the project."	12%	45%	27%	14%	2%
Statement 2 - "Site safety can be improved by designing building elements with Occupational Health & Safety for site workers in mind."	22%	53%	12%	12%	0%
Statement 3 - "Design changes can occur relatively easier in the design stage as opposed to the later stage of the project."	33%	41%	10%	14%	2%
Statement 4 - "The time used to resolve design issues are shorter in the design stage as opposed to the later stage of the project."	6%	47%	33%	12%	2%
Statement 5 - "Design changes made in the design stage are more cost effective than in the later stages of the project."	20%	43%	29%	6%	2%
Statement 6 - "Safety risks and hazards can be reduced for the entire project by addressing Occupational Health & Safety issues and developing appropriate design solutions at the design stage."	10%	41%	35%	10%	4%

Table 4: Respondent's perception towards assessment of safety risks at design (n=49).

Knowledge and current practice of assessment of safety risk at design
The aim of this section is to gauge the participant's knowledge and experience on the concept and method of "assessment of safety risk at design" and the feasibility of implementing the concept into practice. These questions used in this section were sourced from a previous study by Gambatese et al (2005a). Table 5 presents the results of Questions 7 to 20.

Knowledge and experience of assessment of safety risk at design
The results show that the majority of participants (65%) have not heard of nor have knowledge of the concept of "assessment of safety risk at design" (refer Table 5 Question 7). Those who have

knowledge of this concept (35%) may be more inclined to include such concepts in their work or seek to build a foundation where additional knowledge and methods can be developed and implemented. This question is significant as it is one of the criteria for designers to implement assessment of safety risk at design. Further to this, 78% of respondents had not had any experience with external consultation in addressing safety risks during the design stage. This reiterates the lack of understanding and awareness of the concept of assessment of safety risk at design. Those who indicated 'Yes' in Question 8 were asked a follow up question: *"How would you describe the experience in relation to your work?"*

The answers showed that about half of the respondents (55%) have had a positive experience with a construction health and safety consultant. There were still 36% experienced negatively. It would be particularly useful to investigate further into the cause of this negative experience. 37% of participants have been approached previously to address construction workers' health and safety (refer Table 5 Question 12), but only half of these requests were addressed (refer Table 5 Question 13). Those who had not addressed construction worker's health and safety in the design stage may not have been equipped with the knowledge and skills to do so. This is evident in Question 16, where a majority of respondents (76%) had not been formally trained to address construction worker health and safety. This may have considerable implications where training can be improved in the area of design with the consideration of human activities required to construct a building. Additional coaching and exposure to the concept would assist in developing the knowledge needed to perform safety risk identification and assessment. Respondents who did not perform such task may also feel that it is not an area within their scope of expertise, or may not understand the value of addressing on-site safety.

A majority of participants (67%) were comfortable in discussing issues regarding construction workers' health and safety issues during the design stage (Table 5 Question 14), and it is shown in Question 20, where 71% of participants were willing to address safety issue at the design stage. This result is a positive step in encouraging designers to implement assessment of safety risk at design.

Questions	*Yes*	*No*
7. Have you heard of the Design for Safety Concept?	35%	65%
8. Have you ever worked with or hired a construction health and safety consultant in design phase?	22%	78%
10. Have you ever, made design decisions that improved construction worker's healthy and safety?	47%	53%
11. If yes to question 10, do you have a formal process to follow that allows for consideration of construction worker's health and safety?	9%	91%
12. Have you ever been asked to address construction worker's healthy and safety in the design stage?	37%	63%
13. If yes to question 12, did you actually carry out such task?	50%	50%
14. Do you feel comfortable talking about construction worker's health and safety issues at design stage?	67%	33%
15. Have you made any design modification in the design stage to eliminate a potential safety risk that would impact construction worker's health and safety?	51%	49%
16. In your formal education and training, have you had any coursework that addressed construction worker health and safety?	24%	76%
17. Besides your firm, if applicable, are you aware of any design firms that address construction worker's health and safety? If yes, please name	0%	100%
18. Do you believe that addressing construction worker's health and safety in the design stage will increase your liability exposure?	10%	90%
19. Do you believe that the nature and culture of the construction industry precludes you in any way from addressing construction worker's health and safety in design stage?	33%	67%
20. Are you personally willing to address construction worker's health and safety in design stage?	71%	29%

Table 5: Knowledge and current practice of assessment of safety risk at design.

Design decisions and modifications to improve safety
The results show that half (53%) of respondents had not made design decisions improving construction workers' health and safety (refer Table 5 Question 10). Although majority of respondents agree that addressing safety issues during the design stage can reduce safety risks and hazards, as indicated previously, fewer respondents have taken actions to actually improve the health and safety of construction workers. One reason may be that respondents do not know how to implement or apply such concept in to practice. Further to this, participants were assessed whether they have made modifications to designs in eliminating safety risks and hazards, and the results showed that 51% conceded that they have carried out such task (refer Table 5 Question 15). The results show that 91% of respondents do not have formal process to address safety issue in the design stage.

