Association of Schools of Construction of Southern Africa

The Thirteenth Built Environment Conference

2 - 3 September 2019, Durban, South Africa

Conference Proceedings

International Council
for Research and Innovation
in Building and Construction

BUILT ENVIRONMENT CONFERENCE – 2019

13th Built Environment Conference - Technology, Theory, Truth: Constructing a Sustainable Built Environment

2 – 3 September, 2019

Durban, South Africa

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PREFACE

The Association of Schools of Construction of Southern Africa (ASOCSA) Built Environment conference series in its 14th year of existence continues to be one of the major cutting edge built environment conferences on the African continent. Since its inception in 2006, the blind peer reviewed conference proceedings have been referred to by both private and public sector policy and decision makers. The series produces a post-conference edition of the Journal of Construction, which is on the list of journals approved by the South African Department of Higher Education and Training (DHET) for subsidy. The conference series continues to be endorsed by the International Council for Research and Innovation in Building and Construction (CIB), one of the largest global built environment research organizations and recognized by the Australian Institute of Building (AIB). The conference provides an interactive international forum and also networking opportunities among researchers, academics, administrators and practitioners, representing institutions of higher learning, government agencies, contracting organisations, consulting enterprises, financial institutions, and other construction-related organisations.

OBJECTIVES

The 13th Built Environment Conference with its theme of Technology, Theory, Truth: Constructing a Sustainable Built Environment had a range of interesting and cutting edge peer-reviewed research papers addressing topical issues that affect the built environment not only in South Africa but in the regions beyond. Notwithstanding the ever-increasing challenging global economic environment with shrinking sponsorship budgets, the conference continued in the tradition of previous conferences in the series and provided in an international forum with a clear industry development and sustainability focus. This focus provides the opportunity for researchers and practitioners from developed and developing nations to deliberate topical current issues that impact the Built Environment.

The broad objectives of the conference are:

- To provide a forum for multi-disciplinary interaction between academics and industry practitioners;
- To disseminate innovative and cutting edge practices that respond to the conference theme and outcomes, namely Technology, theory, Truth: Constructing a Sustainable Built Environment;
- To provide a world class leading internationally recognized, accredited conference for the built environment; and
- To contribute to the existing built environment body of knowledge (BEBOK) and practice.

The conference organizers brought together in a single forum, a group of researchers and academics from the wide range of built environment disciplines that include; engineers, architects, quantity surveyors, construction and project managers. Delegates were drawn not only from South African institutions of higher education, government agencies, and other construction-related organizations but also from across the African continent, Europe and the United Kingdom.

CONFERENCE THEME AND OUTCOMES

TECHNOLOGY, THEORY, TRUTH: CONSTRUCTING A SUSTAINABLE BUILT ENVIRONMENT

This conference sought responses to questions related to current conversations and debates on infrastructure delivery and sustainability such as,

- Innovative Construction Means, Methods and Materials
- Construction Education, Training and Skills Development
- Construction industry Transformation
- Development Infrastructure Design and Delivery challenges
- SME Contractor Development
- Construction Industry legislative and regulatory framework
- Government initiatives
- Public sector procurement,
- Contracting and innovation
- Construction Health and Safety
- Construction Labour Challenges
- Sustainable Construction and environment

The conference includes papers that address, inter alia,

- Current trends and developments
- Policies
- Legislation and regulations
- Practices
- Case studies.

These internationally peer reviewed and edited proceedings were aimed at contributing significantly to the body of knowledge relative to the science and practice of construction not only in South Africa but everywhere were the products of construction are produced.

Prof Theo C Haupt
Conference Academic Chair (2019)
Durban, South Africa
September 2, 2019

DISCLAIMER

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ACKNOWLEDGEMENTS

The organizing committee of the 13th Built Environment conference, held in Durban, South Africa, is grateful to the Council of the Association of Schools of Construction of Southern Africa and membership universities and individuals for supporting this conference through their valued contributions. Special thanks are also extended to our conference partners for supporting the conference through their valued sponsorships namely; LIMCO, FEM, GTChaane, Kamoarchitects. Without the support received, this conference and the further development and growth of the Association of Schools of Construction of Southern Africa (ASOCSA) with respect to its mission in the region would not be possible. Additionally, this support demonstrates the commitment to the further development of the body of knowledge relative to the science and practice of construction. This commitment is deeply valued and acknowledged.

Further thanks are extended to Professor Theo Haupt (Mangosuthu University of Technology) and Mariam Akinlolu and Mohlomi Raliile (postgraduates at the University of KwaZulu-Natal) who worked tirelessly especially in the co-ordination of paper reviews. The organizing committee also wishes to acknowledge the selfless contributions of the Scientific and Technical Committee and panel of reviewers who ensured that each paper was rigorously refereed for inclusion in the published proceedings of the highest standard that satisfies the criteria for subsidy by the South African Department of Higher Education and Training (DHET) was attained. . The contributions of Prof Kahilu Kajimo-Shakantu (University of the Free State) are appreciated.

The excellent support of our webmaster, Wendal Koopman, in setting up and supporting the conference website is appreciated. The sterling contributions of Ferial Lombardo in the co-ordination and organization of the conference are acknowledged.

CONFERENCE COMMITTEES

ORGANISING COMMITTEE

SCIENTIFIC AND TECHNICAL COMMITTEE

PANEL OF REVIEWERS

PEER REVIEW PROCESS

In order to maintain and ensure the highest quality in the conference proceedings and comply with the requirements for subsidy of the South African Department of Higher Education and Training (DHET), a rigorous two-stage system of peer review by no less than two acknowledged experts in the field has been followed. In terms of this process, each abstract received was twice blind reviewed in terms of:

· Relevance to overall conference theme and objectives;
· Relevance to selected sub-theme;
· Originality of material;
· Academic rigour;
· Contribution to knowledge; and
· Research methodology.

Authors whose abstracts were accepted after a blind peer review process was completed were provided with anonymous reviewers' comments and requested to submit their full papers noting and addressing these comments. Evidence was required relative to the actions taken by authors regarding the comments received. These resubmitted papers were twice blind reviewed again in terms of:

· Relevance to overall conference theme and objectives;
· Relevance to selected sub-theme;
· Originality of material;
· Academic rigour;
· Contribution to knowledge;
· Research methodology and robustness of analysis of findings;
· Empirical research findings; and
· Critical current literature review.

Authors whose papers were accepted after the second review were provided with additional anonymous reviewers' comments and requested to submit their revised full papers. These final papers were only included in both the conference presentation schedule and the conference proceedings after evidence was provided that all comments were appropriately responded to, having been multiple peer-reviewed for publication. At no stage was any member of the Scientific and Technical Committee or the editor of the proceedings involved in the review process relative to their own authored or co-authored papers. The role of the editors was to ensure that the final papers incorporated the reviewers' comments and arrange the papers into the final sequence based on the conference presentation schedule as captured on the conference proceedings and Table of Contents. Of the 65 abstracts originally received, only 39 papers were finally accepted for presentation at the conference and inclusion in these proceedings, representing an acceptance rate of 60%. To be eligible for inclusion these papers were required to receive one of three recommendations from at least two reviewers, namely;

- Accepted for publication or
- Provisional acceptance provided minor changes / corrections are made or
- To re-submit for publication provided author/s reconsider/s the areas of concern

Regards,

Theo Haupt
Conference Academic Chair 2019
Mangosuthu University

TAX BENEFIT

ASOCSA is a registered Public Benefit Organization as defined in Section 30 of the Income Tax Act and a registered Section 21 Company as defined in the Companies Act. Therefore, all donations made to ASOCSA will be fully deductible for income tax purposes and a section 18A certificate, for proof of deductibility will be issued to the donor upon receipt of the donation. The deductible donation is limited to 10% of the donors' taxable income before providing for Section 18A and Section 18 deductions.

Association of Schools of Construction of Southern Africa

2nd September

To whom it may concern,

Dear Author,

RELATIVE CONTRIBUTION OF ACADEMIC INSTITUITIONS TO THE 13TH BUILT ENVIRONMENT CONFERENCE 2019

On behalf of ASOCSA 2019, we confirm that the papers accepted for publication in the 13th Built Environment conference proceedings met the 60-40% conference policy.

A total of 39 (single or co-authored) peer-reviewed papers from 21 national and international universities were presented at the conference.

The total author affiliation breakdown for each of the papers are shown on Table 1.

TABLE 1: BREAKDOWN OF AUTHORS AND AFFILIATIONS

	Institution	First author	Co-authors	Total	Percentage by institution
1	University of Free State	6	8	14	13%
2	Nelson Mandela University	5	8	13	12%
3	Obafemi Awolowo University	1	1	2	2%
4	University of Pretoria	1	1	2	2%
5	Kwame Nkrumah University	1	1	2	2%
6	Mangosuthu University of Technology	0	4	4	4%
7	Namibia University of Technology	1	0	1	1%
8	University of Cape Town	2	2	4	4%
9	University of South Africa	1	0	1	1%
10	Central University of Technology	3	2	5	5%
11	Copperbelt University	1	0	1	1%
12	British University Egypt	3	6	9	8%
13	University of Johannesburg	4	11	15	14%
14	Durban University of Technology	1	2	3	3%
15	London South Bank University	2	4	6	6%
16	Tshwane University of Technology	1	3	4	4%
17	Ardhi University	0	3	3	3%
18	University of KwaZulu-Natal	4	3	7	8%
19	Hong Kong Polytechnic University	0	1	1	1%
20	University of Botswana	1	1	2	2%
21	Vaal University of Technology	1	3	4	4%
	Total	**39**	**64**	**103**	**100%**

The final accepted papers will be published in the conference proceedings with ISBN number: 978-0-6399855-1-0.

Regards,

Prof Kajimo-Shakantu

ASOCSA President

Association of Schools of Construction of Southern Africa

History

ASOCSA is not the first attempt to form a body that addresses, inter alia, matters of construction education and training. In the days of the Building Industries Federation South Africa and the National Development Fund there were regular annual meetings of the Heads of Departments that offered construction-related programs. Recognizing the two-tiered higher education sector in South Africa, there were separate meetings for universities and the former technikons. In the more recent past, the Chartered Institute of Building - Africa initially convened annual educators' forums that did not quite fulfill the same function as the previous forums. However, during 2005 the very first meeting of University Heads of Departments drawn from all higher education institutions in South Africa met for the very first time since the re-landscaping of the sector in the same venue to discuss matters affecting construction, and particularly construction education in the country. This meeting was repeated in 2006 where the need was expressed for the establishment of a formal forum / association of universities to engage in discussion / debate / collaboration / promotion of matters of mutual interest.

