Craig Goldswain & John Smallwood

Toward improved construction health, safety, and ergonomics in South Africa: A working model for use by architectural designers

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Abstract

The construction industry produces a high rate of accidents. Despite evidence that up to 50% of accidents can be avoided through mitigation of hazards and risks in the design phase of construction projects, architectural designers do not adequately engage in designing for construction health, safety, and ergonomics. The article reports on the development of an architectural design-oriented model toward a reduction of construction hazards and risks. The research intertwined a range of secondary data with four provisional studies undertaken in the Eastern Cape Province considered representative of South Africa, and involved quantitative and qualitative methodologies directed at architectural designers registered with the South African Council for the Architectural Profession (SACAP). These served to provide local insight and a line of structured questioning for use in the main study, which was positioned in the action research (AR) paradigm and used focus-group (FG) methodology to solicit vast qualitative data from SACAP-registered participants. Synthesis of the FG data with literature and the provisional studies gave rise to a provisional model comprising six main model components and a range of subcomponents. The provisional model was validated and refined. The evolved model includes a core model embedded in a greater process model, and implementation and use of the core model relies on appropriate knowledge of architectural designers.

It is recommended that tertiary architectural education institutions and those involved in architectural CPD programmes take 'upstream design ownership' and use the model as a basis for designing and implementing appropriate education and training programmes.

Keywords: Construction health, safety, and ergonomics, architectural design model

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Dr Craig C. Goldswain, Senior Lecturer, Department of the Built Environment, Faculty of Science, Engineering and Technology, Walter Sisulu University, East London, South Africa. Phone: +27 43-7094000, email: <cgoldswain@wsu.ac.za>

Prof. John J. Smallwood, Department of Construction Management, Faculty of Engineering, the Built Environment, and Information Technology, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa. Phone: +27 41-5042790, email: <john.smallwood@nmmu.ac.za>

Abstrak

Die konstruksie-industrie het 'n hoë koers van ongelukke. Ten spyte van bewyse dat tot 50% van ongelukke voorkom kan word deur, tydens die ontwerpfase van konstruksie-projekte gevare en risiko's te verminder, raak argitektoniese ontwerpers nie voldoende betrokke in die ontwerp vir konstruksie-gesondheid, -veiligheid, en -ergonomie nie. Die artikel doen verslag oor die ontwikkeling van 'n argitektoniese ontwerp-georiënteerde model vir 'n vermindering van konstruksiegevare en –risiko's. Die navorsing kombineer 'n verskeidenheid van sekondêre data met vier voorlopige studies wat onderneem is in die Oos-Kaap, wat beskou word as verteenwoordigend van Suid-Afrika, asook betrokke kwantitatiewe en kwalitatiewe metodologieë wat gerig is op argitektoniese ontwerpers wat geregistreer is by die Suid-Afrikaanse Raad vir die Argitektuurprofessie (SARAP). Hierdie dien as plaaslike insig en 'n lyn van gestruktureerde vrae vir gebruik in die hoofstudie, wat geposisioneer is in die aksie-navorsing (AN) paradigma en gebruik die fokusgroep (FG) metode om groot kwalitatiewe data in te samel van SARAP-geregistreerde deelnemers. Sintese van die FG data met die literatuur asook die voorlopige studies het aanleiding gegee tot 'n voorlopige model wat bestaan uit 'n model met ses hoofkomponente en 'n verskeidenheid subkomponente. Die voorlopige model is gevalideer en verfyn. Die aangepaste model sluit 'n kernmodel, ingebed in 'n groter prosesmodel in. Die implementering en gebruik van die kernmodel berus op toepaslike kennis van argitektoniese ontwerpers.

Dit word aanbeveel dat tersiêre argitektoniese onderwysinstellings en diegene wat betrokke is in argitektoniese VPO programme 'n 'stroomop ontwerp eienaarskap'-benadering volg en die model gebruik as 'n basis vir die ontwerp en implementering van toepaslike onderwys- en opleidingsprogramme.

Sleutelwoorde: Konstruksie-gesondheid, -veiligheid, en -ergonomie, argitektoniese ontwerp model

1. Introduction

Despite the Construction Regulations (South Africa, 2003; 2014) expecting architectural designers to design for construction health and safety (H&S), inclusive of construction ergonomics, the responsibility for construction H&S has been left to contractors (Mroszczyk, 2005: online). While cost, quality, and schedule are traditionally used to measure project success, they do little to mitigate construction hazards and risks, thus ultimately increasing the cost of construction (Schneider, 2006: online; Smallwood, 2006a). There is an active need for a paradigm shift in architectural thinking to ensure that designs are reviewed to ensure construction H&S, and to include it as a measure of project success (Toole & Gambatese, 2006: online).

Behm (2006: online) suggests that one third of the hazards leading to accidents "... could have been eliminated or reduced if design-for-safety measures had been implemented ...", while the Health and Safety Executive (HSE) (2003) profess that up to half of studied cases could have mitigated the risks through alternative design. Cameron, Duff & Hare (2005: 323) promote effective planning as key to hazard and risk reduction, and the United Kingdom's (UK) Gateway model (HSE, 2004a) and the Australian Construction Hazard Assessment Implication Review (CHAIR) (WorkCover NSW, 2001) provide means for designers to review designs toward hazard and risk mitigation. Numerous recommendations toward improved design for H&S have also been compiled by researchers such as Gambatese in 1997 and Weinstein in 2005, as cited and added to by Behm (2006: online), in order to assist designers. It is essential that designing for construction H&S, or 'constructability' (Toole & Gambatese, 2006: online) be included in design education, while Schulte, Rinehart, Okun, Geraci & Heidel (2008: 118) claim that design education can be enhanced through expansion of curricula and by stimulating professional accreditation. Smallwood (2006a) declares construction H&S education inappropriate, and encourages optimisation of design programmes at tertiary level and raising awareness through CPD courses to change the perceptions of designers. The objective of this article is to disseminate the research and the evolved model as a step toward improved architectural design relative to a healthier, safer, more ergonomic construction industry.

2. Construction health and safety

2.1 The nature of construction accidents

Accidents are multi-causal in nature with the coincidence of a number of factors resulting in an incident. There are two main types of factors that are influenced by a range of attributes. First, 'proximal factors' occurring in the immediate environment on site include the attitude, ability, awareness, health and fatigue status of workers generally affected by the successes of industrial psychology in the form of communication, motivation and training, and current health status of individuals, and site hazards created in the absence of suitable planning, management, and supervision, leading to an absence of H&S culture. Secondly, 'distal factors' are those linked or attached to, such as issues surrounding design, in terms of choice of material and equipment and the design situation in which they are used. Ultimately, these include poor design and planning decisions which lead to "active failures" (Haslam, Hide, Gibb, Gyi, Pavitt, Atkinson & Duff, 2005: 402; HSE, 2003; Gibb, Haslam, Hide, Gyi & Duff, 2006: 47). Similarly, these factors can be grouped as worker factors, site factors and material/equipment factors, which "... are a result of originating influences, such as permanent works design, project management, construction processes, safety culture and risk management ..." (HSE, 2003: 58), which are affected by client requirements, economic climate and the educational ambit of the people involved (HSE, 2003; Gibb *et al*., 2006: 49).

Relative to South Africa, the cidb (2009: 4) reports that "the dominating causes of injuries were struck by (44%), falls onto different levels (14%) and striking against (10%); the dominating causes of fatalities were MVAs (47%), struck by (17%) and falls on to different levels (17%); penetrating wounds (30%) and superficial wounds (31%) predominated in terms of the nature of injuries sustained; multiple injuries caused 47% of fatalities; injuries to hands (24%), head and neck (19%), and legs (16%) were common anatomic regions involved, and in terms of agency automobiles (10%) and hand tools (6%) dominated as causes of injuries".

Internationally and locally, and in order, the main causes of accidents are considered to be "falls onto different levels", MVAs, "struck by", "inhalation, absorption and ingestion", and "WMSD's or body stressing" (cidb, 2009: 4).

