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Tydskrif vir die fisiese en ontwikkelingswetenskappe

Acta Structilia is 'n Suid-Afrikaanse geakkrediteerde tydskrif, wat publikasiegeleenthede bied vir onafhanklikgerefereerde artikels deur plaaslike en buitelandse navorsers op die terreine van die fisiese en ontwikkelingswetenskappe. Elke gekeurde artikel word as sodanig aangedui. Die redaksie oorweeg Afrikaanse of Engelse artikels oor onderwerpe binne studievelde soos: argitektuur, stads- en streekbeplanning, bourekenkunde, konstruksie- en projekbestuur, bou-ekonomie, ingenieurswese, die eiendomsbedryf en die ontwikkelingsveld rondom gemeenskapsbouprojekte. *Acta Structilia* verskyn twee keer per jaar onder die vaandel van die Universiteit van die Vrystaat. Die tydskrif word gelewer aan die betrokke navorsingsinstansies, Suider-Afrikaanse universiteite met bogemelde navorsings-departemente, Suid-Afrikaanse navorsingsbiblioteke, geselekteerde buitelandse instansies en intekenaars. Menings en kritiek in die tydskrif is dié van die outeur(s). Publikasie daarvan is nie 'n aanvaarding dat die Redaksie of die Universiteit van die Vrystaat verantwoordelikheid daarvoor aanvaar nie.

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The South African Council for the Quantity Surveying Profession endorses *Acta Structilia*

The South African Council for the Quantity Surveying Profession (SACQSP) has simplified the submission and assessment of Continuining Professional Development (CPD) requirements of registered persons. CPD submission now requires disclosure of the number of hours invested meaningfully in activities in two main categories. Category 1 activities are those arranged or presented by or to 'external' organisatins such as participation in conferences, congresses, workshops or seminars, presentation of lectures, external examination for academic programmes, publication of articles in journals or magazines, other similar activities. Category 2 activities are less formal 'internal' activities such as in-house training or seminars, small group discussions, self-study of journals, magazines, articles on web pages, etc.

To assist registered persons with access to journal articles related to quantity surveying and, more generally, built environment issues, the SACQSP at its meeting in March 2007 adopted a recommendation to endorse the journal, *Acta Structilia*, which publishes quality, peer-reviewed articles and is accredited by the Department of Education.

Council encourages registered persons to peruse *Acta Structilia* and similar peer-reviewed journals as one of the alternative options to accumulate CPD credits in Category 2 activities. For a limited period, Council will encourage the circulation of *Acta Structilia* to registered persons.

Professor RN Nkado
President

Royal Institution of Chartered Surveyors (RICS) supports *Acta Structilia*

Royal Institution of Chartered Surveyors (RICS) supports the aims and objectives of *Acta Structilia* and welcomes the efforts being made to improve our knowledge and understanding of the built environment, particularly in an African context.

Craig Goldswain & John Smallwood

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

Peer reviewed and revised

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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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	*Unsure*	*Response %* Totally disagree ... Totally agree					*Mean score*
		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		*Response %*					
	Unsure	*Totally disagree ... Totally agree*					*Mean score*
		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.

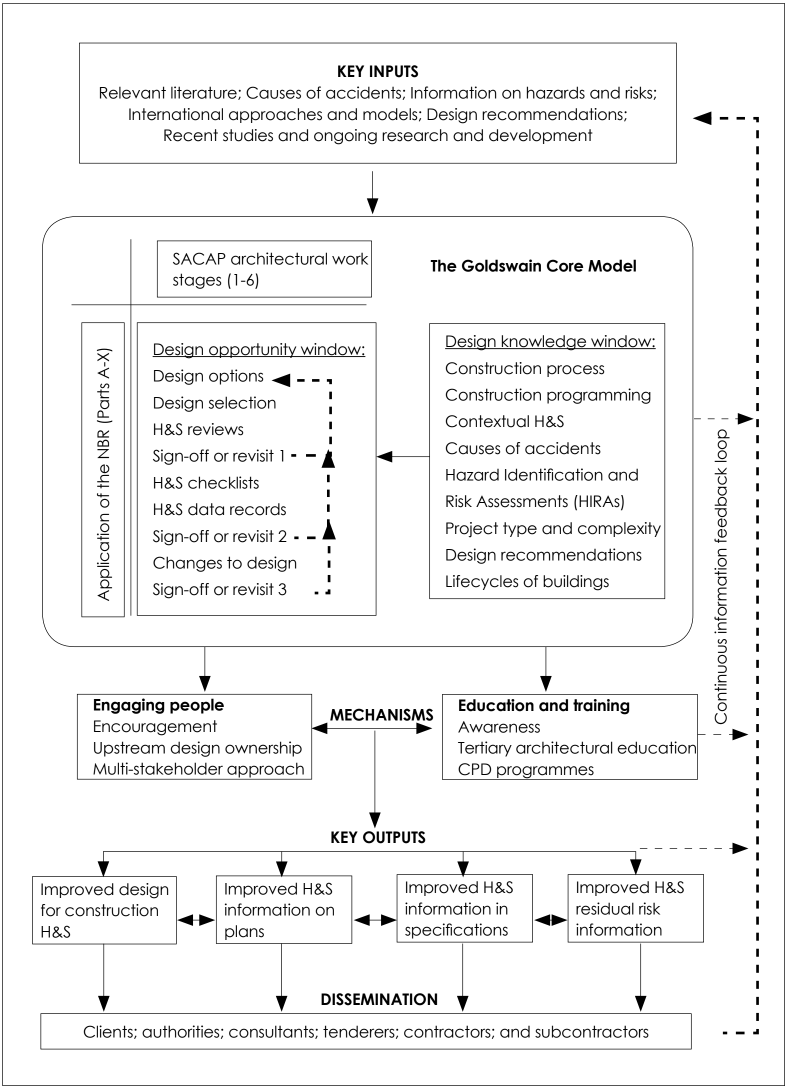

Figure 1: The Goldswain Process Model for safer architectural design in South Africa

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.

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Colin Gewanlal & Michiel Bekker

Project manager attributes influencing project success in the South African construction industry

Abstract

The South African construction industry has suffered the loss of many qualified middle-management-level project managers in recent years. This has resulted in many young, inexperienced project managers being forced to manage large complex projects. In addition, senior project managers, who are still practising locally, are too busy to mentor and guide the younger project managers, due to the shortage of professionals in the local industry. This article reports on a study done to identify the most important attributes that influence project success in the South African construction industry, by extracting a list of factors identified in the existing literature and grouping these factors into six main categories. Each category contains six factors. A questionnaire was compiled and distributed via an online survey tool. The data was analysed using statistical methods including concordance and correlation. The results indicated that 'interpersonal factors' was considered the most important category, followed by 'application of theory'. 'Personal contribution' and 'personal character' were considered the least important categories. However, the most important attributing factors were 'communication skills' and 'leadership style', neither of which was listed under the top two categories. In general, a low level of concordance was achieved, confirming the belief that level of knowledge, experience and mutual agreement among participants in the industry is low.

Keywords: Project manager attributes, project experience, construction management, project manager profiles.

Abstrak

Die Suid-Afrikaanse konstruksiebedryf het in die afgelope paar jaar baie gekwalifiseerde middel-bestuursvlak projekbestuurders verloor. Dit het daartoe gelei dat baie jong, onervare projekbestuurders gedwing word om groot komplekse projekte te bestuur. Hierdie artikel rapporteer die resultate van 'n studie gedoen om die belangrikste faktore wat die projeksukses in die Suid-Afrikaanse konstruksiebedryf beïnvloed, te identifiseer. 'n Literatuurstudie is gedoen om die belangrikste suksesfaktore te bepaal en in ses kategorieë te groepeer. Elke kategorie bevat ses faktore. 'n Vraelys is saamgestel en aanlyn gestuur aan moontlike deelnemers. Die data is ontleed met behulp

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van statistiese metodes, insluitend konkordansie en korrelasie. Die resultate het getoon dat die belangrikste kategorie was 'interpersoonlike faktore', gevolg deur 'toepassing van teorie'. 'Persoonlike bydrae' en 'persoonlike karakter' is beskou as die kategorieë met die minste impak. Die belangrikste faktore vir projeksukses was 'kommunikasievaardighede' en 'leierskapstyl', waarvan beide nie onder die top twee kategorieë verskyn nie. Oor die algemeen is 'n lae vlak van konkordansie bereik wat bevestig dat die vlak van kennis, ondervinding en eenstemmingheid tussen deelnemers in die industrie baie laag is.

Sleutelwoorde: Projekbestuurvaardighede, projekondervinding, konstruksiebestuur, projekbestuurprofiel

1. Introduction

Since the mid-1990s, the South African construction industry has witnessed a significant loss of qualified and experienced project managers to other countries, other sectors of the economy, and retirement (Lawless, 2007: 1). Notwithstanding the lack of experienced and skilled project managers, the South African Government has identified infrastructure development as a means to stimulate the economy (South Africa. National Planning Commission, 2011: 137). A survey conducted by Lawless (2007: 2) revealed that the number of graduates and the quality of education in all spheres of education was declining. This resulted in young and inexperienced project managers being deployed to manage large and often, complex projects. Apart from the inexperience, the shortage of qualified project managers also resulted in young project managers being overloaded with work.

As the key pin to all activities and relationships, the project manager contributes significantly to the success or failure of construction projects. Even though a number of international studies were done on the topic of project competence (Crawford, 2005; Muller & Turner, 2010; Dolfi & Andrews, 2007), limited knowledge exists regarding the key attributes required of project managers in the South African construction industry to deliver successful projects.

The problem statement for this research is: 'The most important project management attributes required for successful projects in the South African construction industry is unknown'.

Given the problem statement, the aim of this study was to identify those project management attributes that extend beyond formal qualifications in the construction industry. A second objective was to assess members of the construction industry's understanding and agreement of what the most important attributes are. In conclusion, the results should guide project managers, recruitment officers and organisations, in general, to assess their current status and approach to project management development in order to improve the likelihood of developing and implementing successful projects.

2. Factors influencing project performance in the construction industry

In various research outputs, Belassi & Tukel (1996) found that there was a great deal of variation among different types and sectors of projects. The construction industry have seen project performance research focusing on individual countries, contribution of stakeholders such as clients, contractors and consultants, as well as technical aspects such as, among others, level of design accuracy, constructability and safety.

Baloyi & Bekker (2011: 62) conducted research on the causes of cost overruns and project delays on the 2010 FIFA World Cup Stadia in South Africa. From a contractor's perspective, one of the most significant causes for cost overruns was the lack of skilled labour. However, for project delays, the contributing factors were again the lack of skilled labour, poor planning and scheduling, as well as labour disputes and strikes.

Ahadzie, Proverbs & Olomolaiye (2007: 684) investigated the critical success criteria for building projects in Ghana and concluded that the "current and future success of an enterprise is a reflection of the effectiveness of the senior team, their vision and leadership, and the combined knowledge and skills of the organisation's workforce". Project leadership and supervision featured as key factors in the research conducted by Odusami (2003: 525) on Nigerian construction projects. This study tested the effect of a team leader's professional qualifications, profession, leadership style and project team composition on the overall success of construction projects. The results indicated that the project leader's qualification significantly affected project performance. Muller & Turner (2007: 22-23) investigated the interaction of the project manager's leadership style with project type and the effect of these two factors on the overall success of the project. Project managers' leadership styles were modelled in terms of intellectual, emotional and managerial competence and compared to the success of their most recent projects. Seven traits of effective project managers were identified: problem-solving ability; results orientation; energy and initiative; self-confidence; perspective; communication, and the ability to negotiate.

Chua, Kog & Loh (1999: 148-149) listed ten critical success factors for construction projects. Apart from technical requirements, the list also included project manager attributes such as competency as well as commitment and level of involvement. Crawford (2000: 13-14) studied the profile of a competent project manager. She presented an analysis of research-based literature concerning the criteria whereby project success is determined, the factors that contribute to the success of projects, as well as the project managers' knowledge, skills and personal attributes that are expected to lead to the achievement of successful project outcomes. In a follow-up study, Crawford examined senior management's perceptions of a project manager's competence. The results suggested different perceptions and expectations of project management competence between project managers and their supervisors or senior management. She defined competence as "an underlying characteristic that is causally related to criterion-referenced effective and/or superior performance in a job or situation" (Crawford, 2005: 8, 15).

3. Categorising project manager attributes

Schultz, Slevin & Pinto (1987: 34) created two broad categories, namely 'strategic' and 'tactical' requirements. Bellasi & Tukel (1996: 142-143) grouped the success factors into five areas, namely factors related to the 'project', 'project manager', 'project team members', 'corporate organization', and 'external factors'. Ahadzie *et al*. (2007: 684-687) found four clusters of criteria, namely 'project environment', 'customer interaction and satisfaction', 'product quality', and 'value and time'. Crawford (2005: 12) contended that competence could be inferred from attributes, which included knowledge, skills and experience, personality traits, attitudes, and behaviours.

In reviewing the above literature and studying the specific traits in the defined categories of the mentioned authors, with specific reference to the findings by Crawford (2005: 12-15), the following six categories for project manager attributes were identified: interpersonal factors, application of theory, personal character factors, personal contribution factors, personal skills, and practical application. Each category was further divided into six factors, as explained in Table 1.