Broad Aims

ASOCSA aims to be the professional association for the development and advancement of construction education in Southern Africa, where the sharing of ideas and knowledge inspires, guides and promotes excellence in curriculums, teaching, research and service. To achieve this aim ASOCSA is partnering with the construction industry to find ways to effectively represent the interests of both construction academic and industry practitioners. ASOCSA will offer a variety of programs and services designed to help its members serve their customers more effectively and succeed in an increasingly challenging environment of construction information management and technology. To this end ASOCSA provides a forum for the debate and discussion of issues of mutual interest to all industry stakeholders. For example, one of the tasks of ASOCSA will be supporting the development of curriculums that address the needs of the construction sector in the Southern African region. ASOCSA convenes an annual conference that is one of only two construction-related conferences accredited by the Department of Higher Education and Training (DHET) where construction academics and practitioners can interact relative to practical experience and the findings of relevant research. This conference series is endorsed and underwritten by the International Council for Research and Innovation in Building and Construction (CIB) as well as several major industry stakeholders.

The Journal of Construction which is accredited by the Department of Higher Education presently published electronically four times per year is the official journal of ASOCSA and in the past more than 5,000 complimentary copies were distributed to all industry stakeholders in the Southern African region. The production and distribution of practice notes and technical papers is a further endeavor to grow the partnership between academia and industry.

With respect to the Southern African region, ASOCSA is committed to the following:

Vision

To drive innovative construction related higher education

Mission Statement

To promote, facilitate, develop and monitor the relevance and quality of construction related curricula, research and graduates in conjunction with higher education institutions, industry and government.

Strategic objectives

The objectives of the Association are:

- to promote and facilitate the development of curricula for construction related programmes
- to assist with the accreditation of construction related programmes
- to hold an annual conference that acts as a forum for multi-disciplinary interaction between academics and practitioners
- to publish an accredited research-based journal and contribute to the built environment body of knowledge (BEBOK)
- to disseminate information dealing with construction education and related matters
- to develop and maintain closer links with industry and government
- to represent the collective views of its members
- to liaise with other organisations and persons to promote the interests of its members
- to promote and support relevant postgraduate research
- to provide bursaries to postgraduate students in accordance with set criteria

ASOCSA continues to seek opportunities to promote both academic and industry employment opportunities. Finally, ASOCSA intends to play a significant role in the accreditation of construction-related academic programs.

Heads Forum meetings

ASOCSA believes that meetings of the Heads Forum comprising of Heads of School and Departments of Construction is a vital component of its functions and holds Heads meetings during each conference.

International Affiliation

ASOCSA has commenced discussions about closer collaboration with similar institutions such as the Associated Schools of Construction (ASC) in the United States, the Royal Institute of Chartered Surveyors (RICS), the Chartered Institute of Building (CIOB), Australian Institute of Building (AIB) and Council of the Heads of the Built Environment (CHOBE) in the United Kingdom. ASOCSA has entered into a Memorandum of Understanding with the International Council for Research and Innovation In Building and Construction (CIB).

In summary, benefits of membership of ASOCSA which are self-evident include participation in meetings of the Heads Forum throughout the region, access to the Journal of Construction, reduced rates at all ASOCSA, MBA and CIB events, involvement at regional level with industry-academia forums, interaction and networking opportunities relative to, for example, collaborative research, curriculum development, external moderation of courses, and external examination

ASSOCIATION OF SCHOOLS OF CONSTRUCTION OF SOUTHERN AFRICA

For more information on ASOCSA and its activities visit www.asocsa.org

02 September 2019

To whom it may concern

Dear Author

PEER REVIEW PROCESS CONFIRMATION: 13TH BUILT ENVIRONMENT CONFERENCE: DURBAN, SOUTH AFRICA 2019

On behalf of the 13th Built Environment Conference 2019, we wish to confirm that the following blind peer review process was strictly followed relative to this conference.
In order to maintain and ensure the highest quality in the conference proceedings and comply with the requirements for subsidy of the South African Department of Higher Education and Training (DHET), a rigorous two-stage system of peer review by no less than two acknowledged experts in the field has been followed. In terms of this process, each abstract received was twice blind reviewed in terms of:

- Relevance to overall conference theme and objectives;
- Relevance to selected sub-theme;
- Originality of material;
- Academic rigour;
- Contribution to knowledge; and
- Research methodology.

Authors whose abstracts were accepted after the blind review process was completed, were provided with anonymous reviewers' comments and requested to submit their full papers noting and addressing these comments. Evidence was required relative to the action taken by authors regarding the comments received. These resubmitted papers were twice blind reviewed again in terms of:

- Relevance to overall conference theme and objectives;
- Relevance to selected sub-theme;
- Originality of material;
- Academic rigour;
- Contribution to knowledge;
- Research methodology and robustness of analysis of findings;
- Empirical research findings; and
- Critical current literature review.

Authors whose papers were accepted after this second review were provided with additional anonymous reviewers' comments and requested to submit their revised full papers. These final papers were only included into both the conference presentation schedule and the conference proceedings after evidence was provided that all comments were appropriately responded to, having been multiple peer-reviewed for publication. At no stage was any member of the Scientific and Technical Committee or the editor of the proceedings involved in the review process relative to their own authored or co-authored papers. The role of the editors was to ensure that the final papers incorporated the reviewers' comments and arrange the papers into the final sequence based on the conference presentation schedule as captured on the conference proceedings and Table of Contents. Of the 65 abstracts originally received, only 39 papers were finally accepted for presentation at the conference and inclusion in these proceedings, representing an acceptance rate of 60%. To be eligible for inclusion these papers were required to receive one of three recommendations from at least two reviewers, namely

- Accepted for publication or
- Provisional acceptance provided minor changes / corrections are made or
- To re-submit for publication provided author/s reconsider/s the areas of concern

The final accepted papers which had undergone a three stage review process (abstract, full paper and final paper) will be published in the conference proceedings with **ISBN number: 978-0-6399855-1-0.**

Sincerely,

Prof Kajimo-Shakantu (ASOCSA President)

Ferial Lombardo (ASOCSA Conference Organizer)

CONTENTS

Session: Innovation Construction Means, Methods and Materials

ASOCSA2019-032

Construction Management's Contributions to Health and Safety (H&S)

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ABSTRACT AND KEYWORDS

Purpose of this paper
A quantitative study was conducted across the three main divisions of a regional entity of a national general contractor, namely building, civil, and roads and earthworks to determine the: beliefs / actions relative to H&S; degree of management and supervisor commitment to and involvement in H&S; degree of integration of H&S into supply chain management and the management of projects, and need for an H&S training analysis.

Design/methodology/approach
The empirical study adopted a quantitative approach and entailed the distributing of self-administered research questionnaires to construction management, and construction H&S personel.

Findings
The salient findings are: there is a relatively healthy H&S culture; management is committed to H&S, and H&S is integrated into supply chain management, and the management of projects.

Research limitations/implications
The study was limited to the three main divisions of a regional entity of a national general contractor, and then construction management and construction H&S personnel.

Practical implications
The study investigated construction management's contributions to H&S. Conclusions include: the H&S culture is partially healthy; management cascades the importance of H&S being a value; there is a relatively healthy H&S climate; management is committed to, and involved in H&S to a degree, and H&S is integrated into procurement.

What is original/value of paper?
The recommendations include management should: address misconceptions related to the H&S culture; select subcontractors based on their H&S records, and their H&S management systems; encourage reporting of H&S issues; broaden the content of H&S communication; be more visibly involved in addressing deviations that are raised in H&S non-conformance reports, in inspections and audit reports, and allow H&S representatives enough time to conduct inspections, and to report to their respective H&S Committees.

Response to the Conference Theme
The paper responds to the conference theme given that H&S promotes sustainability of the built environment.

Keywords: Construction Management; Culture; Commitment; Health and Safety

1. INTRODUCTION

The construction industry has for many years developed a very bad reputation for coping with project cost, H&S, quality, and schedule. Not only does the construction industry sometimes deliver buildings late, it generally contributes to a disproportionate number of work-related injuries and fatalities.

Poor construction H&S performance at organisational and site level is partly due to a focus on production and profit, inadequate management commitment to H&S, inadequate supervision, inadequate H&S training, inadequate worker involvement in H&S, and lack of personal risk appreciation (cidb, 2009). Project H&S management is acknowledged as one of the interventions that could be improved on construction projects to enhance the performance of construction contractors in South Africa.

According to the cidb (2009), the main aim of H&S legislation is to contribute to preventing accidents and the consequences thereof in the work environment, namely injuries, disabilities, fatalities, and disease. This aim could be achieved by compliance with legislation, and effective and accountable enforcement.

Site accidents are more likely when and where there are inadequate organisational policies, unsafe practices, a poor attitude to H&S on the part of construction personnel, inadequate management commitment, and insufficient H&S knowledge or training of workers (Enshassi, Smallwood and Hassouna, 2007). Enshassi et al. (2007) posit that project H&S performance is as much a measure of the success of the project, as project schedule, cost, and quality.
Given the aforementioned, a study was conducted, the objectives being to determine the:

- Beliefs / actions prevalent relative to H&S;
- Degree of management and supervisor commitment to, and involvement in H&S;
- Degree of integration of H&S into supply chain management, and the management of projects, and
- The need for an H&S training analysis.

2. REVIEW OF THE LITERATURE

2.1 Health and safety and the other project parameters

H&S is generally perceived as a hindrance to production. The construction industry incurs many costs due to accidents, and a disproportionate rate of fatalities and injuries. Usually, when an accident occurs on a construction site, operations are halted until preliminary investigations are conducted. Therefore, if construction projects are to be completed without cost overruns, on time, and without experiencing accidents, effective and efficient management of project H&S on site is critical (Enshassi et al., 2007).

Damon (2014) argues that there is an on-going tension between H&S and production, and that metrics are geared towards productivity, while management tends to disregard H&S concerns. In a similar vein, Zanko and Dawson (2012) contend that, as in most other industries, in construction, H&S programmes compete with operational functions for resources, including the time of workers, supervisors, managers, executives, and board members. The construction industry accepts risky and unhealthy operations, resulting in many relatively unpredictable human tragedies that affect cost, productivity, and reputation. Damon (2014) stresses that construction managers tend to focus on productivity, as it affects cost, quality, and time. However, improvements in H&S reduce the risk of injuries and illnesses in the long term, but at the immediate and calculable cost of productivity, profitability, and even quality.

2.2 Economics of Health and Safety

Given that the cost of accidents (COA) is estimated to be between 4.3% and 5.4% of the value of completed construction, whereas the cost of implementing H&S is estimated to be between 0.5% and 3% of project costs, clearly H&S is a 'profit centre' (Smallwood, 2004). Research conducted by Ikpe, Hammond, Proverbs, and Oloke (2011) determined that the benefits of accident prevention outweigh the costs of accident prevention by a ratio of approximately 3:1 - 62% benefit gain to 38% benefit loss. These findings clearly indicate the financial component of the 'holistic role of H&S'.