2.2 Hazards and risks leading to accidents

A 'hazard' "is a condition or event with the potential to cause harm" (European Federation of Engineering Consultancy Associations (EFCA) & the Architects' Council of Europe (ACE), 2006: online), and a 'risk' is "the probability that harm from a particular hazard will occur combined with the likely severity of the harm" (EFCA & ACE, 2006: online). If the main causes of construction accidents are the five broad categories suggested earlier, these must then be considered in terms of construction H&S hazards and risks. It is evident from the outset that inhalation, absorption, and ingestion can be considered integral of construction health hazards and risks; falls onto different levels, MVAs, and struck by are integral of construction safety hazards and risks; WMSDs or 'body stressing' are integral of construction ergonomics hazards and risks, and these notwithstanding any interrelationship between categories. The latter 'ergonomics' discussion is, however, reserved for the next section.

Hazardous chemical substances (HCSs) can enter the human body through inhalation, absorption through the skin, and ingestion. Inhalation refers to the breathing in of airborne contaminants such as dusts, fumes, vapours, mists and gasses resulting in eye irritation, respiratory tract problems, and subtle damage to organs. The handling and processing of construction materials cause dusts. Coughing and sneezing may be an early warning of irritants being inhaled; however, very fine dust particles can still reach the lungs leading to pneumoconiosis (lung disease caused by inhaling mineral or metallic dust over a long period), asbestosis (inflammation of the lungs caused by prolonged inhalation of asbestos fibers), or lung cancers. Inhalation of solvents can result in respiratory problems and central nervous system damage, while complex fumes given off by welding processes can lead to metal-fume fever (Deacon, 2004: 19; Smallwood & Deacon, 2001; Occupational Safety and Health Council, 2004: 6; cidb, 2009: 4). Absorption refers to HCSs being absorbed through the skin. Some examples are the use of solvents which can cause dermatitis, working with concrete, which can cause allergic contact dermatitis as a result of alkaline and abrasive properties, and handling of bitumen and similar products can lead to dermatitis and acne-related skin disease (Deacon, 2003: 19; Deacon & Smallwood, 2010: 52; Occupational Safety and Health Council, 2004: 7; Bureau of Labour Statistics – US Department of Labour, 2007: online; 2008: online; Weitz & Luxenberg, 2010: online). Ingestion refers to the swallowing of HCSs, occasionally erroneously, but more often through carelessness, for example, the handling of products containing HCSs and eating without washing of hands (Deacon, 2003: 57; Smallwood & Deacon, 2001; Occupational Safety and Health Council, 2004: 7; Bureau of Labour Statistics – US Department of Labour, 2007: online; 2008: online).

MVAs occurring on construction sites are considered relevant to this study, as opposed to accidents occurring on public roadways, which require an alternative approach. In terms of design, the design of access routes, warning signs, and a general awareness of vehicular movement on site will serve toward mitigation of related risks. While reverse beepers and other vehicular attributes remain important, these should be focused on by vehicle designers and suppliers, and be maintained in an operational condition by construction firms, construction managers, site managers, and site personnel. 'Falls onto different levels' are often caused by tripping, often as a result of poor housekeeping, falling from and collapsing of scaffolding and support work, falling from ladders, hoists and platforms, falling during demolition, falling into open excavations, falling off buildings and roof structures, and falling through openings. Many of these falls can be attributed to design and scheduling insufficiencies and due to a lack of, or inappropriate barricading and prevention efforts (Behm, 2006: online; cidb, 2009: 23; HSE, 2003; Bureau of Labour Statistics – US Department of Labour, 2008: online; Innes, 2009; Weitz & Luxenberg, 2010: online; HSE 2010b: 10). 'Struck by' accidents are often caused by falling materials, plant, equipment, structures, people and collisions, impact or failure with respect of motor vehicles and could occur during construction, maintenance or demolition work. Other risks include exposure to electrical hazards leading to electrical shock, contact with moving parts of machinery and vehicles, fire- and explosion-related hazards, excavation collapses, and working in confined spaces (Behm, 2006: online; cidb, 2009: 23; HSE, 2003; Bureau of Labour Statistics – US Department of Labour, 2008: online; Innes, 2009; Deacon & Smallwood, 2010: 50; Weitz & Luxenberg, 2010: online; HSE 2010b).

2.3 Ergonomics-related injuries

Smallwood (2007: 619) cites La Dou (1994) claiming that ergonomics "… is an applied science concerned with people's characteristics that need to be considered in designing and arranging things that they use in order that people and things will interact most effectively and safely". The Construction Regulations (Republic of South Africa, 2003: online) definition proposes that ergonomics is "… the application of scientific information concerning humans to the design of objects, systems, and the environment …", while the updated Construction Regulations (Republic of South Africa, 2014: 11) state that designers must "… take cognisance of ergonomic design principles in order to minimise ergonomic related hazards in all phases of the life cycle of a structure". Smallwood (2007: 619) also cites Schneider & Susi (1994) and Gibbons & Hecker (1999), suggesting that relative to construction, ergonomics poses significant problems, and a range of construction tasks adversely affect construction workers. Construction ergonomic problems include repetitive movements, climbing and descending, handling heavy materials, bending or twisting the back, working in awkward positions, reaching overhead, vibrating tools and equipment, repetitive strain injuries (RSIs), exposure to noise, use of body force, handling heavy or inconveniently sized materials, handling heavy equipment, working in cramped positions, reaching away from the body, working in hot conditions, staying in the same position for long periods, working in humid conditions, working in wet conditions, working in cold conditions, and working while hurt or injured (WorkCover NSW, 2001: 40; Smallwood, 2006b: 303; Smallwood, 2007: 624; cidb, 2009: 23; Deacon & Smallwood, 2010: 50; Safe Work Australia, 2010: 9-12; HSE 2010b: 25). Predominating causes of ergonomics-related injuries in South Africa include repetitive movements, climbing and descending, handling of heavy materials, use of body force, exposure to noise, and bending or twisting of the back (Smallwood, 2006b: 307). The construction trades generally give rise to a range of ergonomic problems; however, concreting, reinforcing, formwork and structural steelwork predominate, followed by masonry, roofing, building fabric, plumbing and drainage, electrical, floor finishes, suspended ceilings, painting, and decorating; paving and other external work are main ergonomic hazards that result from the construction process (Smallwood, 2006b: 308-309).

2.4 Designing for construction H&S

Hetherington (1995: 5) suggests that design professionals "… will only be expected to take into account those risks which can reasonably be foreseen at the time at which the design was prepared" and should aim toward "… avoiding and combating H&S risks inherent in the construction process". He further suggests that construction H&S can be addressed through design interventions during the 'concept stage', 'design evolution' and the 'detailed specifications', and that designers should provide information along with their designs to ensure that potential risks and associated issues are identified. Chang & Lee (2004) claim that the use and type of chosen technology influences construction performance and the ability to achieve strategic objectives. It is essential for all stakeholders, including architectural designers, to recognise the design and construction relationship, what Hendrickson (2008: online) perceives as an "integrated system", while Chang & Lee (2004: 2) raise concern that the majority of studies address construction management issues and ignore the construction technology realm. The real issue is "… the implementation of a design envisioned by architects and engineers … performed with a variety of precedence and other relationships among different tasks" (Hendrickson, 2008: online). Integrated into design and technology is 'method', which involves both tactic and strategy. Decisions regarding the best or ideal sequence of operations should be integrated into the design process rather than leaving all decisions up to the production team or contractor (Hendrickson, 2008: online). It is also important that all people involved are not only competent, but also sufficiently motivated to ensure project success (Lester, 2007: 5, 30).

A crucial element of designing for construction H&S is the ability of designers to undertake hazard identification and risk assessments (HIRAs) during the design process, and to apply risk control mechanisms to mitigate such hazards and risks. Simply put – "find it, assess it, and fix it" (WorkSafe Victoria, 2005: online). Gangolells, Casals, Forcada, Roca & Fuertes (2010: 119) promote the need for proactive hazard identification and appropriate elimination thereof, and identified a broad range of main processes such as earthworks, foundations, structures, and more, with the aim of identifying construction hazards related to these processes in order to undertake an assessment of the risks. This involved the calculation of the significance of risks by considering the probability of risks and the severity of the consequences. Risks are also relevant to exposure, which is the direct relationship of time to the volume of required work (Gangolells et al., 2010: 110). Carter & Smith (2006) consider HIRAs in an overall design context and contend that accident causation models focus on how hazards lead to accidents, and that risk assessment is a practical means of risk management. However, they insist that the problem lies in hazards that are not identified as control measures and cannot be implemented without awareness. Method statements are a conventional means of assessing risk, but the level of hazard identification and assessment thereof remains questionable. A comprehensive method statement should include a description, a location, a work sequence, necessary resources, and risk assessments. They suggest that, despite method statements, hazard identification levels are not what they should be (Carter & Smith, 2006: 198). They further maintain that there are two barriers to improving hazard identification. First, there are 'knowledge and information barriers', which constitute a lack of information sharing, a lack of resources, the subjective nature of hazard identification, and reliance on tacit knowledge – that anchored in the head of people and not documented. Secondly, there are 'process and procedure barriers', which constitute a lack of a standard method, and an unclear structure of tasks and related hazards (Carter & Smith, 2006: 201). Carter & Smith (2006: 202) advocate the HSE (1998: 2) who sum things up saying that "A risk assessment is nothing more than a careful examination of what, in your work, could cause harm to people, so that you can weigh up whether you have taken enough precautions or should do more to prevent harm."