Impacts of implementing assessment of safety risk at design
The impacts associated with the implementation of assessment of safety risk at design were tested in Question 22 in the survey. The results are shown in Table 6.

Impacts	*Very Positive*	*Positive*	*Neutral*	*Negative*	*Very Negative*
Safety	18%	65%	16%	0%	0%
Cost Saving	6%	27%	47%	18%	2%
Quality	8%	24%	67%	0%	0%
Productivity	4%	39%	24%	31%	2%
Time	4%	31%	22%	41%	2%

Table 6: Impacts of implementing assessment of safety risk at design.

The results showed that safety performance improvement could be greatly impacted through the implementation of safety risk assessment during design (83% positive response). The next performance characteristic may be affected is quality improvement. Although the data shows 67% neutral response to the increase of quality improvement, there is a 33% response to a positive increase in quality. It is difficult to argue a direct link between safety and quality, but it may be suggested that due to the increase of safe work ethics, less mistake may be produced and thus the increase in quality. Cost saving improvement shows a 33% positive response and a 20% negative response. However, the result shows a 47% neutral response. Thus, it is perceived that cost saving performance has minimal implications when safety risk assessment is implemented. The result for productivity improvement received 43% positive response, 33% negative and 24% neutral responses. Comparing both the negative and positive responses, it is perceived that productivity may be improved. The result of time performance improvement shows 43% negative response compared to 35% positive response. This could be due to more time is required during the preliminary phases of designing, reviewing and evaluating possible design rectifications and solutions.

Barriers to implementing assessment of safety risk at design
Barriers identified in literature review were tested in Question 21 of the survey questionnaire. Participants were asked how they perceived the given barriers in implementing assessment of safety risk at design.

Table 7 summarises the responses.

The major barriers identified in the survey are as follows: 59% of respondents are lack of understanding of potential benefits and agreed that it is a barrier for them. 49% respondents agreed that inadequate skills and knowledge is another barrier to implementation. This reinforces the fact that training and/or formal education is lacking in this area. About half (51%) of the respondents agreed that inadequate resources is a cause of failure to implementation. To date there is no formal system or process in place allowing designers to identify and improve construction safety during the design stage. Insufficient time accounts for 45% of responses. Increase cost accounts for 39% of responses.

Barriers	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Inadequate Resources	8%	43%	27%	18%	4%
Lack of Understanding of Benefits	18%	41%	16%	20%	4%
Inadequate Skills & Knowledge	10%	39%	35%	20%	2%
Insufficient Time	14%	31%	31%	22%	2%
Increased Cost	6%	33%	41%	18%	2%
No evidence to Support Theory	2%	20%	39%	33%	6%
Negative Attitude towards Change	6%	10%	49%	29%	6%
Fear of Increasing Liability	2%	10%	35%	47%	6%
Nature of Subcontracting	2%	29%	24%	39%	6%

Table 7: Barriers to implementing assessment of safety risk at design.

CONCLUSIONS

The primary aim of this research was to understand the current practice and limitations of safety risk identification and assessment during project design phase, in the Australian construction industry. This was achieved by wide coverage questionnaire survey, which seeks to gauge the perception, knowledge, practice/experience, barriers, and impacts of implementing identification, assessment and mitigation of safety risk at design stage of building projects.

The research results indicate that a majority of designers have no knowledge about assessment of safety risk at design, and thus are not equipped to perform such task. This is due to a general lack of information, guidelines, and formal training available on this concept, and the fact that is has not become a mainstream process throughout the construction industry. Impacts such as extended programme time and increase cost were discovered as major concerns of designers in Australia. The major barriers identified were lack of understanding of the potential benefits, inadequate skills and resources. Despite these barriers, the participants were judged to be knowledgeable in the fundamental aspects of the concept and are willing to address construction safety issues during design. Assessment of safety risk at design is a valuable and beneficial concept that can help mitigate safety risks in a project. Understanding the values and benefits should be the first step into overcoming the fear in implementing the concept.

Promotion and additional research of the concept as well as the associated benefits would help in shifting the mindset of designers and clients and build the knowledge and acceptance of this concept. Training and education will help overcome the barriers of inadequate skills, knowledge and resource. While insufficient time and increased cost is seen as a concern to most clients and architects, it is a variable that can impact the project both positively and negatively depending on how it is controlled by the people in control.

The areas of focus for future research should be the development of implementation strategies for conducting assessment of safety risk at design and validation of the effectiveness of these strategies. This should be done in accordance with the relevant Guidelines, Principles and Toolkits set by the Federal and State Governments and Professional Bodies.

REFERENCES

Andres, R.N., (2002), Risk assessment & reduction: A look at the impact of ANSI B11.TR3. *Professional Safety*, 47(1), 20-26.