Table 1: Categories for project manager attributes

Category 1 – Interpersonal factors (attributes concerning interaction with team members)	
1.a	Supervision of project team
1.b	Ability to delegate authority
1.c	Ability to motivate team members
1.d	Sense of teamwork

1.e	Stakeholder management (parent organisation)
1.f	Stakeholder management (client)
Category 2 – Application of theory (professional qualifications and application of theoretical planning , controlling and monitoring tools)	
2.a	Professional qualifications
2.b	Monitoring and controlling (time)
2.c	Planning (integrative)
2.d	Monitoring and controlling (integrative)
2.e	Monitoring and controlling (cost)
2.f	Planning (time)
Category 3 – Personal character (personal motivation and character traits)	
3.a	Leadership style
3.b	Emotional intelligence
3.c	Results orientation
3.d	Energy and initiative
3.e	Self-confidence
3.f	Optimism
Category 4 – Personal contribution (management actions taken to achieve project success)	
4.a	Ability to determine cost – time trade-offs
4.b	Level of involvement in the project
4.c	Ability to determine quality – time trade-offs
4.d	Ability to establish an appropriate organisational structure
4.e	Commitment to meet cost, time and quality constraints
4.f	Desire to achieve success and recognition
Category 5 – Personal skills (managerial skills to apply to projects)	
5.a	Communication skills
5.b	Technical skills
5.c	Organising skills
5.d	Coordinating skills
5.e	Negotiating skills
5.f	Decision-making and problem-solving skills
Category 6 – Practical application (practices to implement during projects)	
6.a	Ability to implement an effective safety programme
6.b	Ability to implement an effective quality assurance programme
6.c	Relevant work experience
6.d	Control of subcontractors' work
6.e	Adaptability to changes in the project plan
6.f	Define and follow strategic direction

It can be argued that all the attributes identified and summarised in Table 1 are important. However, some attributes might be more important than others in the South African construction industry. To find the "perfect" project manager remains an elusive goal, but guidance in selecting the best candidate should help improve the likelihood of project success.

Based on the attributes identified, a questionnaire was designed and distributed to potential participants in the South African construction industry, with the aim to identify the most important attributes required for project managers in the industry.

4. Research methodology

The required attributes, skills and competencies for project managers have been well researched. This research aims to identify those attributes that are most important for the South African construction industry.

In order to identify the most important attributes from a given selection, the rank Kendall *W* concordance method was selected (Legendre, 2005: 227). The Kendall *W* method analyses ordinal values and is a normalisation of the Friedman test. For this research, the absolute value of each attribute is the main value of significance, with agreement among participants secondary. For this reason, the Kendall *W* method is sufficient as opposed to Friedman or even Spearman rho testing.

Primary data was created through the distribution of a questionnaire to construction project managers. The instrument took the form of a self-administered questionnaire containing multiple-choice questions related to the respondent's personal details as well as six categories of six attributes each of project managers to be completed in a rank order from one being the most important[1] attribute to six being the least important attribute.

The process and equations of analysing the ordinal rank-order data with the Kendall W method is given below.

If attribute *i* is given the rank $r_{i,j}$ by respondent number *j,* with *n* attributes and *m* respondents, then the total rank given to attribute *i* is:

$$R_i = \sum_{j=1}^{m} r_{i,j}$$

1 The evaluation criteria assigning one as the most important was clearly set as such and communicated to the participants.

The mean value of the ranks is then calculated as:

$$\bar{R} = \frac{1}{n} \sum_{i=1}^{n} R_i$$

The sum of the squared deviations *S* is then calculated as:

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2$$

Kendall *W*, also known as the Kendall coefficient of concordance, is then calculated as:

$$W = \frac{12S}{m^2(n^3 - n)}$$

The value *W* provides an indication of the degree of unanimity among the respondents. If *W* is 1, then all the respondents are unanimous about their views, whereas a value of 0 indicates no agreement. Intermediate values indicate the lesser or greater degree of agreement.

All surveys were complete anonymously. A request was posted to the South African Institute of Civil Engineering South Africa (SAICE) to forward the questionnaire to their members via email. A bulk email was sent; but the exact number of successful recipients could not be confirmed, due to email not being delivered or no longer existing. It is estimated that approximately 5,000 questionnaires were emailed; this also included emails to project management companies, engineering consulting firms, engineering contractors, and government departments such as the Department of Public Works and the Department of Water Affairs. A total of 163 responses were received, giving an approximate response rate of 3.3%. Even though the response rate was low, the number of responses was satisfactory.

4.1 Analysis of data and interpretation of findings

The data received was entered into a database and analysed using Microsoft Excel.

The demographic profile of the respondents was significant. A total of 53.4% of the respondents had between one and ten years' experience. Only 20.3% of the respondents had over 20 years' experience, with only 18% aged over 50 years. This confirms the observation by Lawless (2007) that the current workforce is fairly young. The respondents were well educated, with 67% of them completing Bachelor's Degrees and 18% Masters degrees. The majority of the respondents (87%) were from consulting companies, with the remainder evenly split between construction and owner organisations. The gender response was 69% for males and 31% for females; this is a fair reflection of the industry profile.

4.1.1 Ranked attributes for each category

The results of the ranked attributes are given in Table 2. Although the coefficient of concordance *W* was low in all the studies, the sample for all the questions was statistically significant at both the 95% and the 99% levels.

Table 2: Ranked attributes for each category

Categories and associated attributes		*Rank frequency*						$\bar{R}$	*Rank*
		1	*2*	*3*	*4*	*5*	*6*		
Category 1 – Interpersonal factors									
1.a	Supervision of project team	44	36	33	23	8	19	2.83	1
1.c	Ability to motivate team members	21	31	39	32	30	10	3.3	2
1.f	Stakeholder management (client)	35	31	22	14	29	32	3.41	3
1.b	Ability to delegate authority	23	27	30	43	23	17	3.41	4
1.d	Sense of teamwork	35	18	22	32	27	29	3.52	5
1.e	Stakeholder management (parent organisation)	5	20	17	19	46	56	4.53	6
Category 2 – Application of theory									
2.c	Planning (integrative)	54	39	31	21	12	6	2.48	1
2.f	Planning (time)	36	50	24	15	19	19	2.93	2
2.b	Monitoring and controlling (time)	14	30	40	49	24	6	3.35	3
2.d	Monitoring and controlling (integrative)	12	16	36	40	36	23	3.87	4
2.e	Monitoring and controlling (cost)	10	13	28	28	58	26	4.16	5
2.a	Professional qualifications	37	15	4	10	14	83	4.21	6
Category 3 – Personal character									
3.a	Leadership style	81	32	25	12	10	3	2.06	1
3.b	Emotional intelligence	31	38	31	27	21	15	3.09	2
3.c	Results orientation	16	35	43	29	21	19	3.37	3
3.d	Energy and initiative	14	30	28	54	23	14	3.52	4
3.e	Self-confidence	18	22	23	26	62	12	3.79	5
3.f	Optimism	3	6	13	15	26	100	5.18	6

Category 4 – Personal contribution									
4.b	Level of involvement in the project	47	31	28	23	25	9	2.85	1
4.a	Ability to determine cost – time trade-offs	27	42	38	40	12	4	2.88	2
4.e	Commitment to meet cost, time and quality constraints	45	27	21	19	38	13	3.1	3
4.c	Ability to determine quality – time trade-offs	9	24	48	35	39	8	3.58	4
4.d	Ability to establish an appropriate organisational structure	19	23	17	39	39	26	3.82	5
4.f	Desire to achieve success and recognition	16	16	11	7	10	103	4.77	6
Category 5 – Personal skills									
5.a	Communication skills	78	37	25	16	3	4	2.02	1
5.f	Decision-making and problem-solving skills	43	47	29	10	10	24	2.81	2
5.b	Technical skills	23	34	29	26	25	26	3.45	3
5.c	Organising skills	11	24	43	44	29	12	3.56	4
5.d	Coordinating skills	5	16	25	46	47	24	4.14	5
5.e	Negotiating skills	3	5	12	21	49	73	5.01	6
Category 6 – Practical application									
6.f	Define and follow strategic direction	66	31	21	9	14	22	2.63	1
6.c	Relevant work experience	42	19	32	23	25	22	3.22	2
6.b	Ability to implement an effective quality assurance programme	20	32	39	30	32	10	3.32	3
6.e	Adaptability to changes in the project plan	15	47	28	27	29	17	3.36	4
6.a	Ability to implement an effective safety programme	18	22	19	38	31	35	3.9	5
6.d	Control of subcontractors' work	2	12	24	36	32	57	4.56	6

The first category evaluated was "interpersonal factors". This group consisted of factors describing project managers' interaction with other project role-players. It gauged the importance of the project managers' interaction with the project team, client and parent organisation. The factor 'supervision of project team' was chosen well ahead of all the other factors for this question. This selection seems logical, since the project manager remains the ultimate responsible person and occupies a leadership role. The majority of the respondents ranked the factor 'stakeholder management (parent organisation)' very low; it had one of the worst average ratings in the entire study. With a great deal of emphasis on stakeholder management in recent publications such as the *Project Management Body of Knowledge*

(2013: 391) and the British Standards Institution's *ISO 21500* (2012: 6) this low ranking was surprising. The remaining factors had a very small spread in the middle of this group. The coefficient of concordance *W* calculated for this question was 0.089, which means that the general agreement among participants was low.

The "application of theory factors" category dealt with the theoretical base from which project managers operate. It describes the project managers' ability to plan, monitor and control cost and time parameters as well as the integration of various activities in running projects. The effect of the project managers' qualifications on the success of projects is also included in this group. The factor 'planning (integrative)' was chosen ahead of all the other factors for this question. The majority of the respondents ranked the factor 'professional qualification', followed closely by 'monitoring and controlling (costs)', very low. The remaining factors were approximately evenly spread in the middle of this group. The coefficient of concordance *W* calculated for this question was 0.141.

The "personal character" category encompassed the innate psychological make-up of project managers. It consisted of attributes that are generally developed over the life of an individual rather than those that can be thought in a class. The factor 'leadership style' was chosen well ahead of all the other factors and, in fact, had the best average rating of all the factors in the study. The majority of the respondents ranked the factor 'optimism' very low. It had the worst average rating in the entire study. This is in contradiction to the findings of the study by Dolfi & Andrews (2007: 681) who found that optimism was an important attribute for successful project managers. The remaining factors had a minimal spread in the middle of this group. The coefficient of concordance *W* calculated for this question was 0.29.

The "personal contribution" category examined how the project managers physically contributed to the success of the project by their involvement and decision-making on a daily basis. Management of cost, time and quality parameters played a major role in influencing this group. The factors 'involvement in project' and 'ability to determine cost/time trade-offs on project' were chosen as the two most important factors in this group. The majority of the respondents ranked the factor 'desire for accomplishment/success/recognition' very low. It had one of the worst average ratings in the entire study. The remaining factors had a minimal spread in the middle of this group. The coefficient of concordance *W* calculated for this question was 0.15.

The "personal skills" category combined attributes related to the project manager;s talents. These are factors for which some project managers may have a predilection ahead of other project managers, despite them all receiving the same training. The factor 'communication skills' was chosen well ahead of all the other factors for this question. The majority of the respondents ranked the factor 'negotiating skills' very low. It had one of the worst average ratings in the entire study. The remaining factors had a reasonably large spread in the middle of this group. The coefficient of concordance *W* calculated for this question was 0.305.

The "practical application" category consisted of those 'hands-on' attributes related to actually running a project. It considered strategic elements of project execution, safety and quality as well as controlling external factors and the relevant work experience of the project manager. The factor 'ability to define and follow a strategic direction in projects' was ranked most important, with the factor 'control of subcontractors' work' ranked least important. The remaining factors had a very small spread in the middle of this group. The coefficient of concordance *W* calculated for this question was 0.124.

This final question required the respondents to rank the six categories of factors relative to each other (Table 3). The category 'interpersonal factors' was ranked as the most important. This observation supports the findings by Ahadzie *et al*. (2007: 684) and Odusami (2003: 525). The 'personal contribution' factor group was ranked as least important by a large margin. The remaining factor groups had a very small spread.

The coefficient of concordance *W* calculated for this question was 0.073. This means that there was a great deal of disagreement among respondents. Again, the concordance of the sample for this question was significant at both the 95% and the 99% levels.

Table 3: Overall ranking of categories

		Rank Frequency							
		1	*2*	*3*	*4*	*5*	*6*	$\bar{R}$	*Rank*
Category 1	Interpersonal factors	57	28	32	18	15	13	2.66	1
Category 2	Application of theory	23	44	26	24	18	28	3.33	2
Category 5	Personal skills	25	26	28	32	28	24	3.52	3
Category 6	Practical application	36	26	16	20	22	43	3.58	4
Category 3	Personal character	16	27	30	34	29	27	3.7	5
Category 4	Personal contribution	6	12	31	35	51	28	4.21	6

Some interesting observations were noted when viewing the results in terms of the demographic information.

Although the majority of the respondents were male, no notable differences could be observed in the responses from males and females.