3. Research methodology

Van Teijlingen & Hundly (2001: online) propose provisional studies to be crucial elements of 'good study design', which increases the likelihood of main study success by providing 'valuable insights'. Four provisional studies were undertaken in order to progressively build information toward development of structured questions for use in the AR FGs. Cumulatively, both quantitative and qualitative methodologies were included and the target population and sample selection comprised SACAP-registered architectural designers in the Eastern Cape region of South Africa. The provisional studies included a quantitative study to establish the perceptions of architectural designers in South Africa relative to mitigating construction H&S risks in which 15 appropriate statements and an open-ended question was distributed among 102 architectural designers, and a total of 18 responses equating to 17.5% were received; a qualitative provisional study in order to determine what would encourage architectural designers to proactively mitigate construction hazards and risks through design, in which 13 semi-structured interview questions were posed to 10 architectural designers following 60 telephonic requests, thus equating to an overall response rate of 16.7%; a quantitative study sought to establish an architectural design model framework toward improved construction H&S in South Africa, in which a range of questionnaire types were included. First, a questionnaire comprising 11 appropriate statements was designed. Secondly, two cross-reference tables, each comprising 30 response opportunities, inclusive of open-ended options, were designed. Thirdly, a third cross-reference table was designed with 20 response opportunities, including an open-ended option. Finally, a separate open-ended question was included. The survey was conducted among 76 SACAP-registered architectural designers, to which 12 responses equating to 15.8% were received, and a final quantitative study sought to identify key inputs that could be integrated into the architectural design model framework identified by the third provisional study, in which 20 appropriate statements, three semi-structured questions, and an open-ended question was distributed among 73 architectural designers, and a total of 15 responses equating to 20.5% were received. The provisional studies ultimately produced nine structured questions.

The main study was located in the AR paradigm using FGs in order to solicit vast qualitative primary data, and served to accomplish the active collaboration of researcher and client, being architectural designers registered with the SACAP, and allowing the importance of co-learning to emerge. The AR process involved the setting up of FG sessions, and included the establishment of the number of FGs; the potential members or population; the size and structure or sample; suitable venues, and extending invitations and the programme to randomly selected potential participants who had participated in the provisional studies. The target of eight participants for the first FG to be held in the Buffalo City Metropolitan Municipality region was met; however, only four participants could be secured for the second FG session to be held in the Nelson Mandela Metropolitan Municipality region. Signing of consent forms was expected, anonymity of the participants was guaranteed, and the same nine structured questions were posed to both FGs. The proceedings were video recorded with additional backup audio recording for transcription purposes, and a few general notes were taken down. Cumulatively, the demographic make-up included a blend of professional registration categories, including seven Professional Architects (58.3%), two Professional Senior Architectural Technologists (16.7%), and three Professional Architectural Technologists (25%), with the average age of the participants being 45 years, with relevant experience averaging 20.75 years. Unfortunately, the demographics are skewed in terms of gender, with only one female (8.3%) being available to participate in the FGs. A wealth of qualitative data was generated and transcribed *verbatim*.

The FG data was synthesised with the literature and the provisional studies, and a provisional model was evolved. However, as Carter & Smith (2006: 203) propose, "[f]or many model development exercises, validation is a crucial aspect and a model cannot be considered complete without it". A model refinement questionnaire comprising both quantitative and qualitative means was developed and disseminated to the FG participants. It focused on the six main components of the model and the overall model by including a statement relevant to each model component, subcomponent and the overall model, with respondents being required to consider and indicate on a Likert-type scale of 1 (totally disagree) to 5 (totally agree) the extent to which they concur. An open-ended question was included directly below each statement. Finally, six statements relative to the use of the model measured against the six research hypotheses were included, using rating scales as before, in order to test the research hypotheses.

4. Interpretation of research results towards a provisional model

The underlying perception of construction health, safety, and ergonomics as the contractors' responsibility was detected in the FG discussions.

The transcribed FG data crossed the boundaries of the nine structured questions and was bracketed into themes and, ultimately, into the model components in what follows.

4.1 The key inputs

The first key input is 'relevant literature', which provided the backdrop to the study. Relative to the fourth provisional study, the degree of concurrence to the statement of 'Consideration of local and international literature would prove beneficial to developing a guiding model suitable for use in the context of South Africa' achieved a mean score (MS) of 3.73, which is above the midpoint score of 3.00, suggesting its suitability as a key input. The FG facilitator probed as to whether there is relevant literature to guide us. Sample data includes: "There is already Health and Safety on construction sites. One needs to adopt that, use that as a basis and to assist with the design process."

The second key input is 'causes of accidents'. Literature provided a range of accident causes. Relative to the fourth provisional study, the degree of concurrence with the statement 'Architectural designers would need to understand the causes of construction accidents in order to design for construction health, safety, and ergonomics' achieved a MS of 4.07, which is well above the midpoint score of 3.00, strongly suggesting its suitability as a key input. The FG facilitator probed as to whether causes of accidents could serve as a key input. Sample data includes: "Yes, I said here (making own notes) reported incidents. I think that needs to be reported to the Department of Labour or something. Court cases?"

The third key input is 'information on hazards and risks'. Literature provided a range of information with respect to hazards and risks. Relative to the fourth provisional study, the degree of concurrence with the statement 'Architectural designers would need to identify hazards and undertake risk assessments in order to design for construction health, safety, and ergonomics' achieved a MS of 3.53, which is above the midpoint score of 3.00, suggesting its suitability as a key input. Sample data includes: "Your hazards, especially with chemicals and use of flammable materials or other hazardous materials. I mean one needs to understand that and the working conditions that go with it."

The fourth key input is 'international approaches and models'. Literature provided insight into the international realm. Relative to the fourth provisional study, the degree of concurrence with the statement 'Consideration of suitable international models would prove beneficial to developing a guiding model suitable for use in the context of South Africa' achieved a MS of 3.53, which is above the midpoint score of 3.00, suggesting its suitability as a key input. Sample data includes: "It certainly could. For instance, if there's an Aussie model, then I think it could be applied."

The fifth key input is 'design recommendations'. Literature demonstrated a range of possibilities. Relative to the fourth provisional study, the degree of concurrence with the statement 'Consideration of existing design recommendations would prove beneficial to developing a guiding model suitable for use in the context of South Africa' achieved a MS of 3.79, which is above the midpoint score of 3.00, suggesting its suitability as a key input. Sample data includes: "Probably yes - again one needs to look at what is the environment in which that design recommendation has been made against our environment."

The sixth key input is 'recent studies and on-going research and development'. While not directly interrogated in the literature, appropriate literature is generally based on recent studies. The second provisional qualitative study raised the point of research and new ideas by suggesting that "It's a new field ... not widely explored. We need research and new ideas". Sample data includes: "In my mind one of the first things I would need is some sort of research or data resource so that I can start understanding the risk class or something for the priorities that one should focus on."

It is argued that 'relevant literature, causes of accidents, information on hazards and risks, international approaches and models, design recommendations, and recent studies and on-going research and development' all constitute key inputs.

4.2 The core model

The core model comprises a framework, a working process within the framework, and identifies the range of requisite knowledge architectural designers require in order to engage the process.