In terms of synergy, a study conducted among construction project managers in South Africa (Smallwood, 1996 in cidb, 2009) determined, inter alia, that productivity (87.2%) and quality (80.8%) predominated among aspects negatively affected by inadequate H&S, followed by cost (72.3%), client perception (68.1%), environment (66%), and schedule (57.4%). This finding underscores the ‘holistic role of H&S’, particularly with respect to enhancing project performance, competitive advantage, marketing, and public relations.

2.3 Causes of Poor Health and Safety Performance and Improvement thereof

The Construction Industry Development Board (cidb) (2009) states that management and leadership at all levels are crucial to improve construction H&S in South Africa. The cidb (2009) further states that H&S relevant education and training (or lack thereof), at all levels, has a major impact on construction H&S. At the tertiary level, not all construction related programmes in South Africa include H&S within their curricula. At the site level, studies suggest that about 18% of site supervisors and about 33% of site workers have not received any H&S training. Dejus and Antucheviciene (2013) contend that education and training of construction workers is the main area of focus to mitigate the risk of H&S risk occurrence. Frank Haslam Milan (FHm), a United Kingdom (UK) contractor achieved its target of a zero-accident rate through a training and awareness initiative. Their employees also increasingly contributed their own ideas to improve H&S, as opposed to simply following management’s H&S instructions, which amplifies the value of worker participation in H&S (Pollitt, 2006).

The Olympic Delivery Authority (ODA) managed to achieve an accident frequency rate significantly better than the construction sector, on the Olympic Park site in east London (Shiplee, Waterman, Furniss, Seal, & Jones, 2011). There were five key elements to the H&S programme, namely safety, health, wellbeing, competence, and culture. Safety aspects included clear policies, risk assessments, method statements, common standards, visual standards, and daily activity briefings. Competence aspects included induction, training, supervisor academy, briefings, apprenticeships, checks, and records. Culture aspects included leadership, action plans, near-miss reporting, communications, reward and recognition, and a climate tool.

The Health & Safety Executive (HSE) (2002) contends that strong, visible management commitment is crucial for good H&S performance, and that commitment must be expressed in practical terms and thus visible at working level. When directors and senior managers visit sites, they should reinforce the H&S messages, as well as listen to workers. A key management task is, therefore, communication. The HSE also refers to risks and states that some major projects now operate a risk register, where all the risks are set out and quantified along with the steps taken to mitigate them.

3. RESEARCH

3.1 Research method and sample stratum

The questionnaire consisted of nine questions, eight closed end questions, and one open end question. The primary closed end question consisted of fifty-four sub-questions, and the other seven were demographic-related.

The sample stratum was comprised of 30 respondents across the three main divisions of a regional entity of a national general contractor, namely building, civil, and roads and earthworks. The target group was H&S Representatives, CHSMs, CHSOs, site agents, construction supervisors, construction managers, and directors.

15 (50.0%) of respondents represented the building division, 6 (20%) the civil division, and 9 (30.0%) the roads and earthworks division.

70% of respondents were males, and 30% females.

46.0% of the respondents are > 18 ≤ 39 years of age, 41.0% are > 39 < 60 years of age, and 13.0% are > 60 years of age.

7% of respondents have between ‘> 0 ≤ 2’ years’ experience, 17% have ‘> 2 ≤ 7’ years, 23% have ‘> 7 ≤ 12’ years, 13% have ‘> 12 ≤ 17’ years, and 40% ‘> 17’ years.

3.2 Research findings

Table 1 indicates the degree of concurrence with beliefs / actions relative to H&S on construction projects in terms of a scale of strongly disagree to strongly agree, and a mean score (MS) ranging between 1.00 and 5.00. 4 / 7 Beliefs / actions are true (T) and 3 / 7 are false (F). The first three true statements have MSs > 4.20 ≤ 5.00, which indicates that respondents' degree of concurrence is between agree to strongly agree / strongly agree. It is notable that the MS of 'H&S is a priority on construction projects (F)' is on the lower point of this range. Managing H&S is everyone's responsibility, not just that of H&S personnel. Furthermore, construction management is responsible for the management of the physical construction process, and managing H&S is no different from managing cost, productivity, quality, and time. H&S should be a value, as priorities can change from day to day, the latter contention actually constituting a threat to H&S.

'Construction is inherently dangerous (F)' and 'All accidents are preventable (T)' have MSs > 3.40 ≤ 4.20, which indicates the respondents' degree of concurrence is between neutral and agree / agree. In the case of the former the concurrence should have been disagree as opposed to agree, as construction is not inherently dangerous, which implies that nothing can be done to mitigate hazards and risk, which is not the case. the existence of hazards and risk.

'Accidents are part of the job (F)' has a MS > 1.80 ≤ 2.60, which indicates the respondents' degree of concurrence is between strongly disagree and disagree / disagree. This is a myth that historically was perpetuated, probably to justify the occurrence of accidents. As in the case of the contention 'construction is inherently dangerous', strategies, systems, procedures, and protocol can mitigate accidents.

Table 1: Degree of concurrence with beliefs / actions relative to H&S on construction projects.

Belief / Action	Response (%)						MS
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
The responsibility of managing H&S is everyone's responsibility in this organisation (T)	0.0	0.0	3.3	0.0	23.3	73.3	4.67
H&S cannot be assumed, it must be demonstrated (T)	0.0	0.0	0.0	6.7	43.3	50.0	4.43
H&S is a value on construction projects (T)	0.0	3.3	3.3	6.7	36.7	50.0	4.27
H&S is a priority on construction projects (F)	0.0	0.0	3.3	13.3	43.3	40.0	4.20
Construction is inherently dangerous (F)	0.0	0.0	6.7	13.3	43.3	36.7	4.10
All accidents are preventable (T)	0.0	6.7	16.7	0.0	46.7	30.0	3.77
Accidents are part of the job (F)	0.0	33.3	36.7	3.3	16.7	10.0	2.33

Table 2 indicates the degree of concurrence with statements / states related to supervisors and H&S in terms of a scale of strongly disagree to strongly agree, and a MS ranging between 1.00 and 5.00. It is notable that only the first statement (T) has a MS > 4.20 ≤ 5.00, which indicates the degree of concurrence is between agree to strongly agree / strongly agree. Communication is critical in terms of H&S, and takes a range of forms, and is necessary to communicate the outcomes of processes. An H&S policy communicates the H&S culture, H&S induction is necessary to make new site participants aware of the H&S issues, the outputs of HIRAs must be communicated, and safe work procedures (SWPs) must be communicated and available on-site.

One statement 'Supervisors manage H&S within their areas of responsibility' has a MS > 3.40 ≤ 4.20, which indicates the respondents' degree of concurrence is between neutral and agree / agree. The concurrence indicates that there is potential for supervisors to improve their management of H&S. Two statements, namely 'Supervisors are familiar with the H&S responsibility attached to their appointment', and 'Supervisors are adequately trained in terms of managing H&S' have MSs > 2.60 ≤ 3.40, which indicates the respondents' degree of concurrence is between disagree to neutral / neutral. The concurrence indicates that there is potential for further training of supervisors in terms of managing H&S, and their H&S responsibilities.

Table 2: Degree of concurrence with statements / states related to supervisors and H&S.

Statement / State	Response (%)						MS
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
Effective communication is essential for a healthy and safe workplace (T)	0.0	0.0	3.3	6.7	33.3	56.7	4.43
Supervisors manage H&S within their areas of responsibility	0.0	0.0	16.7	16.7	63.3	3.3	3.53
Supervisors are familiar with the H&S responsibility attached to their appointment	0.0	6.7	20.0	13.3	53.3	6.7	3.33
Supervisors are adequately trained in terms of managing H&S	0.0	3.3	26.7	26.7	30.0	13.3	3.23

Table 3 indicates the degree of concurrence with statements related to management's commitment to, and involvement in H&S in terms of a scale of strongly disagree to strongly agree, and a MS ranging between 1.00 and 5.00. It is notable that no statement has a MS > 4.20 ≤ 5.00. All eight statements have MSs > 3.40 ≤ 4.20, which indicates the respondents' degree of concurrence is between neutral and agree / agree. This is notable as five of these statements relate to management 'involvement' - chairs H&S committee meetings; forms part of incident investigations; is directly involved with H&S in this organisation; implements corrective actions identified during audits and inspections, and is involved with incident investigations. Two further statements relate to resourcing H&S, and the eighth statement refers to responsibility for planning H&S. Management commitment to H&S is important, however, management involvement is the ultimate hallmark of commitment. The concurrence indicates that management commits resources, including personal time. However, there is potential for improvement, particularly with respect to following up post audits, inspections, and incident investigations.

Table 3: Degree of concurrence with statements related to management's commitment to, and involvement in H&S.

Statement	Response (%)						MS
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
Management effectively chairs H&S committee meetings	0.0	0.0	13.3	10.0	40.0	36.7	4.00
Management is responsible for planning H&S	0.0	0.0	10.0	6.7	63.3	20.0	3.93
Management ensures adequate resources are allocated relative to H&S	0.0	3.3	6.7	6.7	63.3	20.0	3.90
Management forms part of incident investigations	0.0	0.0	13.3	13.3	46.7	26.7	3.87
Management provides funding for H&S training	0.0	0.0	6.7	20.0	53.3	20.0	3.87
Management is directly involved with H&S in this organisation	0.0	0.0	16.7	13.3	40.0	30.0	3.83
Management implements corrective actions identified during audits and inspections	0.0	0.0	13.3	16.7	43.3	26.7	3.83
Management is involved with incident investigations	0.0	0.0	20.0	23.3	36.7	20.0	3.57

Table 4 indicates the degree of concurrence with sixteen statements related to the integration of H&S into supply chain management, and the management of projects, in terms of a scale of strongly disagree to strongly agree, and a MS ranging between 1.00 and 5.00. It is notable that only 2 / 16 (12.5%) statements have MSs > 4.20 ≤ 5.00, which indicates the degree of concurrence is between agree to strongly agree / strongly agree - 'H&S should be used as a criterion in the selection and appointment of subcontractors', and 'Inadequate or lack of H&S negatively affects other project parameters i.e. productivity, quality, cost and schedule'. This indicates a realisation of the role of H&S in overall project performance, and the need to assure H&S performance in the supply chain.

10 / 16 (62.5%) Statements have MSs > 3.40 ≤ 4.20, which indicates the respondents' degree of concurrence is between neutral and agree / agree. With respect to subcontractors, there is an H&S policy in place to manage subcontractors, and they are required to comply therewith, however, there is

a 'play off' in terms of the cost of complying versus not complying. In terms of cost, H&S forms part of project budgets, and the cost of accidents exceeds the cost of H&S. With respect to commitment, management and workers see the benefits of complying with H&S legislation. Then, H&S is integrated into all activities in construction, and non-compliance with regards to H&S is addressed and activities are halted until rectified. The aforementioned is reinforced by 'Findings from H&S inspections are always discussed at the H&S committee meetings'. The concurrence further indicates a realisation of the role of H&S in overall project performance, and the implications of inadequate H&S performance. Furthermore, to realise optimum H&S performance requires a range of interventions. However, the concurrence indicates that there is potential to enhance the degree of compliance.