The male and female subsets ranked the same factors as being the most important for all the groups, with the exception of the 'personal contribution' category. In the 'personal contribution' category, the males ranked 'involvement in project' as the most important factor, whereas the females ranked 'ability to determine cost/time trade-offs' as most important. Similarly, for the least important factors in each category, all but one group was ranked the same by the male and female subsets. In the 'application of theory' category, the males ranked 'monitoring and controlling (costs)' as least important, whereas the females ranked 'professional qualifications' as least important. Since the margins of differences were almost negligible, no significant conclusion could be made from these observations.

A total of 85% of the respondents had a Bachelor's Degree or higher, and 15% had a technical or matriculation qualification. This may have introduced bias into the study, as it is not representative of the construction industry in South Africa.

The two subsets of respondents ranked the same factors as being the most important in that category for all the groups. On the final question, in which respondents were required to rank the categories, the subset with the higher qualifications ranked 'interpersonal factors' as the most important category, whereas the subset with the lower qualifications ranked 'application of theory factors' as most important. For the least important factors in each category, all but one group was ranked the same by the two subsets. The attribute 'professional qualification' in the 'application of theory' category had a significant discrepancy in terms of the rating and was ranked more important by the subset with 10 years' experience or less. This suggests that, as a project manager gains experience in the construction industry, the perception that having the highest formal qualifications may not guarantee the project management capabilities. This, however, contradicts the findings of Odusami (2003: 519), namely that the project leader's qualification significantly affects project performance.

The results indicate some disparity among the levels of qualifications; however, in general, there seems to be overall agreement.

With respect to years of experience, respondents with less than 10 years' work experience and the subset with more than 10 years' work experience had the closest split of all the stratified data in terms of relative size of the subsets, with 60% and 40% of the sample, respectively.

The two subsets ranked the same factors as being the most important for all the categories, with the exception of the 'personal contribution' category. In the 'personal contribution' category, the subset with more than 10 years' work experience ranked 'ability to develop an appropriate organisational structure' as the most important factor. The subset with 10 years' work experience or less ranked 'ability to determine cost/time trade-offs' as most important. Similarly, for the least important factors in each category, all but one group was ranked the same by the two subsets. In the 'application of theory' category, the subset with 10 years' work experience or less ranked 'monitoring and controlling (costs)' as least important, whereas the other subset ranked 'professional qualifications' as least important.

One factor stands out for its extreme rating score, namely 'leadership style' in the 'personal character' category, with an average rating of 1.85 from the subset with 10 years' work experience or less. This is the lowest average rating of any factor for any subset of the sample in the study.

5. Conclusions and recommendations

The ten most important relative factors across the six categories are given in Table 4.

Table 4: Top ten ranked attributes across categories

Categories and associated attributes		*Rank Frequency*						$\bar{R}$	*Rank*
		1	*2*	*3*	*4*	*5*	*6*		
5.a	Communication skills	78	37	25	16	3	4	2.02	1
3.a	Leadership style	81	32	25	12	10	3	2.06	2
2.c	Planning (integrative)	54	39	31	21	12	6	2.48	3
6.f	Define and follow strategic direction	66	31	21	9	14	22	2.63	4
5.f	Decision-making and problem-solving skills	43	47	29	10	10	24	2.81	5
1.a	Supervision of project team	44	36	33	23	8	19	2.83	6
4.b	Level of involvement in the project	47	31	28	23	25	9	2.85	7
4.a	Ability to determine cost – time trade-offs	27	42	38	40	12	4	2.88	8
2.f	Planning (time)	36	50	24	15	19	19	2.93	9
3.b	Emotional intelligence	31	38	31	27	21	15	3.09	10

In reviewing the top ten relative factors, it is notable that the first seven factors are all related to the project manager's managerial and personal behaviour, as opposed to his/her technical skills. Factors ranking high are associated with leadership, strategic direction, communication, problem-solving and supervision. This observation highlights the fact that peers continue to view the project manager as an authoritative figure who needs to be able to lead the team through a project. These observations support the findings of Odusami (2003: 525) as well as of Muller & Turner (2007: 22-23). With technical capabilities also among the top ten out of 36 factors, the importance of a balanced skills set for project managers is once again confirmed and should be considered when designing project management training and skills development programmes.

Despite the various sources, the relatively low number of potential respondents, and the potential of some bias in this study, the findings are interesting and may ultimately still be representative of the South African construction industry. The results of this research and the low level of concordance, to some extent, support the general findings by Lawless (2007) that the civil engineering and construction industries are currently in disarray. The relative disagreement of what should be expected from project managers can cause potential tension during the recruitment and appointment of personnel. It is, therefore, critical that a common understanding be developed among stakeholders of what key attributes are required for project managers in the construction industry.

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The construction project manager in South Africa: Analysis of industry-specific knowledge

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Abstract

Construction project managers in the built environment come from various backgrounds and knowledge bases; therefore, the project managers' project management set may differ. The type of knowledge required to improve CPD training of project managers thus needs to be determined. This would raise the knowledge levels needed for built environment project managers. The aim of this article is to determine the knowledge needed for the successful management of projects within the built environment.

Industry-specific guidelines for construction project management (PMBOK and SACPCMP) were obtained and analysed. Expert interviews were conducted with experienced specialists (n=10) who held a senior managerial position within project management in the built environment. A case study and email questionnaires (n=40) were also analysed to determine the type of knowledge required. Data analysis was done using Microsoft Excel 2003®.

Three areas of knowledge were identified, namely project management knowledge, industry-specific knowledge and knowledge through experience. Of these, industry-specific knowledge was considered the most important, although all three were very important. Project management knowledge areas essential to project managers included the nine PMBOK knowledge areas from the PMI PMBOK guide, 4th edition 2008, four additional PMI Construction extension to the PMBOK areas, experience as well as built environment-specific knowledge. This study was limited to the nine knowledge areas and did not include stakeholder management as the tenth area. The results from all three test methods (interviews, questionnaires and a case study) indicated that knowledge was essential for effective leadership, trust and communication within a project. Without knowledge, these organisational factors were compromised and project success could be negatively affected.

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It is concluded that the knowledge needed for the management of projects within the built environment had to include industry-specific knowledge pertinent to the built environment. The knowledge required does not currently appear in a single document, and it is recommended that a new document or set of required skills be established.

Keywords: Construction project management, built environment, industry knowledge, project management knowledge, experience, type of knowledge required

Abstrak

Projekbestuurpaaie is gewoonlik deur verskeie agtergrond en kennisbasisse, dus mag projekbestuurders se kennisstel verskil. Die tipe kennis wat benodig word om VPO-opleiding van projekbestuurders te verbeter, moet bepaal word. Dit sal die kennisvlakke wat bou-omgewing projekbestuurders benodig, verhoog. Die doel met die artikel is om die benodigde kennisvlakke van 'n projekbestuurder in die bou-omgewing vas te stel.

Industriespesifieke konstruksieprojekbestuurriglyne (PMBOK en SACPCMP) is verkry en geanaliseer. Spesialis onderhoude is met ervare spesialiste (n=10) wat 'n senior posisie in die bou-omgewing beklee, gehou. 'n Gevallestudie en epos vraelyste (n=40) is ook ontleed om die tipe kennis wat benodig word te bepaal. Data-analise is gedoen deur Microsoft Excell 2003® te gebruik.

Die drie kennisareas is projekbestuurkennis, industrie-spesifieke kennis en kennis deur ondervinding. Van die drie areas, is industrie kennis as die belangrikste gereken, alhoewel almal belangrik was. Projekbestuur kennisareas wat belangrik is vir projekbestuurders sluit die nege PMBOK kennisareas van die PMI PMBOK 4de uitgawe 2008 in, en vier addisionele areas van die PMI Konstruksie uitbreiding tot die PMBOK, kennis deur ondervinding en industrie-spesifieke kennis in. Die studie was beperk tot die nege kennis areas en het nie belanghebbendesbestuur as tiende area ingesluit nie. Die resultate van al drie toetsmetodes (onderhoude, vraelyste en 'n gevallestudie) wys op die belangrikheid van kennis vir leierskap, vertroue en kommunikasie tydens 'n projek. Sonder kennis word hierdie organisasiefaktore benadeel en kan projeksukses negatief beïnvloed word.

Dit is bevind dat die kennis wat 'n projekbestuurder in die bou-omgewing benodig industrie-spesifiek binne die bou-omgewing moet wees. Daar bestaan nie tans een dokument wat die totale kennisstel bevat nie. Dit word aanbeveel dat 'n nuwe dokument of stel van vereiste kennis/vaardighede saamgestel word.

Sleutelwoorde: Konstruksieprojekbestuur, bou-omgewing, industriekennis, projekbestuurkennis, ondervinding, tipe kennis benodig

1. General introduction

Construction project managers in the built environment come from various backgrounds and knowledge bases. Some have thorough industry-specific knowledge, while others have limited or no construction knowledge. The type of knowledge a project manager in this industry requires, needs to be determined in order to establish whether their knowledge set fits the set that is needed in the built environment.

2. Aim and objectives of the research

The research aims to determine what type of knowledge is needed for a construction project manager in the built environment. The aim is to compile a knowledge set for construction project managers in the built environment. This knowledge set may prove useful for future training and education of construction project managers, and may increase the effectiveness of the project and the likelihood of project success.

3. Project management in the built environment

The built environment in South Africa is a large industry that consists of both building and civil engineering construction. Companies want to optimise profit. This holds true in the built environment as in other industries. Therefore, companies need to manage and finalise projects as effectively and efficiently as possible. Project managers play a vital part in the successful completion of projects. They are closely involved from inception through to completion. They are thus key players in the success of projects and the financial gain that companies stand to make.

The aim is to keep the project within time, scope, and cost and according to the expected quality (Kerzner, 2013: 1-10; Burke, 2013). Effective project management will help complete the project as it was planned, thereby meeting companies' aim of attaining goals and being as efficient as possible (Daft, Kendrick & Vershinina, 2010). To increase the possibility of project success, project management and the project manager are important factors (Chordas 2008: 66-69; Kerzner, 2013: 1-10; Trebilcock, 2007: 40).

3.1 Project managers

Construction project managers in the built environment have various backgrounds and knowledge bases. These managers are from fields not only within the built environment such as construction management, engineering, town planning, and quantity surveying, but also beyond the built environment. The common ground among these managers is that they are all involved in project management and have a certain knowledge base of project management as a discipline. Project management is a profession that is governed internationally by institutions, associations and councils and for which a body of knowledge has been developed (Klastorin, 2004: 18; Davis & Pharrow, 2003: 3-4). Regulating bodies such as the PMI (Project Management Institute) have project management members from various fields (PMI, 2015), while others are industry specific. The South African Council for the Project and Construction Management Professions (SACPCMP, 2015: Online) is an industry-specific example, focusing on the built environment. This is a statutory body that requires all practising project managers to register (SACPCMP Management Bill, 2000: 2, 8-9).

The profession of project management offers training courses as well as degrees at institutions such as universities to educate future project managers. The education provided is either generic project management or industry specific. What needs to be evaluated is the required knowledge that is essential for a project manager in the built environment. The knowledge that is needed to effectively and productively manage projects has to be clear (Dinsmore, Kloppenborg & Opfer, cited in Morrison, Brown & Smit, 2006: 39; Cooke-Davies & Arzymanow, 2003: 471-478; Shenhar, 2008: 2).

3.1.1 Knowledge and organisational factors

Knowledge has an influence on the organisational elements of leadership, communication and trust, as well as on the specific terms used in a built industry project. This is supported by research by Berry, Verster & Zulch (2009: 12-15), Butler & Cantrell (as cited in Robbins, 1996: 357) and Culp & Smith (1992: 68-69). These organisational elements are addressed as they accentuate the importance of industry-specific knowledge and how it influences project success. Kerzner (2013) states that organisational factors such as leadership, communication and trust contribute to and influence project management in the built environment and contribute to effective and successful project management.

3.1.1.1 Project leadership

Construction project managers should have some leadership role to fulfil in order to be a good leader (Kerzner, 2013). Leadership contributes to project success (Heldman, 2006). Leaders need to be competent (Culp & Smith, 1992: 68-69) and require technical knowledge, interpersonal skills and project management skills (Culp & Smith, 1992: 68-69). Without knowledge, a project managers' leadership will be affected, as leaders give vision and motivate people. This takes place through effective leadership while managing projects (Heldman, 2006). However, effective communication is essential in order to motivate others.

3.1.1.2 Project communication

A project manager needs to communicate effectively (Heldman, 2011) in order to be a leader (Burke, 2013). There is a difference between communication and effective communication. Communication is the receiving and understanding of information, whereas effective communication is the receiving, understanding and subsequent acting in a desirable manner (Goetsch, 2004: 66-67). Good communication is one of the key factors necessary for team performance, effective project management and successful projects (Chiocchio, 2007). However, effective communication depends on knowledge (PMBOK, 2004). A project manager needs to know what questions to ask and be able to interpret what is being said by the professional team. Therefore, knowledge of the industry instruments is essential for a construction project manager (Berry, Verster & Zulch, 2009). This leads to good communication. The credibility of a project manager's communication leads to trust.

3.1.1.3 Project trust

Trust is an essential element of a project and impacts on a project's success. It is, therefore, important to understand how it develops and where it comes from (Romahn & Hartman, 1999: 1).