In terms of the 'model framework', the third provisional study considered a range of documentation familiar to architectural designers which leaned in favour of the application of the National Building Regulations (NBR), with the questioning format included as a matrix within the six SACAP architectural work stages. The importance of the SACAP architectural work stages was later realised and the situation re-examined in the fourth pilot study which confirmed the popularity of the NBR with a MS of 4.00, while the SACAP architectural work stage dominated with a MS of 4.20 when considered against the average score of 3.00. These far outweighed the MSs of 2.33 related to Work Breakdown Structures (WBS), the 2.47 relative to the Preambles for Construction Trades, and the 2.53 relative to Bills of Quantities. No other document options were provided by respondents within an open-ended question opportunity. Sample FG data suggests that the framework of the NBR is appropriate: "If you just look at the headings, yes. When you look at the NBR – if you just look at the index it'll cover the points". Relevant to the SACAP architectural stages of work, sample data considers checking the NBR items: "At each workstage – Ja (Colloquial 'yes'), and then you are combining your processes with your items as well".

The working process gave rise to a 'design opportunity window'. The statement of 'A guiding model should include a process which architectural designers can follow in order to design for construction health, safety, and ergonomics' was incorporated into the fourth provisional study. The responses resulted in a MS of 3.60, which is above the average of 3.00, thus indicating the possible need for inclusion of a design process.

The CDM Regulations (Neil, 1994: 21; Hetherington, 1995; CDM, 2007: online) and the South African Construction Regulations (Republic of South Africa, 2010) attempt to ensure that architectural designers consider construction H&S in exercising their design options. The UKs Gateway model (HSE, 2004a) and the Australian CHAIR model (WorkCover NSW, 2001) provide opportunity for architectural designers, *inter alia*, to review their chosen designs toward establishing the optimum option and selection. The second provisional study questioned the inclusion of H&S into the design process. Selected data suggests that "It should be part of integral thinking ... part of design and documentation", and "The fundamentals of health and safety should be discussed, even at university, and should be monitored and recorded". The FG data demonstrated a cyclic design process, ultimately leading to design selection. Sample data includes: "It is backwards and forwards processes until you get to the final. You can't say I have now finished Stage 1. I can carry on to Stage 2. The ideal of course would be to say I am finished with work Stage 1, work Stage 2, now it is the final stage of development. Call it … preliminary working drawings if you want to."

The UK's Gateway model in complete form, and collapsed form for smaller projects, includes opportunities for H&S reviews at given intervals or Gateways throughout a range of project phases (HSE, 2004a; Cameron *et al.*, 2005: 325). Similarly, the Australian CHAIR model provides architectural designers, among others, the "... opportunity to sit down, pause and reflect on possible problems" (WorkCover NSW, 2001: 4), being the opportunity to conduct H&S reviews through specific phases. The third provisional study incorporated the statement: 'It would be beneficial to have an approach or model which includes a mechanism for interim assessments during the various stages of the design process', which achieved a MS of 3.50, which is above the midpoint of 3.00, thus indicating likely inclusion of H&S reviews. FG sample data supports this in that "… you've got to have a health and safety review".

The Gateway model (HSE, 2004a) includes a range of expectancies created throughout the various phases and creates a roadmap which can quite easily be perceived as a 'checklist' which designers can follow. The Australian CHAIR model (WorkCover NSW, 2001: 27) includes 'guidewords', which can also be construed as a 'checklist'. The fourth provisional study included the statement 'A guiding model should include checklists and allow opportunity for design notes in order to assist the process', which achieved a MS of 4.07, which is once again well above the midpoint of 3.00. FG sample data includes: "I am thinking about a checklist, if you have it as an addition to it. Like people specialising in SANS 204 (NBR) – if they can check your drawings, for example, it might be a good idea if they check it from a specialist point of view to see if you have the finer details right."

Behms' (2006: online) analysis of 450 construction accident reports, and the HSEs' (2003) construction accident study of 100 cases would not have been possible without accurate data records, and record-keeping such as H&S files is considered paramount if designers and others can expect to be defendable in legal situations (HSE, 2004a: 15). Data from the second provisional study included the need for keeping records by recognising that "The fundamentals of H&S should be discussed … and should be monitored and recorded". FG sample data includes: "You may be making a choice that has a higher risk, because of other factors. It needs to be recorded 'why' and then how you mitigate the risk."

Hendrickson (2008: online) suggests that the planning and design of any facility should consider the entire project life-cycle, and states that "… changes of design plan are not uncommon", while these also affect changes in operations that exacerbate construction hazards and risks (HSE, 2004b). Variation Orders (VOs) or changes to design were not directly interrogated in the provisional studies. However, it is argued that these regularly form part of the design and construction process. The statement 'A guiding model should include a process which architectural designers can follow in order to design for construction health, safety, and ergonomics' was provided in the fourth provisional study, which realised a MS of 3.60, which is above the midpoint of 3.00, and theoretically incorporates VOs. FG sample data includes: "I think for the majority, the bulk of it is Ok. If a V.O. comes along we assess it as part of the overall design which goes back to the beginning."

The HSE (2004a: 65) expects the project team to sign-off all review-related items prior to confidently progressing; the CHAIR model (WorkCover NSW, 2001: 8) expects construction elements to be considered relevant to construction H&S and further expects accurate record-keeping. The signing off of records is proffered. Sign-off was not included in the provisional studies; however, based on literature, the notion was included in the FG proceedings. The facilitator probed the opportunity to sign off the designs or revisit the process as part of ensuring designing for construction H&S commitment. Sample data included: "The responsible person can sign it off", and "The problem with signing off is you are signing off your documentation or your process, you can't sign off what the contractor is going to do". Exactly when to 'sign-off' was unfortunately not entertained by the FGs; however, the cyclic or helical nature of both research and design presents a range of opportunities. These are not static and are not discussed in this instance, but are included in the diagrammatic model later.

It is postulated that the 'design opportunity window' comprises design options; design selection; H&S reviews; sign-off or revisit 1; H&S checklists; H&S data records; sign-off or revisit 2; Variation orders (VOs), and sign-off or revisit 3.

The 'design opportunity window' cannot be actively engaged without an adequate knowledge of designing for construction H&S. The question arises as to what architectural designers need to know, meaning what should be, or needs to be, incorporated into the 'design knowledge window', which will give architectural designers an adequate knowledge of designing for construction H&S so that they can make optimum use of the 'design opportunity window'? FG sample data included: "If the designer can refine the design and say there might be better processes or whatever the case might be to achieve the goal, one needs the knowledge."

It is proffered that a knowledge of construction processes, which integrates appropriate technology, is needed in order to achieve specific objectives (Chang & Lee, 2004), while it is essential for designers to recognise the design and construction relationship as an integrated system (Hendrickson, 2008: online). The fourth provisional study data suggested that "[d]esigners and architectural practitioners should be actively exposed to the physical construction process of projects to ensure a practical understanding of the erection and construction process and constraints". FG sample data included: "I think everyone needs to understand the construction process. We are sitting at the moment with a situation, we have a huge part of the industry that doesn't – they have no idea how that is going to turn into a building. You can't design and design safely if you don't understand the construction process."

Hendrickson (2008: online) and Lester (2007: 30) promote a range of fundamental scheduling tools or techniques to achieve optimum sequencing and timing of construction activities, while the HSE

(2004b) includes a hierarchy of influences with causal connotations in their 'influence networks'. The second provisional study raised the point of construction programming by suggesting that "some sort of methodology is crucial ... a method or awareness of the building programme". FG sample data included: "So maybe that is the other way of looking at it, not just bringing it up but when the building is there. I think there is more scope actually getting that. That way we can probably say listen the guy is not going to lay the carpet until such time as the walls are painted or something like that", and that "You should have a program."

Architectural designers should have a broad understanding of the circumstances and the environment within which 'designing for construction health, safety, and ergonomics' occurs. Literature provides a vast expanse of appropriate information which architectural designers can engage toward an improved contextual understanding of construction H&S. Contextual H&S served as basis for all four provisional studies and the main study. While examples are not included in this instance, FG sample data included: "I think first off, a full understanding of the relevant information that is already there"; "They need to have a basic design health and safety – construction health and safety background", and "We need to understand – why is it necessary?"

The main causes of accidents worldwide, including South Africa, includes 'falls onto different levels', 'MVAs', 'struck by', 'inhalation, absorption and ingestion', and 'WMSD's or body stressing' (Haslam *et al*., 2005: 411; Penny, 2007: online; Bureau of Labour Statistics – US Department of Labour, 2008: online; cidb, 2009: 4, Innes, 2009; Safe Work Australia, 2010: 9-12, HSE, 2010b: 6). Relative to the fourth provisional study, the degree of concurrence relative to the statement 'Architectural designers would need to understand the causes of construction accidents in order to design for construction health, safety, and ergonomics' achieved a MS of 4.07, which is well above the midpoint score of 3.00. FG data appears to discuss causes of accidents as 'risk'. However, a definite link is evident. Sample data includes: "Designing at a place with high wind speeds and you have a façade system, so how do you get that up. So there is, I think it is identification of risks … and I have to have it for that so it gives you health and safety risks."