3 / 16 (18.8%) Statements have MSs > 2.60 ≤ 3.40, which indicates the respondents' degree of concurrence is between disagree to neutral / neutral - subcontractors rate H&S as important, there are trained H&S Representatives on all projects, and they are allowed enough time to conduct inspections. The concurrence indicates that there is potential to engender increased commitment to H&S by subcontractors, and that there must be more focus on H&S Representatives in terms of H&S training, and the fulfilling of their H&S responsibilities.

1 / 16 (6.3%) Statement, namely 'H&S is solely the responsibility of the CHSM & CHSOs' has a MS > 1.80 ≤ 2.60, which indicates the respondents' degree of concurrence is between strongly disagree and disagree / disagree, which is correct. The concurrence indicates more disagreement than agreement, however, theoretically the MS should be 1.00 as H&S is the collective responsibility of management, supervision, and workers within the context of the management of the physical construction process.

Table 4: Degree of concurrence with statements related to the integration of H&S into supply chain management, and the management of projects.

Statement	**Response (%)**						**MS**
	Unsure	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
H&S should be used as a criterion in the selection and appointment of subcontractors	0.0	3.3	0.0	10.0	33.3	53.3	4.34
Inadequate or lack of H&S negatively affects other project parameters i.e. productivity, quality, cost and schedule	0.0	3.3	3.3	3.3	36.7	53.3	4.33
There is an H&S policy in place to manage subcontractors	0.0	3.3	0.0	0.0	70.0	26.7	4.17
The cost of H&S forms part of project budgets	0.0	0.0	6.7	10.0	46.7	36.7	4.13
Management see the benefits of complying with H&S legislation	0.0	0.0	0.0	20.0	50.0	30.0	4.11
Subcontractors are required to comply with the H&S policies of this organisation	0.0	0.0	10.0	6.7	46.7	36.7	4.10
The cost of accidents exceeds the cost of H&S	0.0	6.7	3.3	16.7	36.7	36.7	3.93
H&S is integrated into all activities in construction	0.0	0.0	10.0	13.3	50.0	26.7	3.93
Non-compliance with regards to H&S is addressed and activities are halted until rectified	0.0	0.0	13.3	20.0	36.7	30.0	3.83
Employees see the benefits of complying with H&S legislation	0.0	0.0	6.7	26.7	46.7	20.0	3.80
The level of compliance by subcontractors to regulatory requirements is influenced by the perceived cost saving of not complying	0.0	6.7	3.3	20.0	53.3	16.7	3.70
Findings from H&S inspections are always discussed at the H&S committee meetings	0.0	0.0	23.3	10.0	50.0	16.7	3.60
Subcontractors rate H&S as important	0.0	6.7	23.3	13.3	40.0	16.7	3.37
There are trained H&S Representatives on all construction projects	0.0	13.3	23.3	6.7	36.7	20.0	3.27
Supervisors allow H&S representatives enough time to conduct inspections	0.0	10.0	20.0	20.0	36.7	13.3	3.23
H&S is solely the responsibility of the CHSM & CHSOs	0.0	50.0	10.0	13.3	10.0	16.7	2.33

Table 5 indicates the degree of concurrence with H&S training needs analysis for occupations in terms of a scale of strongly disagree to strongly agree, and a MS ranging between 1.00 and 5.00. It is notable that two H&S occupations have MSs > 4.20 ≤ 5.00 – CHSOs, and H&S Representatives. The MS of CHSMs is on the lower point of this range, however, technically it falls within the lower range. The MSs of Construction Managers, and Construction Supervisors are > 3.40 ≤ 4.20, which indicates the respondents' degree of concurrence is between neutral and agree / agree.

Table 5: Degree of concurrence with H&S training needs analysis.

Occupation	**Response (%)**						**MS**
	Unsure	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
CHSOs	0.0	0.0	0.0	6.7	50.0	43.3	4.37
H&S Representatives	0.0	0.0	3.3	6.7	50.0	40.0	4.27
CHSMs	0.0	0.0	3.3	10.0	50.0	36.7	4.20
Construction Managers	0.0	0.0	3.3	13.3	50.0	33.3	4.13
Construction Supervisors	0.0	0.0	3.3	16.7	46.7	33.3	4.10

4. CONCLUSIONS

The aim of the study was to determine construction management's perceptions towards H&S. The findings of the survey revealed that virtually all respondents agree with the statement that the responsibility of managing H&S lies with everyone in the organisation, and not only the H&S personnel. Given this finding, it can be concluded that H&S is a value in the organisation. Although it can be concluded that the H&S culture is partially healthy, there is agreement as opposed to disagreement with respect to 'H&S is a priority on construction projects' and 'Construction is inherently dangerous'. Given that it is acknowledged that supervisors are trained in terms of H&S, know their H&S responsibilities, and manage H&S, it can be concluded that management cascades the importance of H&S being a value, and that there is a healthy H&S climate.

Given the degree of concurrence with statements related to management's commitment, it can be concluded that management is committed to, and involved in H&S.

Given the degree of concurrence with statements related to the integration of H&S into supply chain management, and the management of projects, it can be concluded that H&S is a value in the organisation, management is committed to and involved in H&S, and H&S is integrated into procurement. However, there is potential to improve the level of H&S compliance.

Given the degree of concurrence with the necessity of an H&S training needs analysis relative to various occupations, it can be concluded that H&S is a value in the organisation, management is committed to H&S, and training.

5. RECOMMENDATIONS

Management should address the subscription to the belief that 'H&S is a value on construction projects', and 'H&S is a priority on construction projects' as they are both false.

Subcontractors should be selected based on their H&S records, and their H&S management systems, and not only on their tender price.

Management should develop and maintain effective communication channels with workers. The perception that management encourages reporting of H&S issues, is a good basis for broadening the content of H&S communication, perhaps by adding budget issues, such as the cost H&S and the cost of accidents.

Management should be more visibly involved in addressing deviations that are raised on H&S non-conformance reports, in inspections and audit reports, and be more visible in ensuring that corrective actions are implemented.

Management should also become visibly involved at incident investigations, and ensure that recommendations from these investigations are implemented. They should also be involved in raising awareness of measures to prevent similar incidents.

Supervisors should allow H&S representatives enough time to conduct inspections, and to report to their respective H&S Committees regarding the status of H&S in their work areas, and the training of H&S Representatives should be focused on.

Management should take note that H&S training needs analysis is critical for all employees, since this raises H&S awareness among all stakeholders in the construction industry, thereby raising general commitment and involvement in H&S activities.

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Gender differences in perceptions of workplace interactions among University students' in male-dominated work

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Purpose of this paper
This study explores university students' perceptions of gendered interactions in male-dominated environments. The paper assess whether gender differences affects the perceptions of students regarding gendered workplace cultures.

Design/methodology/approach
Using a quantitative descriptive survey design, 76 university students conveniently sampled across different levels of study were required to complete a questionnaire with closed-ended questions. The samples were drawn from student cohorts enrolled in the construction studies; civil engineering, property development, land surveying and civil engineering program. The independent *t*-test was performed to determine if significant differences in responses exist by gender.

Findings
Majority of the students experienced consistent gendered interactions or practices at their workplaces. These practices included marginalising stereotypical feminine interests, belittling women and making requests based on gender. Students indicated that they responded to these experiences by tolerating and adapting to the situation and sometimes by justifying the interactions they experienced.

Research limitations/implications
The sample is drawn from only one university in South Africa and findings cannot be confirmed as indicative of all students in male-dominated professions in South Africa as they represent only perceptions of a small group.

Practical implications
The study reveals the need for educators to review existing curricula in relevant courses. This would ensure that university students are well informed and prepared for workplace realities. Employers need to re-examine their workplace policies and make conscious effort to provide strategies that address gendered workplace cultures through training, mentorship and enforcement.

Keywords: **Education**, **Gender, Male-dominated work, Women, Workplace cultures.**

1. INTRODUCTION

Numerous studies have reported that despite an extensive range of transformational legislations such as the Employment Equity Act developed to promote women's growth in the economy, women continue to be under-represented in the construction industry and more so among construction students (Gurjao, 2006; Madikizela and Haupt, 2010; English and Hay, 2015; Male, Gardner, Figueroa and Bennett, 2018). Factors ranging from differential socialization and aspirations along gender lines to the culture of the industry have been identified as principal reasons for the under-representation (Hartman and Hartman, 2009; Haupt, 2010).

Of the total employed South African population in 2017, 44% were women, and only 13% of these women were employed in the construction industry (Statistics South Africa, 2017). No changes have occurred over the years, as it has been 44% since September 2002. Furthermore, sectors of the economy such as mining and transportation had low concentrations of female employees (Ibid). Out of the total female workforce which is estimated at 10,250,000, the construction industry only contributes 174,000 (Ibid).

Although women are more successful than their male counterparts as students (English, 2007; Lourens, 2014), women leave the construction profession at higher rates than men (Kaspura, 2014). The masculine culture of the workplace, where interactions marginalize the identities of female engineers has been identified as a prevalent contributor towards women's refusal to take up careers in the construction industry (Hatmaker, 2013). Women experience challenges resulting from the deep-rooted masculinity of the industry which forces them to choose between undoing their gender or acting like the men (Hartman and Hartman, 2009; Franzway, Rhonda, Mills and Gill, 2009).

Numerous initiatives targeted to increase the representation of women within the construction industry have been established (Worral, Harris, Stewart, Thomas and Mcdermott, 2010; Fox, Sonnert and Nikiforova, 2011). Initially, these programmes were designed to create awareness and familiarise female engineering students with engineering courses, and eventually incorporated initiatives focused on improving curriculum, in light of recommendation from studies that concentrate on gender inclusivity in engineering curricula (Godfrey 2003; Godfrey and King 2011; Alves and English, 2018).

Emphasis has been placed on the applications of engineering science and project-based learning (Louw-Harmse, 2015). According to Alves and English (2018), the role of the curriculum is to educate engineering students on how to manage and respond to social challenges at the workplace and should be part of the engineering curriculum. Gill, Julie, Mills and Rhonda (2008) recommended that comprehensive and inclusive curricula should prepare students for the engineering workplace culture. However, suitability of the curriculum as an instrument to engage students on social issues in the industry has not received much attention, which is disturbing, as engineering students experience workplace cultures even before they are out of school (Male *et al*., 2018). At most universities and higher learning institutions offering engineering degree programmes in South Africa, students are required to undergo at least 12 months of relevant work experience.