Robbins (1996) states that trust is based on five dimensions, namely integrity, competency, consistency, loyalty and openness. Competency includes technical and interpersonal knowledge and skills. This once again highlights that a project manager needs to have knowledge in order to be trusted by team members. Trust has an influence on effective communication (Romahn & Hartman, 1999: 1), and communication is essential for successful project management (Chiocchio, 2007: 97). It is very important to have trust within a project to ensure a successful project. It is important for a project manager to improve the ability to communicate, organise, build teams and provide leadership (Birkhead, Sutherland & Maxwell, 2000: 101).

3.2 Types of knowledge

There are two schools of thought on the type of knowledge required by project managers, namely generic or industry specific (Besner & Hobbs, 2008: 16-33; Cadle & Yeates, 2001: 358). Those who support the generic school of thought believe that project management is transportable across different industries. It infers that all that is needed for a project manager to be successful is the project toolkit. This implies that technical knowledge about the industry in which the project manager operates is not important (Turk, 2007: 25). By implication, this means that a construction project manager does not need technical knowledge of the built environment, but that he can rely solely on project management knowledge.

The industry-specific school of thought regards a project manager's knowledge of the industry of the project they are managing as very important. The one common denominator between the two views is project management. The industry-specific view believes that both industry knowledge and project management knowledge should be mandatory for all project managers (Turk, 2007: 25).

3.2.1 Project management knowledge (generic)

Project management knowledge can be viewed as a toolkit. This toolkit is used and transported to any industry, regardless of the project manager's knowledge of the industry being managed. The PMI Project Management Body of Knowledge (PMBOK) 4th edition identified and listed nine generic knowledge areas. The PMI PMBOK 5th edition of 2015 listed ten knowledge areas, with stakeholder management being a new addition (PMBOK, 2015). The research was, however, based on the 4th edition, as the 5th edition was not yet available at the time the research was conducted. The nine knowledge areas are integration management, scope management, time management, cost management, quality management, human resource management, communication management, risk management, and procurement management (PMBOK, 2008).

The PMI Construction extension to the PMBOK identified four extra areas that have been stipulated in the guide, namely financial management, claims management, environmental management, and safety management (PMI Construction PMBOK, 2008: Online).

This indicates that the PMI agrees that a generic approach to the construction industry dsoe not suffice. Publishing a PMI Construction extension to the PMBOK acknowledges the need for further industry knowledge areas. This suggests that industry knowledge is essential for a construction project manager.

3.2.2 Industry-specific knowledge

As stated in the PMBOK (2008), construction project managers need industry knowledge, project management knowledge and general management knowledge in order to be effective in their job. This adds to the efficiency and effectiveness of the management of construction projects. This is also supported by Ashworth & Hogg (2007: 379-380) who state that construction project managers need industry knowledge in order to effectively do certain tasks. This may include developing a project strategy, evaluating tenders, coordinating design processes, and participating in contractor selection (Ashworth & Hogg, 2007: 379-380).

The SACPCMP also supports the importance of industry knowledge. They note that, in order to be able to conduct the projects effectively, a construction project manager needs to have certain competencies, namely project management competencies and technical competencies (SACPCMP, 2015: Online).

Table 1 lists the four areas provided by the SACPCMP and reflects the required knowledge within these areas.

Table 1: Technical knowledge of a construction project manager

Technical knowledge areas	*Required knowledge*
Knowledge of construction science	Understanding structures
	Understanding construction and building sciences
	Understanding construction and building finishes
	Knowledge of building materials
Knowledge of construction processes	Site, plant and equipment
	Formwork systems
	Quality management
	Health and safety management
	Environmental management
	Organisational/Management structures
	General building sequences
	General output and production factors
	Basic knowledge of building trades
Knowledge of design processes	Sequence of design processes
	Time required for design processes
Knowledge of financial and cost factors	Financial processes
	Cost of construction

(SACPCMP, 2015: Online)

In addition to the PMI Construction extension to the PMBOK 4th edition, the suggested knowledge areas set out in the SACPCMP guide may offer further insight into an essential industry knowledge set (SACPCMP, 2015: Online). As reflected in Table 1, these four SACPCMP knowledge areas are construction science, finance and cost, construction process, and design process.

3.3 Suggested knowledge set

The importance or not of industry-specific knowledge in project management has been widely discussed (Cadle & Yeates, 2001: 358; Webb, 1994: 55; Wirth, 1996: 10). Kerzner (2013) emphasises the necessity of industry knowledge, stating that one of the skills that both project and programme managers need is technical skills. Technical expertise is necessary to evaluate technical concepts and solutions, to communicate effectively in technical terms with the project team, and to assess risks and make trade-offs between cost, schedule and technical issues. Kerzner (2013) states that this is the reason why, in complex problem-solving situations, many project managers need to have an engineering background. Project managers working in construction need to have knowledge of the construction industry (Ashworth & Hogg, 2007: 381-384).

An effective project manager needs to have general management and interpersonal knowledge, project management knowledge (Declerk, Eymery & Crener, cited in Pettersen, 1991: 100; Pacelli, 2004: 54), as well as technical knowledge and experience (Kerzner, 2013: 1-15; Lee & Sweeney, 2001: 16; Petterson, 1991: 99). A combination of these knowledge areas is essential in order to effectively manage a project.

The aim of this article is to determine what knowledge is needed. This may add to the tailoring of CPD courses that can help improve the knowledge base of project managers in the industry. It may also add value to the curriculum planning of construction project management degrees. The findings also indicate the importance of professional qualifications and what knowledge should be required. Subsequently, this will improve the quality of project management and thus the outcome.

4. Research

In this study, interviews, questionnaires and a case study were used as empirical research methods. The research was undertaken in the actual environment and not in a laboratory or under simulated conditions. The respondents were people who work in the built environment and who are involved with project management. The research strategy was both quantitative and qualitative.

4.1 Sampling method

Questionnaires were compiled and distributed to a control group. Incorporating a control group is one way of increasing the validity of a study (Leedy & Ormrod, 2010: 226). The control group gave feedback that was used to adjust and improve the questionnaire before circulating it to the respondents. The respondents were built environment professionals who are in close contact with project management. The questionnaire consisted of two sections. Section A used a checklist to answer general questions and section B used the Likert scale as well as open-ended questions that investigated what knowledge is essential. The Likert scale consisted of five categories. Weighted averages were drawn from the data received from the Likert scale.

It was decided to include a project as case study. A project run by a project manager with project management knowledge but without sufficient industry knowledge was selected. The case study was selected as it complied with the selection criteria and the author had contact with the professional team. The project within the built environment was managed by a construction project manager without adequate industry knowledge. This offered an opportunity to view the impact on a project, should the project manager lack industry-specific knowledge. Several instances that occurred and were directly linked to industry knowledge were analysed. Lastly, interviews were conducted with senior professionals working in the built environment. Large reputable companies were contacted to request their participation in the research. Once the companies accepted, the interviewees were selected based on their extensive knowledge and expertise regarding project management within the built environment. The data gathered was then perused, categories were identified and data placed within these categories from which conclusions were drawn.

4.2 Sample size

Ten interviews were conducted with expert specialists. One case study and forty questionnaires were analysed. The use of multiple research methods added to the validity of the sample size.

4.3 Data collection

Organisations that have established a name in the industry as professional experts were earmarked as possible sources of information and opinions for the interviews. The interviewees all held qualifications and registrations within project management. The city and address of the organisations were determined. The interviews were planned, a date was set to meet and individual interviews were conducted. All discussions were recorded and used as the interview data. In order to distribute and collect data from the questionnaires, email addresses were obtained from professionals in the built environment. Selected professionals were invited to participate. The Leedy and Ormrod (2010: 194) list of guidelines for compiling questionnaires was followed. The questionnaire, along with a cover letter explaining the research request, was sent to the prospective respondents. For the case study, the contact person and contact details were obtained. This person discussed the project. All the discussions and emails exchanged were noted. It was also determined how the data would be interpreted. This was a cross-sectional study that was carried out only once (Schoonraad, 2003: 139). The interviews were conducted within two weeks and questionnaires were sent out and returned within a two-month period.

4.4 Response rate

The questionnaire response rate was 57%. Therefore, according to statistical indicators, this response rate could be accepted as valid. Ten interviewees were contacted and asked to participate. All ten agreed to take part in the research. The interviews were conducted with a separate group to the group that answered the questionnaires.

4.5 Data analysis and interpretation of findings

A 5-point Likert scale was used to obtain the opinions of the respondents and to analyse the results. Likert scales need a minimum of two categories and a maximum of eight or nine (Neuman, 1997: 159; Leedy, 2010: 189). For the purpose of analysis and interpretation, the scale measurement between 1 and 5 was used. Likert-type or frequency scales are designed to measure attitudes or opinions. In this research, these ordinal scales measure levels of not important/ very important. The scales were 1 'not important', 2 'fairly important', 3 'important', 4 'very important' and 5 'critically important'. This scale from 1 to 5 was used to calculate weighted averages. The data were captured using Microsoft Excel 2003® and then analysed using the SPSS program. The findings were then reviewed against the literature review. This was used in order to make deductions and increase the understanding of the required knowledge for project management in the built environment.

It was decided to use various research methods such as a case study, questionnaire and interviews in order to increase the validity and reliability of the study. This ensured that the research did not rely on a single set data procurement method and allowed for comparison between the three sets of data. Close attention was paid to maintain a reliable and valid research process and feedback.

4.6 Limitations

It must be noted that this study focused on the 9 PMBOK knowledge areas from the PMI PMBOK guide 4th edition 2008 and not the 5th edition. Therefore, this study was limited to the 9 PMBOK knowledge areas and did not include stakeholder management as the 10th area.

5. Results

The results were analysed according to the type of knowledge and evaluated in each case using questionnaires, interviews and a case study.

The PMI construction extension to the PMBOK areas and the SACPCMP knowledge areas were reviewed in order to interpret the similarities and the gaps within the PMI construction extension and the SACPCMP, respectively. The findings of the in-depth perusal of the PMI construction extension to the PMBOK and SACPCMP showed the following shortcomings, as displayed in Table 2.

Table 2: Construction PMBOK and SACPCMP knowledge areas

Construction PMBOK knowledge areas	*SACPCMP*	
Integration management	Construction science	Understanding structures
Scope management		Understanding building science
Time management		Understanding building finishes
Cost management		Knowledge of building materials
Quality management	Construction processes	Site plant and equipment
Human resource management		Formwork
Communication management		Building sequences
Risk management		Output and production factors
Procurement management		Knowledge of building trades
Safety management	Design processes	Sequence of design processes
Environmental management		Time required for design processes
Financial management	Financial and cost	Cost of construction
Claims management		

It is clear from Table 2 that the construction-specific knowledge areas in the PMBOK do not overlap with the SACPCMP knowledge areas. The required knowledge set of a construction project manager was compiled.

Financial management is the only similar technical area listed. The PMI construction extension lists claims management, health and safety management and environmental management that are not listed by the SACPCMP. The SACPCMP listed construction science, construction processes and design processes that were not listed by the PMI construction extension.

5.1 Types of knowledge

The questionnaires, interviews and case study all indicated that the knowledge set a project manager in the built environment requires is a combination of project management knowledge, industry knowledge and knowledge through experience. The findings from the three research methods (interviews, questionnaires and a case study) are discussed below.

5.1.1 Knowledge through experience

One of the interviewees indicated that the company for which he works sets the benchmark at 10 years' industry experience as sufficient. Less than 10 years was regarded as possibly too little. Should a candidate only have 2 years' experience, for instance, this would not suffice.

The questionnaire respondents supported the importance of knowledge through experience. Table 3 shows how the questionnaire respondents rated the importance of experience in the field of the built environment in order to be successful.

Table 3: Importance of work experience in the built environment

Responses	*1 = Not important 5 = Critically important*					
	1	*2*	*3*	*4*	*5*	*Total*
Percentage of total	0	2.5	2.5	52.5	42.5	100
Average rating	4.35					

The weighted average is 4.35. Of the respondents, 52.5% regarded experience as very important and 42.5% as critically important. All interviewees indicated that experience is important. One company regarded experience as so imperative that they required project managers to have ten years' industry experience before being appointed as construction project manager. The case study also supported the importance of knowledge through experience.

5.1.2 Project management knowledge

Previous theory revealed that project management knowledge is essential knowledge for effective project management (Declerk, Eymery & Crener, cited in Pettersen, 1991; Pacelli, 2004). The theory was researched and the questionnaire findings are presented in Table 4. This is the respondents' opinion on how important generic project management knowledge is for a construction project manager to successfully manage a project.

Table 4: Importance of project management knowledge in the built environment

Responses	*1 = Not important 5 = Critically important*					
	1	*2*	*3*	*4*	*5*	*Total*
Percentage of total	2.5	12.5	37.5	35	12.5	100
Average rating	3.43					

The research results indicated that project managers should have theoretical project management knowledge. This is supported by the weighted average rating of 3.43. The findings add to the research investigating the knowledge base that a project manager in the built environment should have, indicating the necessity of project management knowledge.