WorkSafe Victoria (2005: online) provide explanations of 'hazard identification' and 'risk assessments', but also simplified the terminology – 'find it', 'assess it', and 'fix it'. Carter & Smith (2006: 197) conclude that control measures cannot be implemented in the case where hazards and risks are not identified. The first provisional study established that, relative to South Africa, architectural designers do not adequately conduct HIRAs, and the statement 'Architectural designers would need to identify hazards and undertake risk assessments in order to design for construction health, safety, and ergonomics' was provided in the fourth provisional study. The response achieved a MS of 3.53, which is above the midpoint score of 3.00. FG sample data included: "… so there is an inherent risk of digging down trenches 3, 4, 5m down and say people – it has to be hand dug for whatever geomorphic reason and we have to have personnel down below ground level. I think the professional should identify risks …", and in the event of unresolved hazards and risks, then "They should come up with a mitigation plan with the constructor".

Numerous researchers have contended that 'falls from height' contributes significantly to injuries and fatalities (Haslam *et al*., 2005; Penny, 2007: online; Bureau of Labour Statistics – US Department of Labour, 2008: online; cidb, 2009: 4, Innes, 2009; Safe Work Australia, 2010), while Gangolells *et al*. (2010) consider residential buildings that includes, *inter alia*, single-storey dwellings relative to HIRAs. This variety of study alone suggests that 'project type and complexity' plays an important role. The second provisional study insinuates project type and complexity with commentary such as "Besides that the design may be challenging and unconventional …", and that "there is always a way to carry out works safely, but it is costly for unconventional projects". FG sample data includes: "Also overseas there are more complicated buildings being built in the first world countries – that is more available than here. I think the complexity high rise, etc. has possibly got to do with the high mortality or injury here."

Advocating the contributions of Gambatese, Behm (2006: online) offered a range of design recommendations. Mroszczyk (2005: online) acknowledges that the contributions of Gambatese and Weinstein have purpose. Relative to the fourth provisional study, the degree of concurrence with the statement 'Consideration of existing design recommendations would prove beneficial to developing a guiding model suitable for use in the context of South Africa' achieved a MS of 3.79, which is above the midpoint score of 3.00. FG sample data included: "Probably yes – again one needs to look at what is the environment in which that design recommendation has been made against our environment."

The provisional studies did not question H&S in relation to the 'lifecycles of buildings' *per se*; however, they included it as part of the review of the literature by advocating Cameron *et al*. (2005: 326) who discussed the Gateway approach and identified 'concept, feasibility, design, construction, and maintenance', while WorkCover NSW (2001: 8) refer to 'construction, maintenance, repair and demolition'. FG sample data includes "The framework will have to look at the life cycle of the building not just the design and construct phase", and "From concept to final demolition. There a lot of buildings that go through three, four cycles in their lifespan, and it's becoming more complex."

It is proffered that architectural designers need a sound knowledge of construction processes; construction programming; contextual H&S; causes of accidents; HIRAs; project type and complexity; design recommendations, and lifecycles of buildings.

4.3 The mechanisms

This model component realises the need for 'engaging people' in order to promote healthier and safer design, and the need for 'education and training' in order to ensure adequate knowledge for architectural designers to engage in healthier and safer architectural design. First, engaging people constitutes encouragement, upstream design ownership, and a multi-stakeholder approach. Secondly, education and training constitutes awareness, education and training, and CPD programmes.

Vast recognition has been given to the dangers of the construction industry, and many have sought to encourage designers, including architectural designers, to mitigate construction hazards and risks through the design process (Hetherington, 1995: 5-6; WorkCover NSW, 2001: 8; HSE, 2004a: 24; Hinze, 2005: 1; Haslam *et al*., 2005: 412; Mroszczyk, 2005: online; Toole & Gambatese, 2006: online; Behm, 2006: online; Schneider, 2006: online; Smallwood, 2006a; Behm & Culvenor, 2011: 9). The second provisional study questioned what would encourage architectural designers to engage in healthier and safer design. Some selected commentary, which overlaps with other aspects of the study, included: 'Educating people ... should not limit design'; 'Ongoing education to keep it at the forefront of one's mind ... '; 'It is more a case of awareness …', and 'Architects should have hands on knowledge of what the contractor encounters'. The third and fourth provisional studies offered similar statements relative to encouragement and having a guiding approach or model in place to assist them and achieved MSs of 4.25 and 4.18, respectively, both above the midpoint score of 3.00. On the point of encouragement, FG sample data included: "It's exactly what we've spoken about – if you are convinced that it's worth it to save someone's life, then obviously you can engage with it."

The HSE (2003: 58) distinctly mentions factors that "... are a result of originating influences, such as permanent works design …", thereby insinuating the 'upstream' nature of design, while the Gateway model moves ownership of construction H&S risks upstream in a "... structured, systematic, logical, rigorous and transparent ..." manner (HSE, 2004a: x). While 'upstream design ownership' was not specifically investigated in the provisional studies, some hint of control or ownership was provided. The second provisional study data infers ownership by suggesting "It is up to the professional … we need to educate the client to trust the professional." FG sample data included: "I think that's important – maybe we should be. We need to accept that we need to take responsibility for these issues in the design stage."

The CDM Regulations (Neil, 1994: 21; Hetherington, 1995; CDM, 2007: online) and the South African Construction Regulations serve to protect people by attempting to ensure a multi-stakeholder responsibility, among others, for construction H&S inclusive of designers (Construction Regulations, 2003; Geminiani, Smallwood & Van Wyk, 2005: 40; Smallwood & Haupt, 2005: 2). The UK's Gateway model relies on good people management and warrants a multi-stakeholder approach (HSE, 2004a). Similarly, the Australian CHAIR model promotes a multi-stakeholder approach by providing time for brainstorming (WorkCover NSW, 2001: 8). The first provisional study included the open-ended question 'Do you have any comments in general regarding designing for construction health, safety and ergonomics?' Responses included: "The client, the designer and constructor must always take responsibility to ensure that the work is carried out safely. We cannot point finger to one party, it's a joint responsibility." The second provisional study also included apt data by suggesting that "... working with an engineer the combined effort must cover those sort of things", and "... one would need to interact with contractor to find out how things could be improved." In response to the facilitators' probe of whether architectural designers can engage safe design on their own, FG sample data included: "Probably not. It is teamwork – buildings get built by teamwork", and "I would like to add to that we need the client and we should have the contractor at the …", but "Ideally, ideally yes which is not always the case."

A lack of awareness is evident in literature, demonstrating the hazards and risks to which constructors are exposed and the need for designers, including architectural designers, to mitigate these through the design process (Hetherington, 1995: 5-6; WorkCover NSW, 2001; HSE, 2004a; Hinze, 2005; Haslam *et al*., 2005; Mroszczyk, 2005;

Toole & Gambatese, 2006: online; Behm, 2006: online; Schneider, 2006: online; Smallwood, 2006a; Behm & Culvenor, 2011: 9). More specifically, the need to raise awareness relative to designing for construction H&S was included by Smallwood (2006a) in order to change designers' perceptions and attitude toward the need. The second provisional study raised the point of awareness and touched on education by suggesting: 'It is more a case of awareness, even at university level ... it stems back to Architectural School days'; 'We have the competencies because we are designers ... we can design anything. The only way to enhance those competencies is by being made more aware'. FG sample data included: "I think we first need to be aware that there is a problem – design related – before we actually encompass that problem, before we accommodate, we should be aware that there is a problem."