Numerous studies have investigated the experience of gendered cultures, and gender inclusivity of students in male-dominated workplaces (Schmitt, Branscombe, Kobrynowicz and Owen, 2002; Male *et al.*, 2017; Male and MacNish, 2015; Alves and English, 2018; Madikizela and Haupt, 2010; Powell, Bagilhole, and Dainty 2009). Studies in Europe, America, Australia and Africa have revealed attitudes and experiences consistent with gendered cultures in male-dominated workspaces.

In Australia, Male *et al.* (2017) interviewed nine female and four male students from three universities about their experiences and responses to gendered cultures during their workplace learning placements. All students reported experiences consistent with gendered cultures. The study identified marginalization of women or stereotypically feminine practices or privilege of stereotypically masculine practices or traits.

In the United Kingdom, Powell *et al.* (2009) investigated the perception and responses of female students to the construction industry's masculine culture during their industry placements through interview sessions for 26 female engineering students. The study highlighted the experiences of female students as being assigned to fill in co-worker position and execute supporting activities. The students further reported that women regularly had to work twice as hard as their male colleagues to prove themselves.

In South Africa, Alves and English (2018) interviewed 17 female students about their perceptions and preparedness for male-dominated workplaces, such as the construction industry. Findings showed that the students perceived that they need to act like their male counterparts to be able to prove their worth and continually accept discrimination from male colleagues. Responses from the study are similar to findings from Hatmaker's (2013) study investigating how women in engineering professions in the United States of America created their professional identities and how their interpersonal interactions at the workplace influenced their sense of belonging at the workplace. Using data from interviews with 52 female engineers, the study identified women proving themselves and continuously striving to achieve a reputation. Also, the study found that women responded to these masculine cultures by rejecting gendered expectations.

Madikizela and Haupt's (2010) study surveyed 1435 industry practitioners, 141 first and final year construction students and 17 professional women. The study revealed experiences of gender-based discrimination and sexual harassment.

According to Sipe, Johnson and Fisher (2009) university student's ignore the likelihood of the existence of gendered cultures and interactions in the workplace. Ngo, Foley, Wong and Loi (2003) found that gender differences existed in the perception of gendered interactions in the workplace. Therefore, we hypothesize that the perceptions and experiences of gendered workplace interactions differ between male and female students in male-dominated environments. The aim of the study was to evaluate the perceptions, experiences and coping mechanisms of university students in male-dominated fields in relation to their workplace interactions. The objectives were to present strategies for the elimination of stereotypes, promotion of inclusivity in the workplace interactions of students and recommendation of response mechanisms to better equip students to be able to handle the realities of gendered cultures in the work place. Some limitations noted by previous studies were addressed in this study.

2. THEORETICAL FRAMEWORK

In the feminist theory, the issue of gender is emphasised, and the differences in the experiences of men and women are acknowledged (Schmitt et al, 2002; Steele, James and Barnett, 2002; Ropers-Huilman and Winters, 2011). Feminism recognises that the oppressions and injustices women encounter have developed over time and has emanated from structural problems embedded in the society (Smith and Gayles, 2018). The study is conceptualised from an understanding of masculine cultures in male-dominated workplaces that relegate women and stereotypical feminine traits while promoting men and appreciating stereotypical masculine traits.

Specifically, the study relies on the feminist theory for an in-depth understanding of the influence of social and structural issues on gender and how it relates to the academic and workplace experiences of female students in construction. Intemann (2010) argued that feminist theory creates knowledge by reflecting critically on the experiences and perceptions of women.

Studies have shown that women are more disadvantaged in almost all economic indicators compared to men (Schmitt *et al*, 2002; Madikezela and Haupt, 2010). Most times women find themselves in situations where they are the only female engineers in a workplace, and their needs are often neglected. Physical strength, technical skills and knowledge of construction support stereotypically masculine practices, which are considered as significant in the industry. Unlike professions like medicine, dentistry and law, in the construction industry, the majority of the engineers engage with people in stereotypically masculine domains such as technicians and tradespeople rather than those occupying administrative positions (Faulkner 2007, 2009). A study by Hatmaker (2013) identified imposed gendered expectations, demeaning women and making requests based on gender as types of personal interactions reported by female students that diminish the professional identity of women in male-dominated workspaces.

Bible and Hill (2007); Boselovich (2006) found that persistent gender stereotypes are often reproduced in traditional workplace cultures. Schmit et al (2002) revealed that female students were found to experience more gendered interactions than male students, consequently resulting in negative psychological effects. Female students reported greater experiences of gendered cultures and discrimination than their male counterparts. Although, it has been observed that women tend to experience prejudices, they are often reluctant to confirm the discriminations they are confronted with (Faulkner, 2009; Hartman and Hartman, 2009; Seron, Silbey, Cech and Bubineau, 2016).

Hartman and Hartman (2009) revealed that although only minor differences exist in academic qualifications and performance of male and female and university students, significant gender differences exist in terms of self-confidence, satisfaction and commitment to a future in male-dominated work. To understand the workplace perceptions of students in male-dominated spaces and prepare them for the realities of gendered cultures, the study sought to identify exhibitions of gendered cultures as experienced by students and the coping mechanisms adopted by the students. Furthermore, the study sought to investigate whether gender affected student's perceptions gendered interactions in the workplace.

3. METHODOLOGY

The study implemented a descriptive survey design adopting a quantitative research approach (means, percentage and the standard deviation). Data was obtained through self - administration of a questionnaire with close-ended questions. SPSS version 25.0 was used to capture and compute the data. The independent *t* -test was performed to assess whether gender had influenced the experiences and perceptions of gendered workplace interactions and their responses to these interactions.

As illustrated in Table 3.2, the nine items consisting of interactions consistent with gendered workplace cultures scale had a Cronbach's coefficient alpha of 0.78.

For the five items comprising of students' responses to gendered cultures dichotomous scale, the Krippendorff's alpha test was used to estimate the inter-coder reliability (Hayes and Krippendorff, 2007). Alpha scale points of 1.000 are defined as perfectly reliable and 0.000 as totally unreliable.

Table 3.2 presents results from the Krippendorff's test. A modest degree of inter-coder reliability was found with a nominal α of 0.82.

Table 3.1 Cronbach's Alpha reliability statistics for interactions consistent with gendered workplace cultures scale

Cronbach's Alpha	**Cronbach's Alpha based on Standardized Items**	**N of items**
0.78	0.79	9

Table 3.2 Krippendorff's reliability statistics for students' responses to gendered cultures scale

	Alpha	**LL95%CI**	**UL95%CI**	**Units**	**Observrs**
Nominal	0.82	0.76	0.80	40.000	5.0000

3.1 Participants

Participants in the study were 76 undergraduate students (men=52.6%, women = 47.4%) at a University in the KwaZulu-Natal province of South Africa. The study conveniently sampled a cross section of students across different levels of study enrolled in various courses in the School of Engineering. (e.g. construction studies; civil engineering, property development, land surveying and civil engineering program). The sample was selected from classes that comprise of full time students. These classes were selected based on the researcher's availability to administer the questionnaires in person and the faculty member's flexibility in the classroom. Because the questionnaires were self-administered during class periods, response rate was nearly 100%.

4. DATA ANALYSIS

4.1 Participants Demographics

Participants in the study were confirmed to represent students in male-dominated disciplines. 76 undergraduate students at a University in the KwaZulu-Natal province of South Africa were the participants in this study. Table 4.1 presents the demographic information of students who participated in the study. 48.7% (37) were enrolled in property development, 32.9% (25) were enrolled in land surveying, and 10.5% (4) were studying construction studies and 7.9% (6) were in the civil engineering discipline.

Primarily, participants were 1st year students (2.6%), 2nd year (36.8%) and 3rd year (60.5%). The majority of the respondents had completed their 2nd year of study (55.3%) while the rest had completed 1st year (27.6%) and 3rd year (17.1%).

Table 4.1 Participant Demographics

Characteristics	**Description**	**No of Participants**	**%**
Discipline	Property Development	37	48.7
	Construction Studies	8	10.5
	Land Surveying	25	32.9
	Civil Engineering	6	7.9
Level of Study	1st year	2	2.6
	2nd year	28	36.8
	3rd year	46	60.5
Degree completed at time placement	1st year	21	27.6
	2nd year	42	55.3
	3rd year	13	17.1

Table 4.2 Details about participant's most influential placement

Characteristics	**Description**	**No of Participants**	**%**
Significant work placement	Part-time work	19	25.0
	Vacation employment	33	43.4
	Internship	24	31.6
Number of Professional female engineers at the workplace	1	5	6.6
	2	17	22.4
	3	24	31.6
	4	16	21.1
	5	12	15.8
	6	1	1.3
	9	1	1.3

Details on respondents nominated most prominent placements are represented in Table 4.2. The table shows that 25% (19) respondents indicated that undertaken part-time work was their most influential work placement. 43.4 % (33) indicated vacation employment and 31.6% (24) confirmed internship as their most significant work placement.

Respondents were required to specify the number of professional female engineers employed at their workplace. It is evident from Table 4.2 that the maximum number of female engineers was 9 and was indicated by 1 student (1.3%).

4.2 Frequency of interactions with professional engineers

Relative to being asked about how often the respondents interacted with professional engineers at their workplace; almost all respondents reported that they had frequent interactions with the engineers at their place of work. In Table 4.3, 32.9% (25) indicated that they had "sometimes" interacted while 36.8 %(28) students reported that they "often" had interactions with professional engineers at their workplaces.

Table 4.3 Frequency of interaction with professional engineers

Response	N	%
Never	8	10.5
Rarely	8	10.5
Sometimes	25	32.9
Often	28	36.8
Always	7	9.2
Total	76	100

4.3 Perceptions of gendered interactions

This section sought to investigate the experience and perceptions of respondents on the occurrence of gendered interactions at their work placements. Students were required to rate the level to which they experienced and observed a set of gendered cultures using a Five-point Likert scale, where 1 = Never, 2 = Rarely, 3 = Sometimes, four = Often, and 5 = Always. Table 4.4 shows that marginalizing stereotypically feminine interests (mean score= 3.32), making requests based on gender (mean score = 3.32) and belittling women or drawing attention to their gender (mean score= 3.10) were ranked as the most frequently experienced gendered interactions by the respondents. With a mean score of (1.98), students indicated that they least experienced negative attitudes from their superiors.