The PMI construction extension to the PMBOK guide lists the nine areas as used in the PMBOK guide 4th edition as well as the four industry-related areas. These four areas are occupational health and safety, environmental management, financial management and claims management. The questionnaire asked respondents to indicate the importance of technical knowledge in order to facilitate the 13 areas. Table 5 lists the 13 areas and summarises the findings.

Table 5: Importance of technical knowledge for facilitation of PMBOK areas

PMBOK knowledge areas	*Weighted averages*
Project integration management	3.82
Project scope management	4.00
Project time management	4.10
Project cost management	4.04

PMBOK knowledge areas	*Weighted averages*
Project quality management	3.83
Project human resources management	3.86
Project communication management	3.79
Project risk management	4.01
Project procurement management	3.56
Occupational health and safety	3.70
Environmental management	3.39
Financial management	3.92
Claims management	4.03
Average rating	3.85

Table 5 shows that areas such as project scope management (4.00), project time management (4.10), project cost management (4.04), project risk management (4.01) and claims management (4.03) indicated that it is very important for a project manager to have technical knowledge. The weighted average for all areas is 3.85 and all areas indicated that technical knowledge is important for successful facilitation.

5.1.3 Industry knowledge

The questionnaires reflected the importance of technical knowledge, as shown in Tables 6 to 9. The four main areas of technical knowledge in the built environment as indicated by SACPCMP were used and tested.

The SACPCMP (2015: Online) indicated that construction science knowledge is important for a construction project manager to have. The subareas of construction science knowledge listed are understanding structures, understanding building sciences, understanding building finishes, and knowledge of building materials. Table 6 shows the findings from the questionnaire and the respondents' opinion regarding the necessity of construction science knowledge.

Table 6: Knowledge of construction science

Responses	*1 = Not important 5 = Critically important*
Understanding structures	3.7
Understanding building sciences	3.83
Understanding building finishes	3.78
Knowledge of building materials	3.55
Total average rating	3.72

Table 6 shows the knowledge area of construction science and each of the four subsections. The weighted average of 3.72 indicates that knowledge and understanding of these items are important.

Results of the case study supported the importance of construction science. The consultants, including the architect, the engineers and the quantity surveyor who worked on the project, stated that the project manager lacked knowledge of construction science and construction processes. The findings are supported by Cadle & Yeates (2001: 358) who state that a project manager must have an accurate understanding of the technical requirements of the project in order to address and meet business needs.

Another area which the SACPCMP indicated as important for a construction project manager to have knowledge of is construction processes. The subareas of construction processes are site plant and equipment, formwork, general building sequences, general output and production factors, as well as basic knowledge of building trades. Table 7 shows the findings from the questionnaire and the respondents' opinion regarding the necessity of construction processes knowledge.

Table 7: Knowledge of construction processes

Responses	*1 = Not important 5 = Critically important*
Site plant and equipment	3.63
Formwork	3.45
General building sequences	4.1
General output and production factors	4.05
Basic knowledge of building trades	3.78
Average rating	3.8

Table 7 displays the findings with a weighted average of 3.8, indicating that knowledge of construction processes is important. Kerzner (2013) states that technical knowledge is needed in order to evaluate technical concepts and solutions. The findings in Tables 6 and 7 reiterate the importance of industry-specific knowledge. Project managers require knowledge of construction science and construction processes.

The SACPCMP indicated that design processes knowledge is important for a construction project manager to have.The subareas of design processes are sequence of design processes and time required for design processes. Table 8 reflects the findings from the questionnaire and the respondents' opinion regarding the necessity of design processes knowledge.

Table 8: Knowledge of design processes

Responses	*1 = Not important 5 = Critically important*
Sequence of design processes	3.98
Time required for design processes	3.9
Total average rating	3.94

Table 8 clearly reflects data indicating that knowledge of the design process is important. The weighted average is 3.94.

The fourth area is knowledge of cost and financial factors. The SACPCMP indicated that this is also important knowledge for a construction project manager to have. The questionnaire findings are reflected in Table 9.

Table 9: Knowledge of financial and cost factors

Responses	*1 = Not important 5 = Critically important*
Cost of construction	4.33

The data in Table 9 indicates a very high weighted average of 4.33. Knowledge of financial cost and factors is very important. This knowledge area corresponds with one of the four PMI Construction extension to the PMBOK areas (occupational health and safety, environmental management, financial management and claims management).

The questionnaires' findings indicated that technical knowledge is important for the facilitation of the four construction PMBOK knowledge areas. The weighted averages for these areas are 3.92 for financial, 4.03 for claims management, 3.39 for environmental management, and 3.7 for safety management. It is important when compiling the knowledge set that the technical knowledge consists of a combination of construction PMBOK and SACPCMP industry knowledge sets.

All the interviewees indicated that industry-specific knowledge is essential in order for a project manager to do project planning. Quoting interviewee 7: "How is it possible to plan if there is no knowledge of the industry and the project manager doesn't know how everything fits together?" The case study supported the findings.

The fact is thus that project managers working in construction need to have knowledge of the construction industry (Ashworth & Hogg, 2007: 381-384). Techniques that work for one industry do not necessarily work for the next. For instance, techniques derived from the manufacturing industry will often not work in construction. Ashworth & Hogg (2007: 381) state:

> *Ideally therefore, the project manager will already be a member of one of the construction professions. An understanding of the process and the product of construction, and a working knowledge of the structure of the industry, will clearly be advantageous if not essential. The importation of managers with no knowledge of the industry or its workings has drawbacks, and their appointment should be approached with caution.*

There is thus a need for industry-specific knowledge.

5.2 Knowledge affecting organisational factors

The interviews, questionnaires and case study findings were interpreted and indicate the importance of trust, leadership and communication to effectively manage a project. The study presented evidence that revealed a strong correlation between knowledge and trust, knowledge and leadership, as well as knowledge and communication.

5.2.1 Leadership

Leadership contributes to successful projects. Based on the questionnaire findings, the data in Table 10 shows the importance of leadership to increase project success.

Table 10: The importance of leadership to increase project success

Responses	*1 = Not important 5 = Critically important*					
	1	*2*	*3*	*4*	*5*	*Total*
Percentage of total	0	0	0	43.6	56.4	100
Average rating	4.56					

The questionnaire results indicated that all respondents scored the importance of leadership in project management as either 4 or 5 on the Likert scale. This amounts to a very high weighted average of 4.56.

The ten interviewees all indicated that, in their opinion, a project manager needs to be a leader and that leaders require proficient knowledge. All interviewees indicated that leaders need competency in order to be trusted and respected. This adds to the validation of the study. As indicated in previous research by Chiocchio (2007) and Culp and Smith (1992), trust, leadership and communication are all elements needed for project success. These elements are affected by a project manager's knowledge or lack thereof. The knowledge required includes industry-specific knowledge, project management knowledge and knowledge gained through experience in the industry. All interviewees stated that project managers need to be leaders and leaders need knowledge of the projects they are managing.

The case study analysed a built environment project that had a project manager with insufficient industry knowledge and experience. The project manager in this case study was not regarded as a leader, as he did not instil trust among project team members. They did not trust his expertise as project manager nor his leadership. This was observed through discussions and interviews with the respondents who worked on the project.

5.2.2 Trust

The literature illustrates the importance of trust to ensure project success. The research tested the importance of trust to increase the possibility of project success. The results are presented in Table 11.

Table 11: Importance of trust to ensure project success

Responses	*1 = Not important 5 = Critically important*					
	1	*2*	*3*	*4*	*5*	*Total*
Percentage of total	0	0	13.2	44.7	42.1	100
Average rating	4.29					

Table 11 indicates that it is very important to have trust in order to increase the possibility of project success. The weighted average is 4.29, indicating very important to critically important. This is relevant because knowledge is needed in order to be trusted. Therefore, without the needed knowledge, there will not be adequate trust on a project. The importance of trust supports the need of the requested knowledge.

The questionnaire results emphasised the importance of trust on a project in order to increase the possibility of project success. The weighted average is 4.29 indicating very important to critically important.

All the interviewees stated that a leader needs to be competent in order to gain and retain the respect and trust of followers. A project manager without the required knowledge needed for the specific project is not competent and loses the respect and trust of the project team. This affects time, cost and the quality of a project, thereby impacting on project success.

The case study indicated that there was a lack of trust among team members, due to the project manager's insufficient knowledge base. This became obvious in discussions with the professional team members who indicated that they did not trust the project manager and that they believed that his knowledge of the industry was not adequate. This was obvious not only from discussions with the respondents, but also from incidences that took place during the project. The mistrust was further aggravated by the project manager's ineffective communication ability.

5.2.3 Communication

Chiocchio (2007) stated that communication is a very important part of project management and necessary to effectively manage projects. The data in Table 12 reflects the questionnaire results for the need for technical knowledge in order to facilitate project communication. It analyses the importance of technical knowledge for effective communication in order to collect and distribute information, for performance reporting and managing stakeholders. Technical knowledge is very important for a project manager to facilitate project communication.

Table 12: Need for technical knowledge to facilitate project communication

Responses	*1 = Not important 5 = Critically important*
Information is collected and distributed	3.83
Performance reporting is done	3.7
Stakeholders are managed	3.85
Average rating	3.79

Table 12 indicates that technical knowledge is important in order to effectively facilitate the collection and distribution of information (weighted average of 3.83), do performance reporting (weighted average of 3.7), and manage stakeholders (weighted average of 3.85). The overall weighted average for the three categories discussed is 3.79. Due to communication being important to project management, it can be stated that it is very important for a project manager to have technical knowledge in order to support effective project management.

The case study revealed that the project manager did not understand what the team members were saying and the implications of what they were saying. Neither did he know what questions to ask. Therefore, he asked the wrong questions. This became obvious in discussions with the team members on separate occasions and based on various incidents.

The project manager was the link between the project team and the client (a large international company). He communicated project information to them. His lack of industry-specific knowledge led to miscommunication during the project. The client asked questions which the project manager was unable to answer. Miscommunication was one of the factors that contributed to the client losing faith in the project, resulting in the project being cancelled.

All interviewees indicated that industry-specific knowledge is important in order for a project manager to communicate. The research feedback revealed that a project manager needs specific knowledge in order to be able to ask the right questions from the project team. The project manager must understand the feedback provided by the project team and be able to communicate the feedback and status to the client. The project manager must also anticipate potential problems, make the necessary decisions and take action in order to prevent the problems. This supports the research by Turk (2007) and Cadle and Yeates (2001). Interviewee 7 stated that project managers have to anticipate potential project problems: "Project managers need to spot a potential problem before it occurs." This is only possible if the project manager has industry-specific knowledge and experience working in the built environment. Interviewee 5 stated that, without the required knowledge, a project manager cannot communicate effectively with the team. He further mentioned that problems with communication impact on the time, cost and quality of a project. Project meetings need to be proactive and goal oriented. To meet these requirements, a project manager needs the required knowledge.

Interviewee 2 stated that knowledge affects the quality of the message communicated by the project manager. The interviewee mentioned that the project manager must lead and know what questions to ask. If the project manager's knowledge about the industry is insufficient, he will not be able to understand the feedback and to make intelligent deductions from the feedback received.

Figure 1 was compiled based on the research findings. It illustrates the elements of the knowledge a project manager needs in order to be able to communicate effectively. As stated by Chiocchio (2007: 97), communication is very important to ensure effective project management.

Figure 1 shows five elements in a circle that are dependent on a project manager's knowledge and subsequently his communication ability. These elements are: asking the right questions, understanding team feedback, communicating feedback to clients, anticipating potential problems and planning, and taking action to prevent problems. If a project manager is not knowledgeable and an incompetent communicator, these essential elements will not be realised.

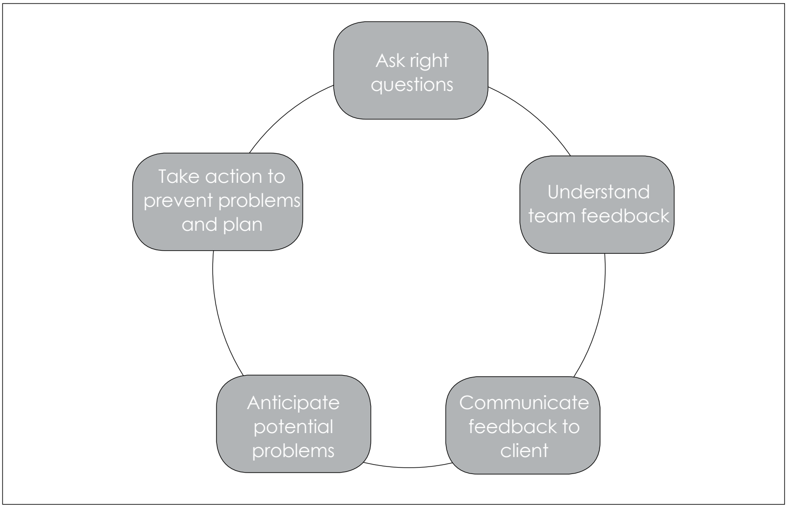

Figure 1: Project manager needs competency in order to communicate effectively
Source: Burger, 2013: 188

Figure 1 indicates that industry-specific knowledge is essential for a project manager. As indicated earlier, a project manager needs knowledge in order to ask the right questions. Figure 1 illustrates that a project manager needs to be competent in order to communicate effectively – to ask the right questions, to understand team feedback, to communicate feedback to clients, to anticipate potential problems and plan, and to take action to prevent problems. The interviews supported this, since the interviewees' feedback supported the need for competency to ask the right questions, understand the feedback that is given, communicate the feedback to the client, anticipate potential problems and take action to plan and prevent problems.