A lack of knowledge and experience, due to inappropriate tertiary architectural education, is evident; improvement of curriculum and enhanced tertiary architectural education was included as an enabler toward education and skills provision (Cowley, Culvenor & Knowles, 2000; Schulte *et al.*, 2008; Smallwood, 2006a). The first provisional study included the open-ended question 'Do you have any comments in general regarding designing for construction health, safety and ergonomics?' One response included "More emphasis should be placed on CHS (respondents' acronym) in training in the construction industry". Where to position this in terms of tertiary education remains debatable and is not the main focus of the study. However, the second provisional study revealed that "It will have to fit somewhere between Building Design and Construction, which run parallel ... the Building Construction component. How do we put a building together and how do we document it? It needs to be an integral component – a separate course won't receive the emphasis it deserves". The third provisional study included the statement "It would prove beneficial if the guiding approach or model was incorporated into architectural education and continuous professional development (CPD) programmes" This achieved a MS of 4.25, which is well above the midpoint score of 3.00. FG sample data included: "All the kind of stuff that the safety guys have experienced on site – that should be fed back into the education system. So the guys who are coming out of the university are already aware of what is expected and what to cover when they design."

Stimulating professional accreditation and engaging CPD courses are considered to be an enabler toward education and skills provision (Cowley *et al.*, 2000; Schulte *et al.*, 2008: 118; Smallwood, 2006a). The second provisional study raised the point by suggesting "An ongoing process to sensitise people ... CPD makes it easier to introduce", and "Ongoing education to keep it at the forefront of one's mind ... it's becoming more visible as a topic". The aforementioned MS of 4.25 relevant to architectural education and CPD programmes is also noteworthy in this instance. FG sample data included: "It must be specific. Another aspect that was mentioned is CPD, those of us who are not covered by any – but not only to cover people who are not qualified, but to continue your learning experience", and "Provided that the CPD thing actually teaches you and it is not only an attendance thing".

Engaging people and education and training are proffered as constituting the 'mechanisms' inclusive of the subcategories demonstrated.

4.4 The key outputs

This model component realises architectural design and a range of documentation, which can be improved in terms of designing for construction H&S, if architectural designers adequately engage the process.

Hetherington (1995) proposed design interventions during the 'concept stage', 'design evolution' and the 'detailed specifications', thereby suggesting that design, drawings, details and specifications are undertaken by architectural designers. He also claims that designers should provide information along with their designs to ensure that potential risks and associated issues are identified. The lists of design recommendations offered by Behm (2006: online), advocating Gambatese and Weinsteins' earlier work, also make reference to design and drawings. The range of key outputs was not directly questioned in the provisional studies; however, some aspects insinuate the work and documentation undertaken by architectural designers. As an example, the first provisional study included the statement 'Appropriate design and specifications can mitigate the use of hazardous materials which cause illness and terminal disease'. A MS of 4.05, which is well above the midpoint score of 3.00 was recorded, clearly indicating that design and specifications form part of the work and documentation undertaken by architectural designers. Relative to the 'products' produced, FG sample data included: "You produce your design, your drawings, and specifications". The facilitator probed: "Design, drawings, specifications — can all construction hazards and risks be eliminated through the design process?" A clear "no" resounded. The facilitator asked: "What can designers do if they are aware of unresolved hazards and risks?", to which responses included: "You need to point that out to the contractor", and "Make the contractor aware of the unresolved risks".

Relative to safer design, it is proffered that the 'key outputs' produced by architectural designers include improved design for construction H&S; improved H&S information on plans; improved H&S information in specifications, and improved H&S residual risk information.

4.5 Dissemination

WorkCover NSW (2001) includes the need for 'information transfer' as an essential requirement of the Australian CHAIR model, while Hetherington (1995: 5-6) insists that designers should provide information along with their designs to ensure that potential risks and associated issues are identified. The 'dissemination of information' was not directly included in the provisional studies. However, statements included in the first provisional study such as 'Appropriate design and specifications can mitigate the use of hazardous materials which cause illness and terminal disease', and 'Appropriate design can mitigate hazardous construction work which places contractors at risk', which achieved MSs of 4.05 and 3.29, respectively, both above the midpoint score of 3.00, insinuate that, *inter alia*, design documentation exists and filters through to contractors, in order for construction to take place. FG data as to the distribution of the range of key outputs included: "They should be part of the contract documentation"; "They are actually – or not? They should be, ja (Colloquial 'yes')"; "We give it to the tenderers"; "The client and the contractor"; "and to the quantity surveyors for the bills of quantities"; "to a regulating authority who is responsible to regulate that …"; "If it was me it would be the entire project team (Participants nod)", and "They should be part of the process all the way through".

Due to every project being different in terms of the number and nature of the stakeholders involved, it is argued that, for purposes of the model, the range of 'destinations' remain broad and that architectural designers define all stakeholders by specific project.

4.6 The continuous information feedback loop

Literature was not directly interrogated in terms of 'a continuous information feedback loop'. Research, however, alludes to this as Booth, Colomb & Williams (1995) consider a research process which really includes feedback, but is possibly better defined by Leedy & Ormrod, (2010) who advocate Cresswell (1998) and consider an up and down 'data analysis spiral', really helical in nature, meaning that feedback is essential for further development – and in this case sustainability of the model in question. The UK's Gateway model (HSE, 2004a) and the Australian CHAIR model (WorkCover NSW, 2001) both insist on the need for accurate record-keeping for use on current and future projects – a means of 'feedback' itself. The notion of a continuous information feedback loop was not directly included in the provisional studies either; however, data commentary included in the second provisional study such as 'On-going education to keep it at the forefront of one's mind …', and the fact the provisional studies which constitute research ultimately facilitated the development of the structured questions used in the main study, would beg the question of the purpose of education and research if it were not ploughed back into 'the system'? FG sample data included: "Once you get to a recipe that you know is fool-proof, it talks to a standard – and informs the next one", and "Isn't that the purpose – It should be". The facilitator probed: "Can this evolve into continuous H&S improvement on projects?" Brief responses indicated "Yes", and "Definitely (nodding from participants)".

The importance of a 'continuous information feedback loop' is proffered to ensure continual evolution of the model and to maximise potential for mitigation of construction hazards and risks

4.7 The Process Model for safer architectural design in South Africa

While the provisional model is not demonstrated in this instance, a logical approach toward sequencing and assembly thereof was undertaken. The final model is demonstrated following the validation and refinement which follows. The provisional model comprised:

- First, the 'key inputs' are considered toward development and ongoing updating of the model as more information becomes available and feeds into the core model.
- Secondly, the 'core model' comprises a matrix 'model framework' which incorporates a 'design opportunity window' (cyclic design process) supported by a 'design knowledge window' (requisite knowledge needed to support the cyclic design process), and is envisaged to create a development platform to feed the 'mechanisms'.
- Thirdly, the 'mechanisms' involve the use of the core model toward development of appropriate 'education and training' and that of 'engaging people' in order to prepare architectural designers to use the core model.

- Fourthly, the 'key outputs' rely on the ability of architectural designers to use the model effectively in order to produce the range of 'improved' key outputs toward mitigation of construction hazards and risks.
- Fifthly, 'dissemination' relies on the distribution of the improved key outputs to all stakeholders involved in a project.
- Sixthly, the 'continuous information feedback loop' can emanate from virtually any aspect of the overall model and loops back toward improving the model through a cyclic or helical process.

The provisional model comprised a core model embedded within a greater process model, and was forwarded to the focus-group participants toward validation and refinement.

5. Refinement of the model

Based on an 83.3% response rate, the percentage responses relative to the five-point scale relating to the model components are presented in Table 1.

Table 1: Degree of concurrence relative to the model components, the subcomponents and the overall model statements

Statements	*Response %*						*Mean score*
	Unsure	*Totally disagree ... Totally agree*					
		1	*2*	*3*	*4*	*5*	
The range of 'key inputs' are valuable toward development and ongoing updating of the model (model sustainability).	0.0	0.0	0.0	0.0	40.0	60.0	4.60
The 'matrix framework' comprising the NBR structure and the SACAP architectural work stages is appropriate.	0.0	0.0	0.0	20.0	40.0	40.0	4.20
The range of opportunities in the cyclic 'design opportunity window' incorporated in the matrix framework is appropriate.	0.0	0.0	0.0	0.0	60.0	40.0	4.40
The range of requisite knowledge offered in the 'design knowledge window' is appropriate.	0.0	0.0	0.0	0.0	70.0	30.0	4.30
The range of 'mechanisms' toward implementation / use of the model is appropriate.	0.0	0.0	0.0	0.0	40.0	60.0	4.60
The range of 'improvements' relative to construction H&S is appropriate as 'key outputs'.	0.0	0.0	0.0	10.0	50.0	40.0	4.30