Table 4.4 Perceptions of gendered interactions

Experiences	1	2	3	4	5	T	M	SD	R
Marginalizing stereotypically feminine interests	15.8	7.9	31.6	17.1	27.6	76	3.32	1.37	**1**
Making requests based on gender	13.2	14.5	19.7	31.6	21.1	76	3.32	1.32	**2**
Belittling women or drawing attention to their gender	15.8	25.0	18.4	14.5	26.3	76	3.10	1.44	**3**
Lack of respect from tradespeople or technicians e.g. being ignored by male team members	13.2	23.7	34.2	22.4	6.6	76	2.85	1.11	**4**
Imposing gendered expectations e.g. keeping female engineers from going site	25.0	22.4	26.3	14.5	11.8	76	2.65	1.32	**5**
Difficulty asking for support e.g. difficulty seeking help due to macho expectations	26.3	25.0	38.2	3.9	6.6	76	2.39	1.12	**6**
Rough culture on site	34.2	25.0	18.4	15.8	6.6	76	2.35	1.28	**7**
Unfair judgement of women's work	28.9	31.6	21.1	14.5	3.9	76	2.32	1.15	**8**
Negative attitude from superiors	46.1	27.6	11.8	10.5	3.9	76	1.98	1.17	**9**

4.4 Responses to gendered workplace interactions

Table 4.5 Responses / coping mechanisms to gendered cultures

Responses	Yes		No	
	N	%	N	%
Leaving the workplace	11	14.5	65	85.5
Tolerating and adapting	62	81.6	14	18.4
Justifying interactions experiences	37	48.7	39	51.3
Denying the gendered culture	33	43.4	43	56.6
Reporting	31	40.8	45	59.2

Respondents were required to indicate how they responded or coped with the gendered interactions at their work placements. In Table 4.5, 14.5% (11) reported that they left the job to avoid the culture while 85.5% (65) indicated that they stayed in the workplace. 81.6 %(62) of the students reported that they tolerated and adapted to the gendered interactions. In terms of justifying the gendered interactions experienced, 48.7% (37) indicated that they made excuses for the culture while 51.3% (39) reported otherwise. Notably, more than half of the respondents indicated that they recognise the occurrence of gendered interactions but did not report the issues.

4.5 Independent *t* Test Results

Table 4.6 Group Statistics: Perception of gendered workplace interactions

	Gender	N	Mean	SD
Gendered interactions	Male	40	2.43	0.79
	Female	36	3.00	0.61

Table 4.7 Independent *t* Test Results or Gender differences in the Factor Analysis Groupings: Perception of gendered workplace interactions

Factor grouping	df	*t*	p
Perception of workplace gendered interactions			
Gender	74	-3.48	0.07

Table 4.8 Group Statistics: Responses to gendered workplace interactions

	Gender	N	Mean	SD
Responses to gendered interactions	Male	40	1.56	0.18
	Female	36	1.51	0.23

Table 4.9 Independent *t* Test Results or Gender differences in the Factor Analysis Groupings: Responses to gendered workplace interactions

Factor grouping	df	*t*	p
Responses to gendered interactions			
Gender	74	1.01	0.09

For questions on perceptions of gendered workplace interactions and responses to interactions, the mean response in each factor analysis grouping for perception of gendered interactions and responses to gendered interactions was calculated.

These variables were then tested to determine the significance of gender on students' perceptions of gendered workplace interactions.

An independent sample *t* test was conducted to determine whether a significance difference exists in the responses of men and women in each factor grouping. In the factor grouping, equal variances were assumed because Levene's test of equality of variance was not significant.

Table 4.6 and 4.8 shows that no statistically significant difference in the meaning ratings among the gender groups.

From the independent *t* test results shown in Table 4.7 it was found that male students experienced gendered workplace interactions as much as the female students did t (74)= -3.48, p < .07. Table 4.9 presents the sample test results for gender differences in the responses to gendered workplace interactions. No statistically signiicant differences were found in the reponses of male and female students t (74)= 1.01, p < .09.

5. DISCUSSION

5.1 Interactions consistent with gendered cultures

Clearly students experienced interactions consistent with gendered cultures at their work placements. The study found that the most experienced gendered interactions were marginalising stereotypically feminine interests, making requests based on gender and belittling women or drawing attention to their gender.

Marginalising stereotypically feminine interests

It is apparent from the study that students experienced a gendered workplace culture where stereotypically masculine interest where prioritised over feminine activities. Connell (2013);

Male et al. (2017) identified the presence of multiple masculine traits and practices in male-dominated workplaces which were mostly desired and given preference over stereotypically feminine traits. Martin and Barnard (2013) found that predominant gender stereotypes exist in the workplace and form the basis for discriminatory employment regulations and management strategies exist in the workplace and form the basis for discriminatory employment regulations and management strategies that hinder women from making progress in male-dominated professions.

Making requests based on gender

The survey showed that students confirmed that during their placements, tasks were assigned to them based on their gender. Male *et al*. (2017); English and Alves (2018) indicated that women were assigned to undertake supporting roles such as secretarial duties which limits their opportunities and career progression. Although none of the women in the study intended to leave their male-dominated occupations, they demonstrated a reluctance to progress into the more intensely competitive male roles because of these negative self-perceptions. Rather, they opted for those 'softer' roles while remaining in male-dominated environments.

Belittling women or drawing attention to their gender

Respondents reported that they mostly experienced interactions that belittled women and drew attention to their gender. Hatmaker (2013) identified interactions that demeaned women as marginalising the interests and identities of professional women engineers. Similarly, Male et al. (2017); Male and McNish (2015) reported discomfort experienced by female students as a result of comments made about their gender. Examples were comments made by male contractors about prostitutes and comments on avoiding the use swear words because a woman was present.

5.2 Students coping strategies for gendered cultures

Findings from the study showed that students' response to the gendered interactions they experienced are as follows;

Leaving the workplace

Majority of students in this study reported that they did not resign from their jobs because of the gendered cultures they experienced at their work placements. Although Martin and Bardin's (2013) found that despite the negative work-identity interactions experienced, none of the women reported intentions to leave the workplace. However, the women displayed an attitude of low self-esteem and lack of confidence.

Reporting

In this study, respondents reported that they did not report the gendered interactions that they experienced. Male et al. (2017) argued that reporting discriminatory incidents and harassments to the appropriate authorities was one of the few responses that could initiate change and provide support.

Tolerating and adapting

Tolerating and adapting the interaction was one of the coping mechanisms reported by students as a response to gendered cultures. Franzway et al. (2009) indicated that many women choose to accept the masculine culture of the industry by trying to fit in because of the financial benefits they get from their jobs. They are less concerned with the vulgar language and discrimination they experience.

Justifying the gendered culture

Findings from the study indicate that students were indifferent in their response to justifying the gendered interactions. Hatmaker (2013) found that students' justified and make excuses for the gendered interactions at their workplace which discriminated against stereotypically feminine practices and marginalised their professional identities. An example of excuses respondents made was making arguments that it was challenging for an employer to accommodate the needs of different genders.

Denying the gendered culture

The study findings suggest that majority of the students denied gendered interactions at their workplace. Seron et al. (2016); Powell et al. (2009) found that students did not recognise the interactions they experienced as gendered. The studies concluded that there was uncertainty about whether the students did not recognise these cultures or chose to deny it.

5.3 Gender Differences

Drawing from previous studies, the study expected to find that female students were more likely to perceive gendered work place interactions than would male students. In this study, students' responses rejected this hypothesis. Clearly, there are no differences in the perceptions of gendered workplace cultures among male and female students. The study found no relations between genders and perceived gendered interactions in the work environment.

6. CONCLUSION AND RECOMMENDATIONS

Findings from this study established that university students experienced gendered interactions at their work placement, especially against women. This is consistent with findings in Male et al (2017); Miller and Katz (2018); Alves and English (2018); Sipe et al. (2009) which reported that students are usually unprepared for the types of workplace interactions they experience in their professions. Consequences of this unpreparedness are noteworthy. The gendered workplace cultures and coping strategies reported shows that employers need to make efforts to recruit women by proactively providing support and opportunities to attract them into male-dominated professions.

Employers need to review their workplace policies and introduce solid initiatives geared towards creating a conducive environment which provides mentorship and accommodates the needs of women who are considering taking up careers in male-dominated fields. The realities of gender workplace cultures should be addressed in the development of curricula. Students need to understand the layers of discrimination and the challenges in male- dominated industries from their first contact with the occupations.

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Green Office Buildings contributing to the productivity and job satisfaction of staff members

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ABSTRACT AND KEYWORDS

Purpose of this paper
The primary objective of this study was to identify the difference in productivity, job satisfaction, absenteeism and presentism between occupants in conventional office buildings, office buildings with green design features and green-star rated office buildings in South Africa.

Design/methodology/approach
Relevant literature of the key concepts was reviewed to establish the foundation and provide a context for interpreting the results. This was followed by a case study analysis in the form of using four office buildings (two conventional, one with green design features and one green star rated office building) to provide a more holistic view on the design features that were used and how these design/physical components could potentially influence the conditions of the indoor environment. The research design incorporated both quantitative methods in the form of self-administrative questionnaires and qualitative methods in the form of structured interviews.

Findings
It is widely believed that 'green' buildings are more comfortable, healthier, and lead to higher levels of productivity than conventional buildings due to the implementation of certain green features and design strategies. The empirical study however determined that there are inconsistent perceptions concerning physical work conditions in various types of office buildings and could thus not link physical work conditions.

Research limitations/implications (if applicable)
The empirical research was limited to four office buildings in South Africa.

What is value of paper. This paper provides a form of standardization, as four types of office buildings are compared which are all associated with the banking industry in South Africa.

Keywords: Green office buildings, Indoor environmental quality, Job satisfaction, Productivity

1. INTRODUCTION

Over recent years, many questions have been asked about the link between the indoor environmental quality (IEQ) of working environments and the productivity of occupants in office buildings (Vischer, 2003; Byrd & Rasheed, 2016). The conditions of the indoor environment in which occupants spend nearly 90% of their time affects the occupants' physical and psychological well-being (Mahbob, Kamazuzzaman, Sulaiman, Salleh, 2011; WGBC, 2015). These elements can have a major impact on occupants' health, quality of life and personal relationships (Edwards & Naboni, 2013: 4; Sarode & Shirsath, 2014).

If the condition of the environment leads to negative impacts on occupants' health, comfort and well-being, it could point directly to improper design or technical flaw in the building system (ScienceDirect, 2016). When staff are emotionally and physically in a good condition, their productivity performance and output will increase automatically. There are a number of benefits associated with a good and healthy working environment, which all lead to an increase in work performance and productivity (Myde, 2012; Koima, 2015).

The quality of the conditions in which occupants' work, is referred to as the indoor environmental quality (IEQ). The operating cost benefits that a good IEQ in 'green' buildings have to offer, are appealing to developers and organisations, although the physical and psychological conditions of the occupants within the buildings have often been ignored (Byrd & Rasheed, 2016). It is important that developers and organisations investing in 'green' office buildings apply ergonomic principles to the design, and maintenance of office buildings (Sarode & Shirsath, 2014). It appears that not only should organizations take energy efficiency in mind, but also health and safety that includes both the physical and psychological factors (Edwards & Naboni, 2013: 4-5).