In summary, all respondents interviewed agreed that a project manager needs the required knowledge and experience in order to increase both the effectiveness of project management and the probability of project success.

6. Conclusion and recommendations

Project managers require three types of knowledge in their knowledge set in order to successfully manage projects. This knowledge set needs to consist of project management knowledge, knowledge through experience, and industry knowledge. The project management knowledge areas are the nine knowledge areas set out in the PMBOK 4th edition as well as the four PMI Construction extension to the PMBOK. The nine knowledge areas are based on the PMI PMBOK 4th edition and not the PMI PMBOK 5th edition of 2015, which added stakeholder management as a 10th area. The nine areas are: integration management, scope management, time management, cost management, quality management, human resource management, communication management, risk management, and procurement management. The four areas from the PMI Construction extension to the PMBOK are: occupational health and safety, environmental management, financial management, and claims management. According to SACPCMP, there are four industry knowledge areas along with their subsections that are essential. These four areas are: construction science, construction processes, design processes, and having financial and cost knowledge. These research findings together offer a knowledge skill set that can be used as baseline. This research indicates the type of knowledge required as well as the critical importance of industry-specific knowledge. Further research could test project managers' proficiency levels of the various knowledge fields. Forthcoming research investigates the level of each type of knowledge required and offers a construction project management knowledge model. This will assist in knowing to what knowledge depth project managers need to be educated and trained. The level of knowledge findings will be presented in the near future.

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The use of the critical path and critical chain methods in the South African construction industry

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Abstract

The purpose of this article is to report on an investigation of the use of critical path and critical chain methods in the South African construction industry. Through a questionnaire survey, data was collected to establish which construction sectors apply these methods, the percentage of construction professionals using these methods, the reasons why these methods are applied, and the factors that influence the use of these methods.

Based on the findings, the critical path and critical chain methods are mostly used in the South African construction industry by the building sector, in comparison to the civil and industrial sectors. The critical path method is used more than the critical chain method, with over 70% of the responding companies applying the critical path method and only 22% applying the critical chain method. The latter method is considered to be a relatively new project management tool and requires a culture change in the company. Users of the critical path method believe that the method mainly improves their project understanding, planning, scheduling and control, with all these improvements ultimately leading to better on-time completion of projects and cost saving.

Keywords*:* Critical path method, critical chain method, construction, project management, CCPM

Abstrak

Die doel van die artikel is om die Suid-Afrikaanse konstruksiebedryf se gebruik van die kritiesepadmetode en die kritiesekettingmetode te ondersoek. Data is deur middel van 'n vraelys ingewin om te bepaal watter konstruksiesektore die metodes gebruik, asook die persentasie-gebruik deur professionele persone in die konstruksiebedryf, die onderliggende redes vir die toepassing van die metodes en die faktore wat die gebruik hiervan beïnvloed.

Die navorsing het bevind dat die kritiesepadmetode en die kritiesekettingmetode in die Suid-Afrikaanse konstruksiebedryf meer in die bousektor gebruik word

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as in die siviele en industriële sektore. Die kritiesepadmetode word deur meer maatskappye en op meer projekte gebruik as wat die kritiesekettingmetode deur die konstruksiebedryf gebruik word, met meer as 70% van die responderende maatskappye wat van die kritiesepadmetode gebruik maak teenoor 22% wat die kritiesekettingmetode gebruik. Die laasgenoemde metode word as 'n jong metode beskou en implementering vereis kultuurveranderinge in die maatskappy. Gebruikers van die kritiesepadmetode glo dat die metode help met die verbetering van projekbegrip, beplanning, skedulering en beheer, met al die verbeteringe wat lei tot beter optydafsluiting van projekte en kostebesparing.

Sleutelwoorde: Kritiesepadmetode, kritiesekettingmetode, konstruksie, projekbestuur

1. Introduction

The critical path method (CPM) has been in use for approximately 55 years (Dilmaghani, 2008: 10) and has become the construction industry's main standard for project scheduling. The critical chain method (CCM) has been in use for only 17 years (Goldratt, 1997).

Since its introduction in the late 1950s, the CPM has proven to be a useful tool for planning and controlling construction projects (Dilmaghani, 2008: 10). The CPM allows project managers to identify critical activities by evaluating the times when activities can start and finish, determining activity float, and assessing the effect of adjustments in duration and logical relations on the overall project duration. Over the past three decades, the use of the CPM has drastically increased in the construction industry, due to its benefits and the noteworthy advancements that have been made in both computer hardware and scheduling software. The CPM is a valuable asset for construction projects, because it enables contractors to determine resource requirements, vendors to finalise material deliveries, and subcontractors to establish when work can be performed.

Goldratt's book *Critical chain* (1997) introduced the CCM, often referred to as critical chain project management (CCPM), as a new technique for scheduling, monitoring and controlling. Any organisation that implements this relatively new methodology hopes to make the most of the opportunity to reduce the project completion time significantly. The theoretical basis of the CCM, the theory of constraints (TOC), claims that the weakest link in the system determines construction efficiency (Goldratt & Cox, 1984). Therefore, the core factor influencing the efficiency of construction is the capability of the weakest link. According to Goldratt (1997), the critical chain is the longest path formed from resource balances on the basis of a detailed consideration of the logical and resource constraints that exist between project activities.

No comprehensive, structured investigations have been conducted to establish what circumstances influence the utilisation of the CPM and CCM in South Africa's construction industry. Furthermore, no publications differentiate the factors associated with the implementation success of the CPM and CCM in this sector in South Africa. Therefore, South African construction professionals' experience and use of the CPM and CCM are unknown. The primary focus of this article is to determine the application of the CPM and CCM in the South African construction industry with the following subobjectives:

- To determine which of the construction sectors (building, civil and/or industrial) apply the CPM and CCM.
- To obtain the percentage of professionals who use these methods.
- To define the prevailing reasons why these methods are applied.
- To clarify the factors that influence the use of the CPM and CCM.

2. Background

2.1 Development of the critical path method

Henry Laurence Gantt introduced the Gantt chart (bar chart) in 1916 (Weaver, 2012: 7). Since then, bar charts have been used extensively for planning and monitoring construction projects. Menesi (2010: 10) states that, although this is a simple format that efficiently communicates the required information, such bar charts have restrictions, as the logical relationships between activities are not considered. This complicates the updating of the schedule as the project progresses. In the late 1950s, E.I. Du Pont de Nemours Company, as well as the Univac Applications Research Centre of Remington Rand collaborated to develop the CPM, which is based on the bar chart (Dilmaghani, 2008: 10).

The CPM is an algorithm for scheduling a large number of activities in complex project plans, where the "critical path" is the sequence of dependant tasks, where if there is a delay, will cause the end date to move out (Stelth & Le Roy, 2009: 23). For example, a project manager can determine the critical path of activities by evaluating the start and finish times of activities, determining the activity float/delay and assessing the effect of duration modifications.

2.2 Development of the critical chain method

In their book entitled *The goal: A process of ongoing improvement,* Goldratt & Cox (1984) introduced the TOC as an operations management method with the purpose of continuously improving profit, return on investment, and cash flow. The TOC considers that the total system output is determined by a bottleneck or single constraint, with the best possible system performance being accomplished by managing the constraint. The TOC emphasises that constraints and non-constraints require different management and behavioural rules to manage flow by allowing for uncertainty, for example, rework and unscheduled stoppages. The TOC proposes a five-step sequence: identifying the constraint, exploiting the constraint, subordinating the constraint, elevating it, and repeating the process (Pretorius, 2014).

Goldratt extended the TOC to the project environment by introducing the concepts of the CCM in his book *Critical chain*, which offers a better understanding of how the TOC concepts can be applied to single- and multi-project environments. In TOC, the constraint determines system (organisational) performance. Similarly, in projects, TOC states that the critical path determines project performance. Thus the constraint in a project is the critical path (Goldratt, 1997).

The purpose of the critical chain is to enable projects to finish promptly, within budget, and without curtailing the project scope. Cook (1998: 21) summarised the following key features of the critical chain:

- It is a cultural change in project management.
- Multi-tasking is avoided.
- It accumulates all safety buffers at the end of the project instead of building them into activity estimates, and protects the critical chain against insecurity.
- It focuses on the project constraint (the longest chain of dependent resources or activities).

Different terminologies for the CCM are also used in the literature, for example, CCPM (Dilmaghani, 2008: 2), critical chain scheduling (CCS) (Yang, 2007: 25), and critical chain scheduling/buffer management (CCS/BM) (Herroelen, Leus & Demeulemeester, 2002: 48).

2.3 Comparison and differences between the CPM and CCM

The Project Management Institute (2013: 176-178) defines the critical path, the CPM, the critical chain, and the CCM as follows:

- The critical path is the longest link of successive activities that determines the project completion date on a schedule, where the entire schedule will be delayed by delays in the critical path.

- The CPM is the method used for planning, monitoring and controlling the project schedule based on the determined critical path.
- The critical chain is the longest link of successive activities taking resource constraints into consideration, where the completion date of the project is only finalised after a project buffer has been added to the end of the critical chain.
- The CCM is the project schedule planning, monitoring and controlling method that uses the critical chain, first, for scheduling, by determining the critical chain and buffers and, secondly, for monitoring and controlling the project schedule in terms of the buffers.

The safety buffers (SB) of the CPM schedule are included in each activity (see Figure 1), whereas CCPM refers to a single project buffer (PB) at the end with the CCM. Feeding buffer (FB) is located wherever a non-critical path feeds into a critical path. The CPM is further only used on a single-project basis, while the CCM can be used as a multi-project scheduling solution, in addition to its applicability for single-project use (Lechler, Ronen & Stohr, 2005: 53).

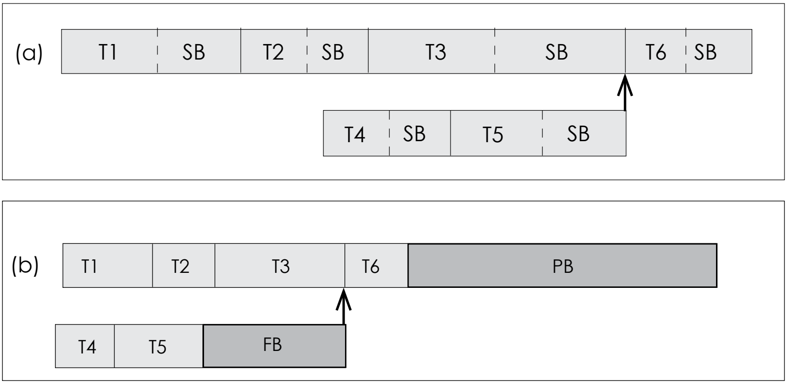

Figure 1: The (a) CPM with implicit safety buffers and the (b) CCM with explicit project buffers with T = task; SB = safety buffer; PB = project buffer; FB = feeding buffer.

Table 1 provides a comparison of the main characteristics of the CPM and CCM as adapted from Stelth & Le Roy (2009: 32-33).

Table 1: Comparison of the CPM and the CCM

Characteristic	*Critical path method*	*Critical chain method*
Project finishing date	A realistic date is believed to be met.	It has a high level of probability and is assured throughout with buffers.
Project schedule	CPM establishes the project start and end. The path can be adjusted during the project.	CCM determines the end of the project, but the start is often determined by a non-critical activity. The chain does not adjust.
Project variation	Variation is implicit and expected to balance out throughout the project.	Variation is explicitly planned and handled during the project with buffers.
Schedule management	Each activity must be kept on schedule according to the calendar in order to keep the project on schedule.	Buffers are managed to absorb variation efficiently in order to keep the project on schedule.
Schedule tracking	Activity starts and finishes are thoroughly tracked. Schedule slippage is important and must be monitored closely.	Buffer status is thoroughly tracked. When any task starts or finishes with respect to the calendar is insignificant.
Task completion	People are assessed in terms of whether or not their tasks are late with regard to their committed calendar date for activity completion.	Half of all tasks are anticipated to take longer than scheduled and the buffers absorb such variation.
Project reviews	Fixed reviews are scheduled to assess the project progress to date.	Floating reviews are set off by phase completion and buffer status is reviewed for the probability of project completion.
Non-critical activities slack	The total slack that non-critical paths have is irrelevant and not monitored.	Non-critical activities should have adequate feeding buffers to protect the critical chain.
Resource management	Resources should be multi-tasked to make progress on every project.	Multi-tasking of resources is avoided at all costs.

2.4 Use of the CPM and CCM by construction industries

Several surveys have confirmed that the use of the CPM in the construction industry has been growing over the years. Kelleher (2004: 36) analysed the data from three surveys conducted in 1974, 1990 and 2003, respectively. These surveys investigated how the top 400 contractors in the USA, as identified by *Engineering News Record* (*ENR*), used the CPM. The study revealed that the CPM was used on

75% of contracts and was regarded as a valid management tool by 98% of the respondents in 2003.