Statements	*Unsure*	*Response %*					*Mean score*
		Totally disagree ... Totally agree					
		1	*2*	*3*	*4*	*5*	
The range of 'stakeholders' for distribution of the key outputs is appropriate.	0.0	0.0	0.0	0.0	40.0	60.0	4.60
The 'continuous information feedback loop' is appropriate for updating and improving the model.	0.0	0.0	0.0	10.0	20.0	70.0	4.60
The overall model, in time, can serve toward improved designing for construction health, safety, and ergonomics.	0.0	0.0	0.0	10.0	30.0	60.0	4.50

The lowest MS constituting 11.2% of the nine statements is 4.20, which indicates that the degree of concurrence can be deemed to be at the uppermost extreme of the range 'neutral to agree/agree'. The balance of the MSs constituting 88.8% of the nine statements range from 4.30 to 4.60 and indicate that the degree of concurrence can be deemed to be between 'agree to totally agree/totally agree', and are all well above the midpoint score of 3.00. The significantly high range of MSs is representative of the high level of concurrence and the positive outlook provided by the respondents, and further demonstrates the accurate reflection of the FG deliberations and the data. It is notable that there were no unsure responses. The components and the overall model are all considered acceptable – at least in the eyes of the FG participants – with the refinement process seeing the change of terminology from 'variation orders' to 'changes to design', due to VOs being specific to a limited range of contract documentation. Based on the refinement process, the researcher intentionally removed the word 'provisional' from the model title. Diagram 1 demonstrates the refined model.

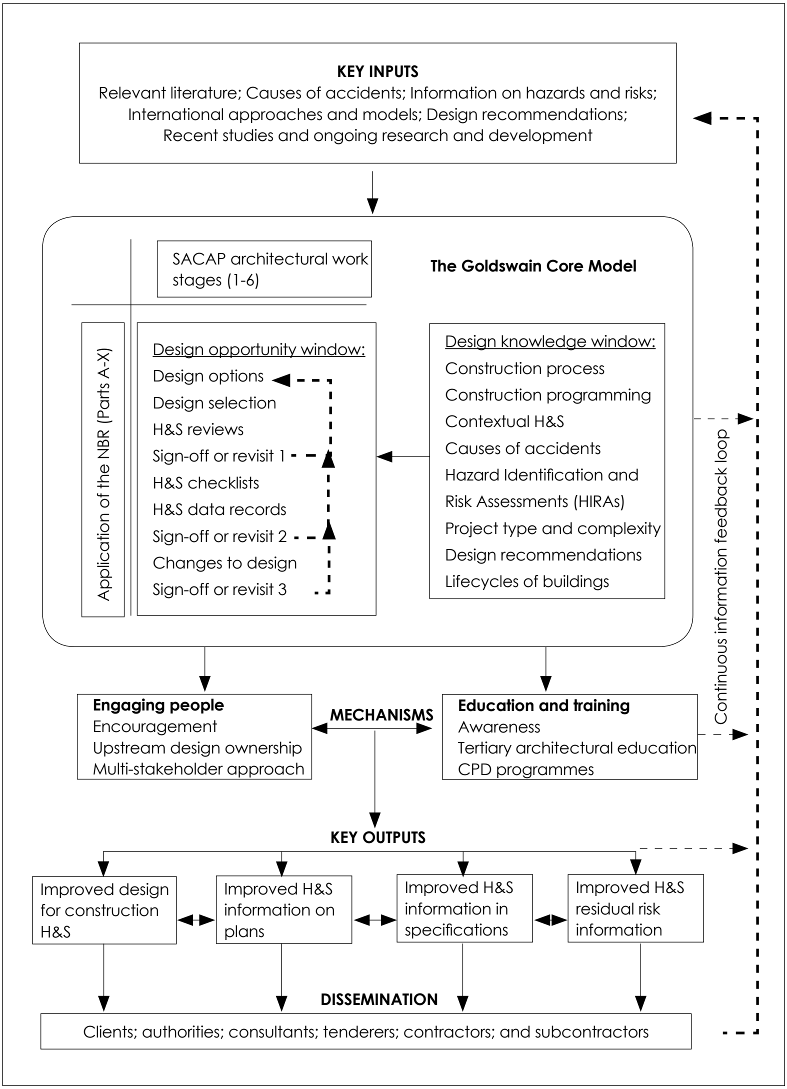

Figure 1: The Goldswain Process Model for safer architectural design in South Africa

6. Conclusions and recommendations

Appropriate literature and the four provisional studies gave rise to a range of structured questions, which were used to solicit a vast richness of qualitative data from the FG participants within the AR paradigm. Synthesis of the data with literature and the provisional studies gave rise to a provisional model which was validated and refined while simultaneously testing the research hypotheses by means of FG participants. The model includes a core model embedded in a greater process model. Implementation and use of the core model relies on the knowledge of architectural designers relative to designing for construction H&S. It is, therefore, recommended that the interrelated 'mechanisms' included in the greater process model are of utmost importance. These include 'engaging people', which proffers the encouragement of architectural designers to take upstream design ownership and to involve a multitude of stakeholders in an enthusiastic attempt at designing for construction H&S. It is acknowledged that this is no simple task, and further recommendation is therefore made in terms of 'education and training', whereby architectural designers gain awareness through various means, including tertiary architectural education and architectural CPD programmes. In order to achieve this, role players such as tertiary education institutions offering architectural programmes and their academic staff, and those interested in developing and offering architectural CPD programmes themselves take 'upstream design ownership' and use the model as basis for designing appropriate tertiary academic programmes and architectural CPD programmes.

This research does not consider the model as a complete means to an end. Further investigation is needed in order to design the recommended programmes and thus populate the model accordingly. While the research touched on the mechanisms for inclusion of the model into tertiary architectural education, the findings were far from conclusive. Further research in this regard is essential. From adversity comes opportunity. This is an opportunity to realise a paradigm shift in architectural thinking and practice – the new upstream owners of safer construction.

References list

Behm, M. 2006. An analysis of construction accidents from a design perspective. [online]. Available from: <http://www.elcosh.org/en/document/841/d000795/an-analysis-of-construction-accidents-from-a-design-perspective.html> [Accessed on 9 September 2010].

Behm, M. & Culvenor, J. 2011. Safe design in construction: Perceptions of engineers in Western Australia. *Journal of Health and Safety Research and Practice*, 3(1), pp. 9-23.

Booth, W. Colomb, G. & Williams, J. 1995. *The craft of research*. Chicago, ILL: The University of Chicago Press.

Bureau of Labour Statistics – US Department of Labour (BLS). 2007. Fatal occupational injuries by occupation and event or exposure, All United States, 2007. [online]. Available from: http://www.bls.gov/iif/oshwc/cfoi/cftb0227.pdf [Accessed on 20 April 2010].

Bureau of Labour Statistics – US Department of Labour (BLS). 2008. Fatal occupational injuries by occupation and event or exposure, All United States, 2008. [online]. Available from: http://www.bls.gov/iif/oshwc/cfoi/cftb0236.pdf [Accessed on 20 April 2010].

Cameron, I., Duff, A. & Hare, B. 2005. Achieving integration of safety, health, environment and quality management in construction project management by a best practice "gateway" model. In: *Proceedings of the 4th Triennial International Conference, Rethinking and Revitalizing Construction Safety, Health, Environment and Quality*, Port Elizabeth, 17-20 May 2005. Port Elizabeth: CREATE, pp. 323-331.

Carter, G. & Smith, S. 2006. Safety hazard identification on construction projects. *Journal of Construction Engineering and Management*, 132(2), pp. 197-205.

Chang, A.S. & Lee, K.P. 2004. Nature of construction technology. In: Bertelsen, S. & Formoso, C.T. (Eds.) Proceedings of the *12th Annual Conference of the International Group for Lean Construction.* Helsingør, Denmark, 3-5 August 2004, pp 1-10.

Construction Design and Management (CDM). 2007. The Construction (Design and Management) Regulations 2007 No. 320. [online]. Available from: http://www.opsi.gov.uk/si/si2007/uksi_20070320_en_1 [Accessed on 5 March 2009].

Construction Industry Development Board (cidb). 2009. *Construction health and safety in South Africa - Status and recommendations*. Pretoria: cidb.

Cowley, S., Culvenor, J. & Knowles, J. 2000. *Safe design project – Review of literature and review of initiatives of OHS authorities and other key players*. Victoria: Commonwealth of Australia.