According to the World Green Building Council (2015), typical business operating costs consist of 90% staff costs, which include benefits and salaries, 9% rental costs and 1% energy costs. Furthermore, it has been estimated that over the lifetime of a building, the costs of the employees' and their salaries can be as much as 10 to 40 times the maintenance and operational costs of the building, and 80 to 200 times the initial construction costs (Sullivan, Baird and Donn, 2013). Although, the ratios may vary between different types of buildings (William & Fisk, 2002; Sullivan, et al., 2013), the value of the employees is far more important than that of the building itself. The importance of employee productivity, can therefore not be emphasized enough.

According to Myde (2012), the condition of the office environment directly influences the quality and quantity of work generated by staff. Even a small improvement on productivity can have a major impact on the financial well-being of any organization (WGBC, 2015; Ambrose, 2016). There is overwhelming evidence which demonstrates that the design of an office impacts the health, wellbeing and productivity of its occupants, but this evidence has not yet had a major influence on the mainstream real estate sector, and is not yet translating at scale into design, finance and leasing decisions (WGBC, 2014).

Developers in South Africa are more focused on the perceived higher cost implications of green buildings than they are about the long-term financial benefits that a productive workforce may offer in green office buildings. When developers invest in green office buildings, the physical and psychological well-being of the occupants are often ignored. Developers in SA are not aware of the benefits associated with the implementation of certain green elements that may result in an improved indoor environmental quality and subsequently result in increased productivity, job satisfaction and presenteeism amongst employees.

This study determined what indoor environmental elements drive occupants in green office buildings to be more productive and how the level of productivity, job satisfaction and absenteeism differed in conventional office buildings to those of green office buildings. The difference in productivity, job satisfaction, absenteeism and presenteeism between occupants in conventional office buildings, office buildings with green design features and green star rated office buildings in South Africa were compared.

2. STUDY SETTING

Table 1 presents the four buildings used for the case study.

Table 1: Comparison of the case study buildings

Building	Name	Location	Details	Indoor air quality and ventilation	Thermal comfort	Acoustical quality	Outside views and external spaces	Daylight and lighting
A	FNB & WESBANK	Bloemfontein (Free State)	Green design features Since 2016 GFA: 8284m^2 400 employees	Natural cross ventilation and HVAC system	No individual control over temperature. Sufficient window provision	Open plan with no partitions	Inadequate outside view	Inadequate north elevation. Special lighting and sunscreens
B	FNB & WESBANK	Randburg (Gauteng)	4-star rating from GBCSA Since 2008 GFA 150000m^2 5000 employees	Natural cross ventilation and HVAC system	No individual control over temperature. Sufficient window provision. Double glazing	Open plan with no partitions	Sufficient view to outside and nature	North elevation: good access to sunlight/daylight. Special lighting, sunscreens and tinted windows
C	FNB	Frankfort (Free State)	Conventional building Since 1970 GFA 486m^2 11 employees	Natural cross ventilation and HVAC system	Individual control over temperature. Insufficient window provision	Open plan with no partitions	Inadequate outside view	Inadequate north elevation. Lack of window. Insuffi-cient lighting. Tinted windows
D	Standard Bank	Frankfort (Free State)	Conventional building Since 1972 GFA 750m^2 14 Employees	HVAC system only due to ballistic glazing	No individual control over temperature. Insufficient window provision	Cubicle offices	Inadequate outside view	Inadequate north elevation. Lack of window. Special lighting. Tinted windows

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3. METHODOLOGY

A literature review was conducted in order to identify the elements and features in green office buildings that led to greater productivity. The research design used was a mixed method approach that consisted of collecting, analyzing and integrating quantitative and qualitative data.

The quantitative self-administered questionnaires were selected as the primary technique of data collection, which were handed out to occupants currently working in green and conventional office buildings. Questions included occupants' demographics, responses to the building environment, and how well they think it served their needs (Sullivan, et al., 2013).

The qualitative survey comprised structured interviews with the occupants. Furthermore, four case studies were conducted in order to establish how the basic design features present in each of the various office buildings could have had an impact on the physical and psychological well-being of the occupants. Physical wellbeing was assessed using the Sick Building Syndrome (SBS) questions (Thatcher & Milner 2014). Psychological wellbeing was assessed using the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS) (Thatcher & Milner 2014). Absenteeism was measured using a single item from Biron, Brun, Ivers and Cooper (2006) established as "During the last 12 months, how many days sick leave have you taken?" Presenteeism also measured using a single item from Biron et al. (2006) asking "During the last 12 months, how many days did your work despite being ill because you felt you had to?" This was assessed on a single item asking from (Thatcher & Milner, 2014) asking "On a scale of 0-100 percent (where 100% is full capacity), rate how well you have been working over the last month in relation to your full capacity". Job satisfaction was assessed by a single item from (Thatcher & Milner, 2014) asking "Taking everything into consideration how do you feel about your job as a whole?" (from very dissatisfied to very satisfied).

Cronbach's alpha is a measure used to assess the reliability, or internal consistency, of a set of scale or test items (Tavakol & Dennick, 2011). These values were obtained by using the ANOVA two factor without replication from Microsoft Excel. An independent sample t-test was used from Microsoft Excel to establish whether the means of the variables from the different sample groups were statistically different from each other (Trochim, 2006).

Permission to conduct the study was obtained from the relevant financial institutions and the Ethics Committee of the University of the Free State. Participation was voluntary, informed consent was obtained and anonymity ensured.

4. RESULTS

Occupants' demographic information and time spent in buildings and workstation, and incidence of chronic diseases are given in Table 2.

Table 2: Occupants' demographic information and time spent in buildings and workstation, and incidence of chronic diseases

	Bank A		**Bank B**		**Banks C and D**	
Sample	**Fre-quency**	**%**	**Fre-quency**	**%**	**Fre-quency**	**%**
Gender	25	100	15	100	15	100
Male	3	12	6	40	7	46.6
Female	21	84	9	60	8	53.3
Race	25	100	15	100	15	100
White	13	52	11	73.3	4	26.6
Coloured	6	24	0	0	6	40
African	6	24	4	26.6	5	33.3
Age range (Years)	23 – 52		19 – 55		21 – 52	
Average time spent in building (hours)	8.54		8.13		7.55	

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Average time spent at desk/work station	5.16		5.60		6.30	
Chronic illness*	8		5		5	

* Cardiovascular, asthma, hypertension, cancer, epilepsy, psychiatric, diabetes

Table 3 illustrates the perception of physical work conditions between the green office building and the conventional office buildings using the T-test.

Table 3: Occupants' perceptions of physical work conditions between the green office building and the conventional office buildings

	Mean Green office building	**Mean Conventional office building**	**T-Statistic**	**P-value**	**Sign**
Air Temp too warm	3.61	3.72	0.99	0.33	N/S
Air Temp too cold	2.69	3.27	-1.41	0.17	N/S
Light too dim	3.84	4.81	-2.71	0.01	Signifi-cant
Light too bright/glaring	4.38	4.00	0.85	0.40	N/S
Insufficient ventilation	4.00	3.84	-0.327	0.74	N/S
Too drafty	4.72	3.92	-2.50	0.02	Signifi-cant
Too little air movement	4.18	3.92	-0.70	0.48	N/S
Air to dry	4.18	4.07	-0.27	0.78	N/S
Air too humid	4.45	4.30	-0.46	0.64	N/S
Distracting ambient noises	3.92	3.63	0.71	0.48	N/S
Unpleasant odours	4.15	4.36	-0.60	0.55	N/S
Stale air	4.38	4.72	-1.18	0.24	N/S
Dusty air	4.72	3.30	-3.0	0.007	Signifi-cant
Electrostatic shocks	4.69	4.81	-0.59	0.56	N/S

The mean scores for most of the variables seemed to vary slightly, showing no apparent positive effect between the occupants working in green office buildings, as opposed to those working in the conventional office buildings.

The means scores showed a slightly more positive effects for the 'green' office building with regard to the glaring/bright lighting (4.38>4.00), ventilation (4.00>3.84), air movement (4.18>3.92), dryness (4.18>4.07), humidity (4.45>4.30), and noise (3.92>3.63). The conventional office building showed more positive results for air temperature (3.72>3.61) and (3.27>2.69), non-present odours (4.36>4.15), stale air (4.72>4.38) and electrostatic shocks (4.81>4.69). The results showed a significant result for the lighting being too dim in the 'green office building as opposed to those in the conventional office building (3.84<4.81). However, there was also a significant result showing that the air in the conventional office buildings were far more drafty (4.72>3.92) and dustier (4.72>3.30) as opposed to the 'green' office building.

There was no significant difference between physical well-being, absenteeism and presenteeism for occupants working in the green office building as opposed to those working in the conventional office buildings (Table 4). However, there was a significant difference between the psychological well-being, job satisfaction and productivity showing greater positive results for the occupants working in the green office building.

Table 4: Comparison of psychological well-being, physical well-being, job satisfaction, productivity, absenteeism and presenteeism between the green office building and the conventional office buildings.

Variable	Mean Green office building	Mean Conventional office building	T-Statistic	P-value	Sign
Psychological well being	3.71	3.20	4.71	3.66×10^{-6}	Signifi-cant
Physical well-being	3.49	3.39	1.30	0.19	N/S
Job Satisfaction	4.06	3.27	2.16	0.04	Signifi-cant
Productivity	87	68.75	2.40	0.04	Signifi-cant
Absenteeism	2.46	6.65	-1.08	0.31	N/S
Presenteeism	8.20	13.70	-1.04	0.31	N/S

The mean scores for most of the variables seemed to vary slightly, showing no overt positive effect between the occupants working in green office buildings, as oppose to those working in the office building with green design features (Table 5). The mean scores showed a more positive effects for the 'green office' building with regard to the air temperature not too warm (3.61>3.15), ventilation (3.84>3.38), air movement (3.92>3.61), dryness (4.07>3.84), humidity (4.30>4.19), stale air (4.38>3.96) noises (4.30>4.19). The office building with green design features showed more positive results for air temperature not cold (2.92>2.69), lighting not too dim (4.38>3.81), Light not too bright/glaring (4.42>3.38), draft air (3.96>3.92) and unpleasant odors (4.30>4.15). The results showed a significant result for the air being dustier (3.30<4.42) in the 'green' office building, as oppose to the office building with green design features. However, there was also a significant result showing that the electrostatic shocks in the office building with green design features was far more than those of the green office building (4.69>3.69).

Table 5: Perception of physical work conditions between the green office building and the office building with green design features.