Given the mixture of both small and large contractors, Hawkins (2007) conducted a survey in 2007 that proved that small and medium-sized construction firms also utilise the CPM for project management and that it is not only the *ENR*'s large top 400 firms that do so.

A study by Georgy, Marzook & Ibrahim (2013) revealed that the main reasons why construction professionals in Egypt and Saudi Arabia use the CPM are that no highly sophisticated skills are required; it assists in dispute resolution; it is valued as a management tool; cost and time are saved, and it is mostly a contract requirement.

Georgy *et al.* (2013: 8) state that, of the construction professionals in Egypt and Saudi Arabia, 10% and 44% of the respondents, respectively, were of the opinion that the CCM does not add any genuine value to project planning. However, the CCM is appreciated as a fresh and innovative methodology.

2.5 Criticism of the critical path method

The study by Kelleher (2004: 38) indicated that the CPM's disadvantages are excessive implementation work, logic abuse, too much reliance on specialists, and lack of awareness of field personnel requirements. Contractors may find the CPM beneficial for progress status analysis and updating activity data, but not as useful in supporting other essential aspects, such as corrective actions and identifying execution problems. Kuhn (in Hegazy & Menesi, 2010: 1078), states that, while the owners and managers of contracting companies recognise the value of using CPM, contractors cannot use it effectively, because the critical path does not reflect reality. This is supported by Menesi (2010: 2) who states that the CPM algorithm is based on two idealistic assumptions during the project planning stage, namely that resources are limitless and that the project deadline is unrestricted.

2.6 Criticism of the critical chain method

Trietsch (2005: 33) claimed that most of Goldratt and Cox's concepts preceded the publication of their book *The goal: A process of ongoing improvement*. For example, he referred to a book by Pervozvansky as the original idea of the constraint. However, he conceded that Goldratt made a notable contribution to project management. Steyn (2001: 368-369) states that the application of the TOC to project management was not customary prior to the introduction of the CCM, and he quotes sources that argued that the critical chain philosophy derived a great deal from old-fashioned methods. In a case study, Lechler *et al.* (in Repp, 2012: 45) pointed out that a reason for failures of the CCM was that the critical chain was becoming extremely difficult to manage, as there were too many buffers. Herroelen *et al.* (2002: 59) state that it is possible for different software packages to determine completely diverse critical chains and non-minimal baseline schedules, with the critical chain then having to be selected randomly.

The literature reveals that a higher percentage of construction professionals are now using the CPM than in the past. It is hard to identify any single reason why use of the CPM has grown; it is rather a combination of factors. Overall, users of the CPM are of the opinion that they are successfully reaping the benefits of the method. The literature further uncovers that the CCM, although it may be successfully implemented in certain industries, is still unfamiliar in the construction industry. Though many construction professionals have doubts about achieving positive results with the implementation of the CCM, many still expect partial success.

3. Research methodology

3.1 Research questions and hypotheses

This research study is descriptive and conclusive, as it is aligned with the identified research questions and hypotheses. Table 2 indicates the research questions and hypotheses that were formulated for this research study.

Table 2: Research questions and hypotheses

Number	*Questions*	*Hypotheses*
1	What types of construction companies (building, civil or industrial) use the CPM in South Africa?	H1: The CPM is used by all types of construction companies in South Africa.
2	What types of construction companies (building, civil or industrial) use the CCM in South Africa?	H2: The CCM is used by all types of construction companies in South Africa.
3	What is the percentage of construction professionals' use of CPM in South Africa?	H3: The CPM is implemented by approximately 90% of construction professionals in South Africa.

Number	*Questions*	*Hypotheses*
4	What percentage of construction professionals in South Africa use the CCM?	H4: The CCM is used by approximately 15% of construction professionals in South Africa.
5	Why do construction professionals in South Africa use the CPM and the CCM?	H5: Construction professionals in South Africa use the CPM and the CCM mainly for project scheduling, tracking, and control.
6	What factors influence the use of the CPM in the South African construction industry?	H6: The use of the CPM is mainly influenced by contract requirements.
7	What factors influence the use of the CCM in the South African construction industry?	H7: The use of the CCM is mainly influenced by improving systems throughput.

3.2 Research philosophy and approach

The philosophy that is associated with the research problem is the positivism paradigm, which is followed throughout the research process. The key concepts of the positivism philosophy are the following:

- i The researcher is detached from, independent of, and not influenced by the research subject.
- ii The research emphasises a highly structured methodology for replication intentions.
- iii The research produces quantifiable observation that can be examined statistically.

A deductive approach is more appropriate for a positivism paradigm, which classifies this research study as deductive or theory testing in nature. Zikmund (2002: 46-47) states that deductive reasoning involves the process of reasoning from one or several general statements in order to achieve a logical conclusion. The key concepts of the deductive approach are as follows:

- The approach forms a hypothesis or theory and devises the research to investigate the hypothesis.
- It is more oriented to positivism.
- It is scientific research.
- It strives to clarify fundamental relations between variables.
- It is more probable to gather quantitative data.
- The approach is very structured.

3.3 Methodology

The data collection tool was a questionnaire that was set up in an electronic web-based program (Survey Monkey). A questionnaire was deemed to be the most appropriate method of data collection for this research. Albaum, Wiley, Roster & Smith (2011: 687) state that it is fast becoming the favoured method of distribution for self-administered surveys. The questionnaire for this research is self-administered and respondents were contacted by email. The questionnaire design is based on closed-type questions. Zikmund (2002: 333) maintains that closed-type questions are easier to answer, as they require little skill and less time from respondents. The questionnaire consisted of three sections:

- The first section clarified the study and asked for basic information, such as the respondent's name, company name, and current management level. The purpose of these questions was to determine the company and the respondent's management position in the company.
- The second section tested the various respondents' application of the CPM. These questions were all pre-coded. An open-ended option was included in case the respondent's response did not fall into one of the pre-coded options provided. The purpose of these questions was to determine the application of the CPM in the South African construction industry.
- The third section tested the various respondents' application of the CCM. These responses were also pre-coded; with the choice of an open-ended response, should the response not fall into one of the pre-coded options provided. The purpose of these questions was to determine the application of the CCM in the South African construction industry.

Because descriptive research seeks to answer certain questions, Welman, Kruger & Mitchell (2005: 23) propose it to clarify the characteristics of a population or phenomenon. This research study is descriptive and conclusive, as it will be aligned with the identified research questions and hypotheses. Construction professionals' application of the CPM and the CCM is clearly defined and well researched by Kelleher (2004), Hawkins (2007), Repp (2012) and Honiball (2012), which substantiates the quantitative nature of this research.

A survey is believed to be appropriate for the collection of data and to accomplish the research objectives. The benefits of surveys are the reason for the selection of this strategy. Zikmund (2002: 195) highlights that surveys can provide accurate, economic and fast means of attaining information for objectives. Saunders, Lewis & Thornhill (2009: 94) state that the survey approach affords the researcher more control over the research process.

Wyse (2012) highlights the following shortcomings of online questionnaires:

- Respondents may not always provide honest answers, as they could be concerned that they present themselves in a negative manner.
- Closed-type questions might give the survey a lower validity rate, as question non-responses could result in data errors. Bias could also be created if the number of respondents who choose to answer a certain question differs from those who choose not to answer.
- Self-administered surveys run the risk of having errors.

3.4 Population and sample

The contact information of members of the South African Council for Project and Construction Management Professionals (SACPCMP), Master Builders South Africa (MBSA), and the National Home Builders Regulation Council (NHBRC) was obtained from each organisation's website. These organisations represent employers and contractors who operate in the construction industry and are leading national representative bodies in this sector. E-mails requesting the company's participation in the study were sent directly to company staff members. The e-mails provided a link to the survey. Response to the survey was voluntary.

From the 321 companies, 63 respondents agreed to participate in the survey. However, 22 respondents were disqualified, due to incomplete responses. Therefore, 41 responses (13%) were used to evaluate the study's results. It is, however, not possible to conclude that the survey results represent the entire range of contractors. The low responses provided a limitation to the generalisation of the results to the entire industry. However, the results represent the section of companies/ industries that chose to participate.

4. Results and discussion

4.1 Profile data on company and respondents

Figure 2 categorises the responding companies by size according to annual construction revenue. The majority (41%) of the respondents are from a large company with an annual construction revenue exceeding R50 million. The least number (27%) of respondents are categorised as medium-sized firms (annual revenue between R15 million and R50 million), and 32% represented the small company category with an annual construction revenue of less than R15 million.

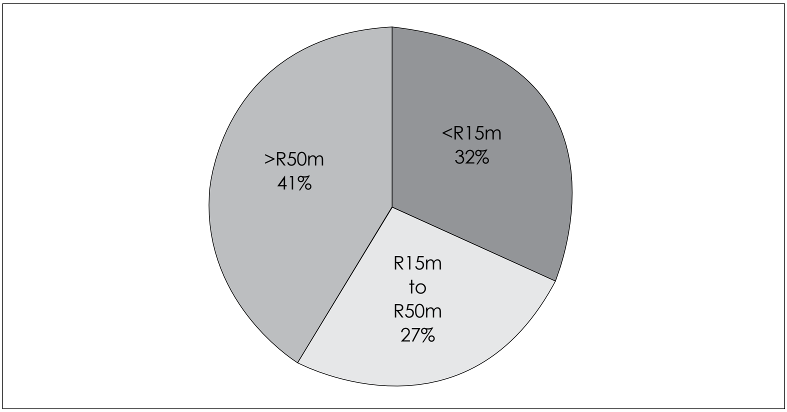

Figure 2: The size of representative companies according to annual turnover

Figure 3 indicates the construction industry sectors, in which the responding companies that use the CPM and the CCM are involved. The majority (59%) of the respondents conduct building construction, 41% civil construction, and 14% industrial construction. The "other" option was selected by 45% of the respondents and included electrical, mining and petrochemical construction, as well as regulation of the home-building industry, power plants, reticulation networks and solar energy. The survey results showed that 35% of the companies are involved in more than one construction sector.

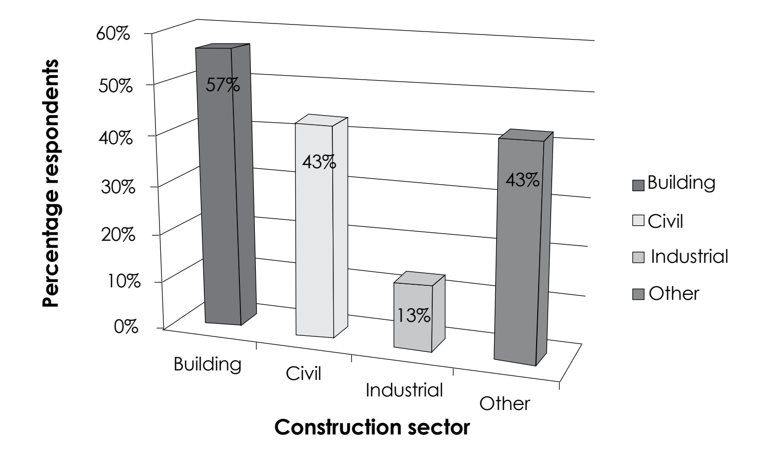

Figure 3: The different construction sectors in which the respondents who use the CPM and the CCM are involved

Table 2 illustrates that a relatively high percentage (34%) of the respondents are project managers who manage individual projects. The second-most selected option was "other" (27%) and included chief executive officers, provincial managers, proposal estimators, contract managers, co-managing directors, construction managers, and several quantity surveyors. These results indicate that the respondents represent a relatively wide distribution of positions within the companies.

Table 2: The respondents' positions within the companies

Position in company	*Main task*	*Response percentage*
Project team member	Works on project tasks	20%
Project manager	Manages individual projects	34%
Programme manager	Manages a portfolio of projects	12%
Senior management	Is reported to by project and programme managers	20%
Project management consultant	Provides guidance on managing projects	7%
Contractor	External contractor/subcontractor/supplier	2%
Other		27%

4.2 Use of the CPM and the CCM

The CPM was used more than the CCM, with over 70% of the responding companies applying the CPM and only 22% applying the CCM (see Figure 4). The majority (82%) of the large companies used the CPM, compared to 69% and 64% of the small and medium-sized companies, respectively. The majority of the smaller companies made use of the CCM, compared to medium-sized and large companies.

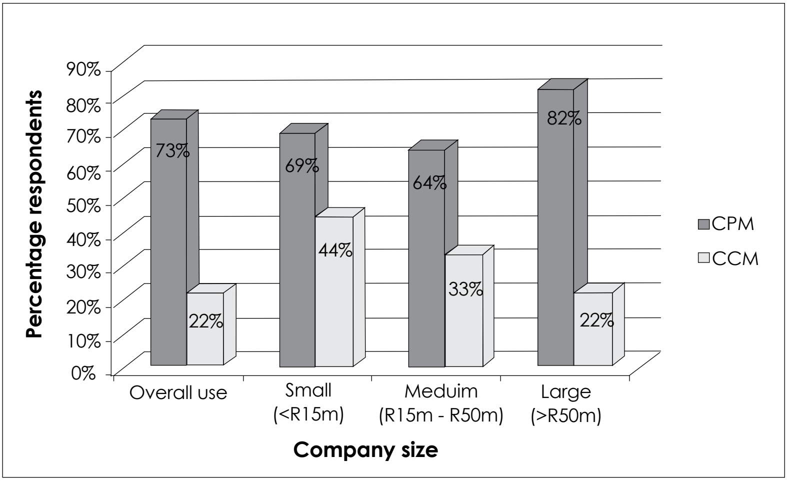

Figure 4: Overall usage of the CPM and the CCM according to company size (some companies make use of both CPM and CCM, resulting in >100%).