Deacon, C.H. 2004. The health status of construction workers. Unpublished M.Cur. thesis. Port Elizabeth: University of Port Elizabeth.

Deacon, C. & Smallwood, J.J. 2010. Ergonomics in construction: Where does it hurt? *Ergonomics SA*, 22(2), pp. 49-65.

European Federation of Engineering Consultancy Associations (EFCA) and the Architects' Council of Europe (ACE). 2006. Designing for safety in construction: Taking account of the general principles of prevention. [online]. Available from: http://www.efcanet.org/Portals/EFCA/ELKONET/1232/DesigningForSafety.pdf [Accessed on 23 April 2011].

Gangolells, M., Casals, M., Forcada, N., Roca, X. & Fuertes, A. 2010. Mitigating construction safety risks using prevention through design. *Journal of Safety Research,* 41(2), pp. 107-122.

Geminiani, F.L., Smallwood, J.J. & Van Wyk, J.J. 2005. A review of the effectiveness and appropriateness of the occupational health and safety inspectorate in South Africa. In: Smallwood, J.J. & Haupt, T.C. (Eds.) *Proceedings of the 4th Triennial International Conference: Rethinking and Revitalizing Construction Safety, Health, Environment and Quality*, Port Elizabeth, 17-20 May 2005. Port Elizabeth: CREATE, pp. 38-50.

Gibb, A., Haslam, R., Hide, S., Gyi, D. & Duff, R. 2006. What causes accidents? *Proceedings of the Institution of Civil Engineers (ICE)*, 159(6), November, pp. 46-50.

Haslam, R.A., Hide, S.A., Gibb, A.G.F., Gyi, D.E., Pavitt, T., Atkinson, S. & Duff, A.R. 2005. Contributing factors in construction accidents. *Journal of Applied Ergonomics*, 36(4), pp. 401-415.

Hendrickson, C. 2008. *Project management for construction: Fundamental concepts for owners, engineers, and architects.* 2nd edition., version 2.2. [online]. Available from: http://pmbook.ce.cmu.edu/index.html [Accessed on 5 December 2012].

Hetherington, T. 1995. Why involve design professionals in construction safety? *Structural Survey*, 13(1), pp. 5-6.

Health and Safety Executive (HSE). 1998. *Five steps to risk assessment*. INDG163(rev1). Sudbury, Suffolk: HSE Books.

Health and Safety Executive (HSE). 2003. *Causal factors in construction accidents – Research Report 156.* Sudbury, Suffolk: HSE Books.

Health and Safety Executive (HSE). 2004a. *Integrated gateways: Planning out health and safety risk – Research Report 263.* Sudbury, Suffolk: HSE Books.

Health and Safety Executive (HSE). 2004b. *Improving health and safety in construction. Phase 2 – Depth and breadth: Volume 6 – Generic model for health and safety in construction – Research Report 235*. Berks: Bomel Ltd for HSE Books.

Health and Safety Executive (HSE). 2010a. European comparisons – Tables [online]. Available from: http://www.hse.gov.uk/statistics/european/tables.htm [Accessed on 19 April 2010].

Health and Safety Executive (HSE). 2010b. *Construction Statistics 2005/06(p) – falls down, trips up*. Sudbury, Suffolk: HSE Books. [online]. Available from: http://www.hse.gov.uk/statistics/overall/hssh0506.pdf) [Accessed on 20 April 2010].

Hinze, J. 2005. A paradigm shift: Leading to safety (Keynote Address). In: Smallwood, J.J. & Haupt, T.C. (Eds.) *Proceedings of the 4th Triennial International Conference: Rethinking and Revitalizing Construction Safety, Health, Environment and Quality*, Port Elizabeth, 17-20 May 2005. Port Elizabeth: CREATE, pp. 1-11.

Innes, J. 2009. *OHS management in the construction industry.* SafetyLine Institute, West Perth: WorkSafe.

Leedy, P.D. & Ormrod, J.E. 2010. *Practical research planning and design*. 9th edition. (international edition.). Cape Town: Pearson Education International.

Lester, A. 2007. *Project management, planning and control*. 5th edition. Oxford: Elsevier Ltd.

Mroszczyk, J.W. 2005. Designing for construction worker Ssafety. [online]. Available from: http:www.asse.org/membership/docs/John%Mroszczyk%20Article.doc [Accessed on 2 October 2008].

Neil, I. 1994. Risk management for premises managers 1993-94. *Facilities*, 12(4), pp. 21-24.

Occupational Safety and Health Council. 2004. Guidance notes on health hazards in construction work. South Africa, Department of Labour: Occupational Safety and Health Branch. [online]. Available from: <http://www.labour.gov.hk/eng/public/oh/OHB82.pdf> [Accessed on 14 November 2010].

Penny, E. 2007. Deaths and fatalities in construction: What you really need to know. [online]. Available from: http://www.contractjournal.com/Articles/2007/04/19/54532/deaths-and-fatalities-in-construction [Accessed on 10 April 2010].

Republic of South Africa. 2003. Construction Regulations 2003. [online]. Available from: <http//www.labour.gov.za/> [Accessed on 16 July 2008].

Republic of South Africa. 2010. *SANS 10 400: The application of the National Building Regulations (NBR)*. Pretoria: SABS Standards Division.

Republic of South Africa. 2014. *Construction Regulations 2014*. *Government Regulation Gazette No. 10113*, 7 February 2014. Pretoria: Government Printing Works.

Safe Work Australia. 2010. *Compendium of workers' compensation statistics Australia 2007-2008.* Canberra: Commonwealth of Australia.

Schneider, S.P. 2006. The economics of health and safety in construction. Labourers Health and Safety Fund of North America. [online]. Available from: http://www.lhsfna.org/files/construction_economics.pdf [Accessed on 9 September 2008].

Schulte, P.A., Rinehart, R., Okun, A., Geraci, C.L. & Heidel, D.S. 2008. National Prevention Through Design (PtD) Initiative. *Journal of Safety Research*, 39(2), pp. 115-121.

Smallwood, J.J. 2006a. The influence of architectural designers on health and safety (H&S) during construction. In: Haupt, T.C. (Ed.) *Proceedings of the 3rd South African Construction Health and Safety Conference, A Team approach to Construction Health and Safety*, Cape Town, 7-8 May. Port Elizabeth: CREATE, pp. 29-46.

Smallwood, J.J. 2006b. Ergonomics in construction: South African perspective. *Proceedings of CIB W107 International Symposium on Construction in Developing Economies: New Issues and Challenges, Santiago*, Chile, *18-20* January. Rotterdam: CIB, pp.303-310.

Smallwood, J.J. 2007. The influence of architectural designers on construction ergonomics. In: Boyd, D. (Ed.) *Proceedings of the 23rd Annual ARCOM Conference*, 3-5 September 2007. Belfast, UK: Association of Researchers in Construction Management, pp. 619-628.

Smallwood, J.J. & Deacon, C.H. 2001. Construction materials and processes: General Contractor (GC) health-related perceptions. In: Kelly, J. & Hunter, K. (Eds.) *Proceedings of the RICS Foundation – Construction and Building Research Conference (COBRA)*, Glasgow, 3-5 September *2001*, pp. 367-374 (Volume 1).

Smallwood, J. & Haupt, T. 2005. The need for construction health and safety (H&S) and the construction regulations: Engineers' perceptions. *Journal of the South African Institution of Civil Engineering*, 47(2), pp. 2-8.

Toole, M. & Gambatese, J. 2006. The future of designing for construction safety. CIB Leadership in Construction Conference. [online]. Available from: http://www.designforconstructionsafety.org [Accessed on 18 February 2009].

Van Teijlingen, E.R. & Hundley, V. 2001. The importance of pilot studies. *Social Research Update*, Issue 35, Winter 2001, University of Surrey. [online]. Available from: file://localhost/C:/Documents%20and%20 Settings/All%20Users/Documents/Research/Website%20Info/The%20 [Accessed on 4 August 2009].

Weitz & Luxenberg, P.C. 2010. Construction death statistics, 2008. [online]. Available from http//www.weitzlux.com/construction-deaths_1937852.html [Accessed on 19 April 2010].

WorkCover NSW. 2001. *CHAIR Safety in design tool.* Suffolk: WorkCover NSW.

WorkSafe Victoria. 2005. Hazard identification, risk assessment and risk control in the workplace. [online]. Available from: https://archive.is/hTF8y [Accessed on 18 November 2011].