Australia Safety and Compensation Council, (2005), *Information sheet - Construction*, viewed 18 Oct 2006, http://www.ascc.gov.au/ascc/AboutUs/Publications/StatReports/.

Australian Safety and Compensation Council, (2006a), *Guide on the principles of safe design for work, health and safety*, Australian Government, Canberra.

Australian Safety and Compensation Council, (2006b), *Compendium of worker's compensation statistics 2002-2003*, Australian Government, Canberra.

Australia Safety and Compensation Council, (2006c), *Guidance on the principles of safe design for work, May 2006*, Australian Government, Canberra.

Australian Safety and Compensation Council, (2007), *Information sheet, Construction*, Australian Government, Canberra, pp. 1-2.

Biggs, H.C., Dingsang, D.P., Sheahan, V.L., Cipolla, D., and Sokolich, L. (2005). Utilising a safety culture management approach in the Australian construction industry. In *Proceedings The Queensland University of Technology Research Week International Conference, 4-8 July 2005*, Brisbane, Australia.

Bovis Lend Lease, (2004), *Safety in design guidelines*.

Bluff, L., (2003), *Regulating safe design and planning of construction works: A review of strategies for regulating OHS in the design and planning of building, structures, and other construction projects, Working paper 19*, The Australian National University, Canberra, ACT, Australia.

Gambatese, J.A., (1998), Liability in designing for construction worker safety. *Journal of Architecture and Engineering*, 4(3), 107-112.

Gambatese, J.A., (2000), 'Designing for safety', in *Construction safety and health management*, Prentice Hall, NJ, pp. 169-192.

Gambatese, J.A., Behm, M., and Hinze, J., (2003), Engineering mandates stipulated in OSHA regulations, In *Proc. 2003 Construction Research Congress, American Society of Civil Engineers*, Reston, VA.

Gambatese, J.A., Behm, M., and Hinze, J., (2005a), Viability of design for construction worker safety. *Journal of Construction Engineering and Management*, 131(9), 1029-1036.

Hadikusumo B.H.W. and Rowlinson S., (2002), Integration of virtually real construction model and design-for-safety-process database. *Automation in Construction*, 11, 501-509.

Hecker, S., Gambatese, J.A., and Weinstein, M., (2004), Designing for safety and health in construction: An introduction, designing for safety and health in construction, in *Proceedings of Research and Practice Symposium, University of Oregon*, Eugene, Oregon

Her Majesty's Stationery Office, (1994), *Construction (Design and Management) Regulations*, Statutory Instrument No. 3410, HMSO, London.

Hinze, J. and Wiegand, F., (1992), Role of designers in construction work safety. *Journal of Construction Engineering and Management*, 118(4), 677-684.

Institute for Safety Through Design, (2001), *Benefits of safety through design*, National Safety Council, Itasca, Illinois, viewed 20 April 2007, http://www.nsc.org/istd/aboutus.htm.

National Occupational Health and Safety Commission, (2005), *Regulation impact statement*, National Occupational Health and Safety Commission, Australia.

National Occupational Health and Safety Commission, (2003), *Eliminating hazards at the design stage (Safe design) options to improve occupational health and safety outcomes in Australia Issue paper*.

New South Wales Government, *Occupational Health and Safety Act 2000 (NSW)*, Part 2, Division 1.

NSW WorkCover, (2001), CHAIR Safety in design tool.

NSW WorkCover (2001), Safely building.

Queensland Government, *Workplace Health and Safety Act 1995*.

Toole, T.M., (2004), Rethinking designers roles in construction safety, in *Designing for Safety and Health in Construction: Proc., Research and Practice Symp.*, S. Hecker, J. Gambatese, and M. Weinstein, eds., UO, Press, Eugene, Oregon.

Weinstein, M., Gambatese, J. And Hecker, S., (2005), Can design improve construction safety? Assessing the impact of a collaborative safety-in-design process. *Journal of Construction Engineering and Management*, 131(10), 1125-1134.

Zou. P.X.W., Hinze. J, and Mahmud. S.H., (2007), Shaping a zero incident construction safety culture, in *Proceedings of the CRIOCM2007 International Symposium on Advancement of Construction Management and Real Estate, 8-13 August 2007*, Sydney, Australia

Zou P.X.W., Redman S. and Windon S. (2008), Case studies on risk and opportunity at design of building projects in Australia: Focus on Safety. Architectural Engineering and Design Management, Vol 4, pp. 221-238.

Zou. P.X.W., Windon. S, and Mahmud. S.H., (2006), Culture change towards construction safety risks, incidences and injuries: literature review and case study, in *Proceedings of CIB W99 on Global Unity for safety and health in construction*, Fang, Choudhry and Hinze, eds., 629 – 639.

Zou P.X.W. and Zhang G.M., (2009), Comparative study on the perception of construction safety risks in China and Australia. *ASCE Journal of Construction Engineering and Management*, 135(7), 620-627.