Figure 5 further indicates that for the companies making use of CPM and/or CCM, the smaller companies were mainly involved in building and civil construction, whereas the larger companies had a presence in all construction sectors. The industrial sector was dominated by the medium-sized industries.

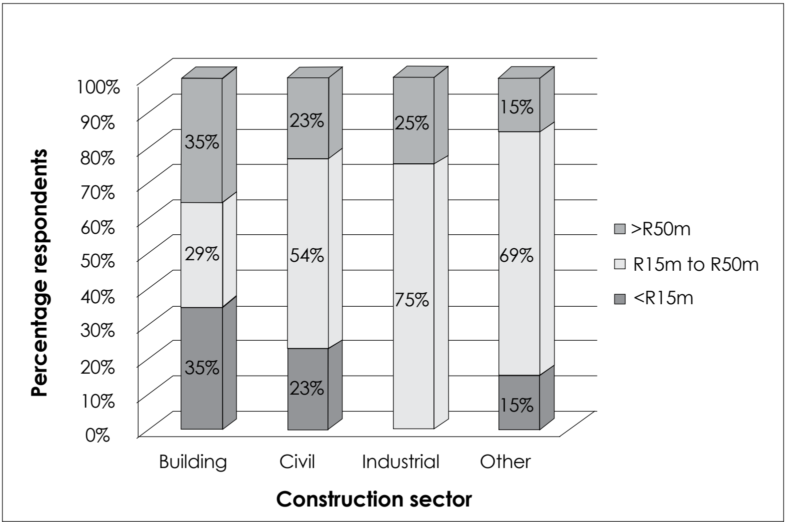

Figure 5: Graph indicating the construction sector and size of companies making use of CPM and/or CCM

Figure 6 summarises the regular use of the CPM and the CCM in relation to contracts. Approximately 34% of the respondents use the CPM for all contracts, whereas only 22% use the CCM for all contracts. Approximately 70% of the respondents use the CPM and the CCM on more than 50% of their contracts.

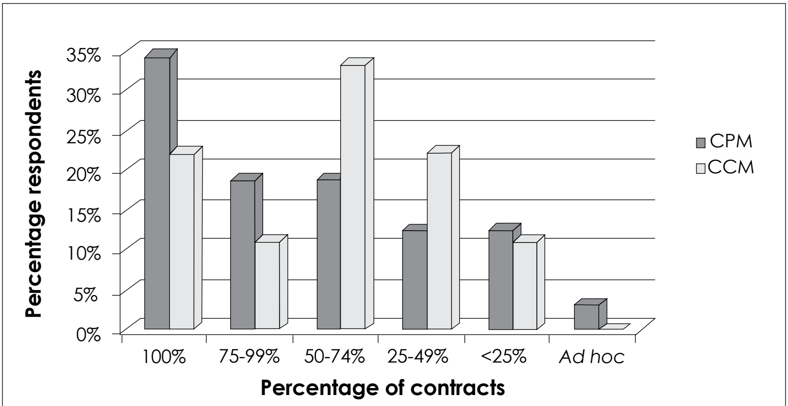

Figure 6: The regular use of the CPM and the CCM on contracts

The main reason why construction professionals use the CPM is because more than 80% of the respondents who apply the method consider it to be a valid management tool (see Figure 7). Other reasons are that it improves communication among project parties and is often a contract requirement, while it is also increasingly used in dispute resolution and litigation. In contrast to companies using the CPM, all the responding companies that use the CCM regard it as a valid management tool. Of the CPM and the CCM users, 72% indicate that it improves communication among the project parties, while only the CPM users apply it for dispute resolution, litigation and as a contract requirement.

Users of the CPM confirmed that the method mainly improves their project understanding, planning, scheduling and control, with all these improvements ultimately leading to more punctual completion of projects. The CPM is mostly used for planning and controlling construction work. More than 80% of the respondents who apply the method use it to plan their projects, while over 50% also use it to monitor and control project progress (Table 3).

Users of the CCM indicated that the method mainly improves their project planning, scheduling and response time to problems, which saves time.

On the other hand, the majority of the respondents who do not use the CPM indicated that they are unfamiliar with the method or see no need to use it, due to projects being relatively small. A few indicated that the method does not reflect reality. None of the respondents indicated that the method does not identify execution problems or does not support corrective actions.

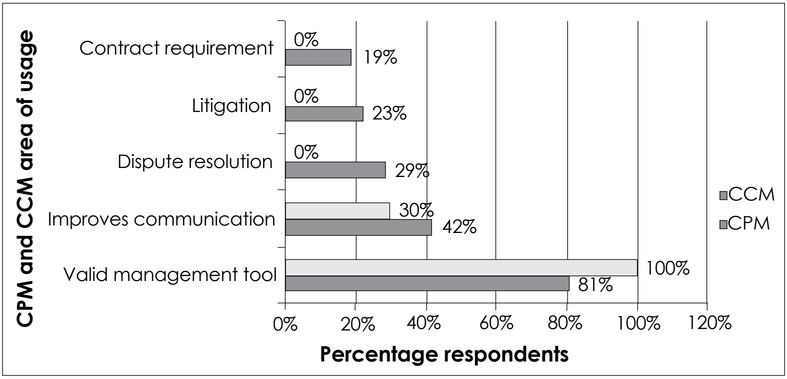

Figure 7: Reasons why companies use the CPM and the CCM

Table 3: Project areas where the CPM is applied

Project areas	*Response percentage*
Detailed planning of construction work	84%
Periodic control of construction work	55%
Operation and maintenance of projects	36%
Estimating and bidding	29%
Design development (conceptualisation, feasibility, etc.)	23%
Other	3%

Respondents who do not use the CPM provided reasons such as their projects being too small to justify the use of the CPM and the method being unnecessary for their needs, as well as it not reflecting the actual state of activities. The most prominent reason for not using the CCM is that companies do not regard the CPM as being problematic, therefore the CCM is deemed unnecessary.

They are further of the opinion that the CCM is too much effort to implement, with some companies simply being unwilling to embark on a culture change. The Besner and Hobbs (2008:16) survey-based study revealed that the use of the CCM was very limited, which the researchers partly accredited to the newness of the method.

4.3 Advantages and disadvantages of the CPM and the CCM

Although many companies see benefits in the application of the CPM, with the majority of the respondents stating that the method has no major disadvantages, some concern was also expressed. Figure 8 shows that the main perceived advantages of the CPM are improved planning, scheduling and project control. A further advantage is improved understanding of the project, which increases the on-time completion and reduces delays. Some of the users were concerned by the fact that the method depends too much on specialists, is not responsive to field personnel needs, and requires excessive implementation work.

In comparison, the companies applying the CCM also realise its benefits, with some users stating that the method has no major disadvantages for them. However, the concerns highlighted were that the CCM becomes difficult to manage when there are too many buffers and that the critical chain is not always clear after resource scheduling, since several chains could be identical. Improved scheduling and faster response to problems (both 78%) were considered the main advantages of the CCM. Improved planning and time saving (both 67%) were the next most cited advantages.

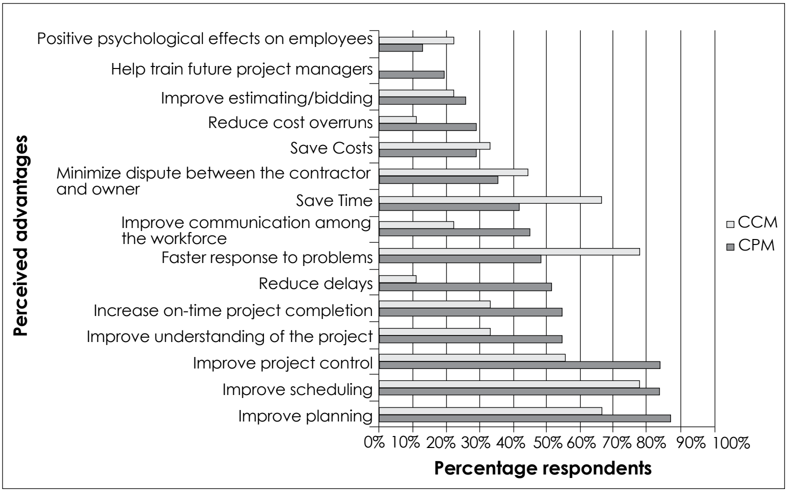

Figure 8: The perceived advantages of the CPM and the CCM

4.4 Importance of the CPM and the CCM for future company success

Generally, the CPM and the CCM are considered important methods to be used in the construction industry in South Africa. Only 3% of the respondents indicated that the CPM would likely be unimportant to their company's future success (see Figure 9). Furthermore, about 47% of the large companies and 36% of the medium-sized companies were of the opinion that the CPM should be deemed an important method for future projects. The CCM is mainly considered a moderately important method for future success, and only 22% of the respondents indicated that it will be very important in the future.

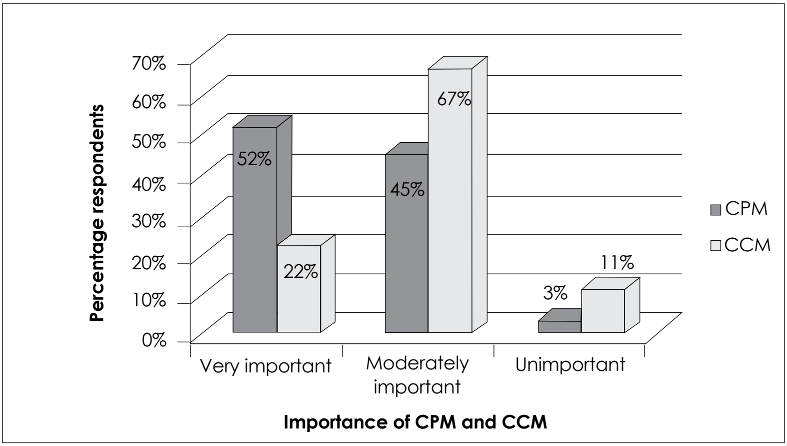

Figure 9: The importance of the CPM and the CCM to the future success of companies

CPM users are also of the opinion that they are more successful at achieving the advantages of the method than are users of the CCM. Large companies appear to get the most out of the CPM application. The fact that they use the CPM more frequently and trust the information provided by the method is probably the reason why nearly all of the companies regard the CPM as being moderately important to very important to their future success.

5. Conclusions

The primary focus of this paper was to determine the application of the CPM and the CCM in the South African construction industry, with the following subobjectives:

- To determine which of the construction sectors (building, civil and/or industrial) apply the CPM and the CCM
- To obtain the percentage of professionals who use these methods
- To define the prevailing reasons why these methods are applied
- To clarify the factors that influence the use of the CPM and the CCM

This study has established that the CPM and the CCM are proving to be versatile project scheduling tools in the South African construction industry. The results indicate that the CPM and CCM are widely used in the building industry, closely followed by the civil construction industry. The CPM is used on more than 50% of projects by just over 70% of the respondents who apply the method, with 34% of users applying it on all their contracts. In comparison, the CCM is used on more than 50% of the projects by over 60% of the respondents who apply the method, with 22.2% of users applying it on all their contracts.

Large companies appear to get the most out of the CPM application. The fact that they use the CPM more frequently and trust the information provided by the method is probably the reason why nearly all the companies regard the CPM as being moderately to very important to their present and future success.

The respondents in this study found the CPM to be beneficial and consider it important to the general success of their companies. The main reason why construction professionals use the CPM is that more than 80% of the respondents who apply the method consider it a valid management tool. Other reasons are that it improves communication among project parties and it is often a contract requirement, while it is also increasingly used in dispute resolution and litigation. The CPM has grown over the years and it appears that it will continue to grow, based on the companies' views of the CPM's importance to their future success in South Africa.

The CCM is used less than the CPM. Although it is not a difficult methodology to grasp, it is still considered to be a relatively new project management tool. The CCM appears to be challenging to implement, as a shift in mindset, behaviour and culture is required in the organisation. CCM users believe that the method mainly improves their project planning, scheduling and response time to problems, which saves time.

The most prominent reason for not applying the CCM is that companies do not regard the CPM as problematic. Therefore, they deem the CCM to be unnecessary. They further believe that the CCM is too much effort to implement, with some companies simply being unwilling to embark on a culture change.

The responding companies that apply the method mostly regard the CCM as being moderately important to present and future success.

6. Recommendations

This study has identified the need for further research relating to the CPM and the CCM in South Africa. A brief description of the potential areas for further research is provided by formulating a hypothesis, or providing a brief problem statement:

- Construction companies in South Africa use the CPM and the CCM for single- and multi-project management.
- The success factors of the CPM and the CCM differ during each phase of the project life cycle.
- The expansion of this study to gain a bigger sample will contribute significantly to more verified results.

Acknowledgements

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