	Mean Green office building	Mean office building with green elements	T-Statistic	P-value	Sign
Air Temp too warm	3.61	3.15	1.61	0.11	N/S
Air Temp too cold	2.69	2.92	-0.65	0.52	N/S

Light too dim	3.81	4.38	-1.37	0.18	N/S
Light too bright/glaring	3.38	4.42	-0.19	0.84	N/S
Insufficient ventilation	3.84	3.38	1.18	0.24	N/S
Too drafty	3.92	3.96	-0.10	0.91	N/S
Too little air movement	3.92	3.61	0.74	0.45	N/S
Air to dry	4.07	3.84	0.54	0.58	N/S
Air too humid	4.30	4.19	0.35	0.72	N/S
Distracting ambient noises	3.92	3.38	1.26	0.21	N/S
Unpleasant odours	4.15	4.30	-0.52	0.60	N/S
Stale air	4.38	3.96	1.32	0.19	N/S
Dusty air	3.30	4.42	-2.43	0.02	Significant
Electrostatic shocks	4.69	3.69	2.33	0.03	Significant

There was no significant difference between psychological well-being, job satisfaction, productivity, absenteeism and presenteeism for occupants working in the green office building as opposed to those working in the office building with green design features (Table 6). However, there was a significant difference between the physical well-being of occupants showing a p-value <0.05.

Table 6: Comparison of psychological well-being, physical well-being, job satisfaction, productivity, absenteeism and presenteeism between the green office building and the office building with green design features.

Variable	**Mean Green office building**	**Mean Office building with green elements**	**T-Statis-tic**	**P-value**	**Sign**
Psychological well-being	3.71	3.70	0.17	0.86	N/S
Physical well-being	3.49	3.17	4.74	2.69×10^{-6}	Significant
Job Satisfaction	4.06	3.96	0.44	0.66	N/S
Productivity	87.00	79.52	1.84	0.07	N/S
Absenteeism	2.46	3.20	-0.51	0.61	N/S
Presenteeism	8.20	2.84	1.31	0.20	N/S

The main findings from the qualitative interviews are presented in table 7.

Table 7: Main findings from qualitative interviews

Participants working in green office buildings	**Participants working in conventional office buildings**
More aware of the importance of green and sustainable design	Less aware of the importance of green and sustainable design
Appreciated that that green features contribute to their psychological well-being	Believe that green features may contribute to their psychological well-being
Do not believe that green features contribute to their physical well-being	Do not believe that green features may contribute to their physical well-being
Satisfied with working environment despite the condition of the building	Satisfied with working environment despite the condition of the building
Varied perceptions concerning indoor environmental quality	Varied perceptions concerning indoor environmental quality

5. DISCUSSION

It must be noted that the variables regarding the perception of physical working conditions showed inconsistency between the occupants in the ‘green’ and conventional office buildings. It is therefore impossible to link the implementation of IEQ features to indirect benefits such as greater job satisfaction, physical and physiological well-being, decrease in absenteeism, and a more productive workforce with the quantitative results. This is in direct contrast with the findings of the literature study, since all sources used for the literature study indicated that there are a multitude of direct and indirect benefits associated with the implementation of IEQ features to staff members.

The most probable reason why these variables showed such unexpected results with almost half the variables in favour of the conventional office building or with averages slightly less than the ‘green’ office building, could be because the qualitative results indicated that the participants in the conventional office building had no or little knowledge of ‘green’ buildings and the associated indoor environmental quality features. The occupants may have become accustomed to their working environment, and thus their lack of understanding about positive working environments could have influenced their answers to the questions. Therefore, the results indicated a more positive response from occupants than expected. Additionally, the results did not deliver conclusive evidence to support the findings from the literature study.

The results depicted that the only significant difference between the four buildings was physical well-being of the occupants, showing more positive results for the ‘green office’ building. Furthermore there was no significant evidence which proved more positive results for the green office building with reference towards the psychological well-being, job satisfaction, productivity, absenteeism and presenteeism. The perception of physical work conditions showed positive results for the ‘green’ office building specifically pertaining to electrostatic shocks. However, the ‘green’ office building has shown a negative result in terms of the air being far dustier.

The results also indicated that the conventional office building has shown a positive impact in terms of the lighting not being too dim. In terms of the perception of the physical work conditions as a whole the results have also shown inconsistency between the ‘green’ and conventional office buildings.

Overall, the participants working in the ‘green’ office building commented on the importance of the movement towards green which indicated knowledge concerning the subject of green and sustainable design, whereas the participants in the conventional office building had little knowledge of what ‘green’ buildings have to offer.

It was evident from the responses of the participants that they appreciated that the ‘green’ building contributed to their psychological well-being one way or the other. Although it was impossible for the respondents in the conventional office building to give feedback on this question, one of them mentioned that it would definitely contribute to her psychological well-being, while the other stated that it would make no difference. Not one of the participants expressively commented on the contribution of the office building towards their physical well-being. From the indoor environmental quality theme, it was evident that the perception of the respondents varied according to their own perception and needs.

From the job satisfaction theme, it is clear that all the participants are satisfied with their working environment, despite the fact the condition of the office building are less than ideal.

6. CONCLUSION AND RCOMMENDATIONS

The purpose of the study was to identify the difference in productivity, job satisfaction, absenteeism and presentism between occupants in conventional office buildings, office buildings with green design features and green-star rated office buildings in South Africa.

The results indicated that there was no significant difference between physical well-being, absenteeism and presenteeism for occupants working in the green office building as opposed to those working in the conventional office buildings. However, there was a significant difference between the psychological well-being, job satisfaction and productivity showing greater positive results for the occupants working in the green office building.

Most of the variables seemed to vary only slightly, showing no overt positive effect between the occupants working in green office buildings, as oppose to those working in the office building with green design features. There was however no significant difference between psychological well-being, job satisfaction, productivity, absenteeism and presenteeism for occupants working in the green office building as opposed to those working in the office building with green design features.

It can be concluded that green office buildings do present some indirect productivity benefits, however human attitude also has an influence on productivity. People are poor at assessing performance based on variables, and are prone to biases and distortions that make subjective assessments inaccurate and potentially misleading.

Perceived comfort levels in office buildings are very subjective, and depend on a number of factors such as individual preference, age, gender and physiology. A major issue in modern or 'green' buildings is that occupants need to share the same working space as a result of efficient space planning and cost saving. Without individual control systems in place, employees tend to be uncomfortable and complain about the temperature being too cold or too hot or, insufficient ventilation and lighting levels. The information obtained from the participants showed that they spend a minimum of 81% of the time at their desks or workstations every day. It is therefore important to note that the change of providing adequate comfort levels will begin by providing a working space that serves each individual according to their specific needs.

The findings of the study are contradictory to current perceived ideas and theories which could indicate that wider and more in depth research is required in order to establish a true reflection of the status quo surrounding the contribution of green features to staff members' productivity and job satisfaction.

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IMPACTS OF RECENT CONSTRUCTION HEALTH AND SAFETY LEGISLATION CHANGES ON CONSTRUCTION WORKERS' HEALTH AND WELLBEING

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ABSTRACT AND KEYWORDS

Purpose of this paper
Recent legislation in South Africa has been amended to achieve optimum H&S throughout all construction project phases. However, the primary purpose for compliance with H&S legislation requirements among contractors is to avoid penalties and for profit maximisation. The construction industry is perceived to be dangerous, unfair and unpredictable regarding the adequate protection of construction site workers often violating their fundamental human right. The purpose of this study is to investigate the impact of recent H&S legislation changes on construction workers' health and their sustainability within the South African construction industry.

Design/methodology/approach
This exploratory study is quantitative, and data were analysed using descriptive statistics methods on IBM SPSS v25. Structured questionnaires were distributed to 40 randomly sampled contractors in the Kwa-Zulu Natal province for self-completion.
Findings
Findings indicate that the impact of recent H&S legislation to improve workers health and wellbeing has not yet been determined to date. Therefore, infringement on H&S still poses a threat to workers` wellbeing and their sustainability within the industry.

Value

Based on the findings, the paper proposes measures for contractors to engender full compliance and apply all aspects of construction regulations; improve working conditions, consider the health and wellbeing of workers and treat H&S as a value and not just a priority.

Keywords: Health and Safety, Construction Legislation, Workers Wellbeing, Sustainability, Performance improvement

1. INTRODUCTION

The construction industry is one of the most significant contributors to the overall growth of a country's economy (Murie,2007). According to the International Labour Organisation (ILO,2015), the construction industry accounts for approximately 10% of the global Gross Domestic Product (GDP) and employs 7% of the global population. In South Africa, the industry accounts for 3.9% of the country's GDP and employs more than 1.4 million people (Stats SA, 2018) on approximately 12,500 construction sites (DoL Government Statement Release, 2017). The construction industry has potential in reducing poverty, improving the living standards and working conditions through the implementation of internationally recognised labour standards (Murie, 2007).

The ILO estimates for global accident costs across all sectors are 4%, making workplace prevention an issue of concern (Murie, 2007). In South Africa alone, the cost of claims for fatalities, injuries and occupational diseases exceeds R2 billion annually (DoL, 2017). It has also been reported that a worker dies every 15 seconds; about 6,300 fatalities per day as a result of accidents and occupational disease (ILO, Department of Labour (DoL, 2017). Moreover, a total of 313 million injuries are encountered or 860,000 injuries per day globally. The construction industry alone contributes approximately one-sixth of fatal workplace accidents globally (ILO, Global Wellness Institute, 2017). According to the International Labour Organisation (ILO), although the construction industry employs only 7% of the global population, it accounts for 30-40% of the world's fatal injuries.

The increase in construction accidents has led to the revision of Construction Regulations 2014 in South Africa. However, instead of contractors focusing on improving the health and sustainability of construction workers, the primary focus is on compliance with the regulations in order to avoid fines or to have construction work stopped for non-compliance. The other reasons for compliance are profit maximisation and satisfying the requirements of the Department of Labour or Department of Public Works. Improving construction workers' health and wellbeing go beyond just providing PPE, ticking checkboxes and securing projects. It must be seen more as a value! This study seeks to explore the impacts if any, of recent construction health and safety legislation changes and their impacts on construction workers' health and wellbeing. The study further explores how legislation has improved workers' sustainability in an industry that does not protect workers' rights.

2. LITERATURE REVIEW

2.1 THE NATURE OF CONSTRUCTION INDUSTRY

Construction projects are known for their complexity as they combine multi-array of interdependent tasks all taking place at the same time. However, these processes are believed to be the most complex and risky undertakings of any industry (Gidado & Wood, 2008).

The construction industry is well-known as a heavy industry, with workers required to perform repetitive manual tasks (Asanka & Ranasinghe, 2015). These tasks involve heavy lifting, twisting, turning in awkward and cramped positions (ibid). Furthermore, activities are performed in unpleasant conditions where there is noise, dust, insufficient light, low ventilation and more so has high rates of staff turnover (ibid). It is further noted that the industry is still facing further challenges dealing with the increasing complexity in mega projects. In comparison to other industries, construction is believed to have the 3rd highest death rate (USA Bureau of Labour and Statistics, 2002).

Procurement procedures contribute significantly to the improvement of occupational health and safety on construction projects. However, the most common method for awarding tenders in developing countries is through competitive tendering by the government (Wells & Hawkins, 2010). Wells & Hawkins (2010), add that this method of procurement is usually evaluated on the basis of lowest price meaning that contractors must keep their prices low and this affects labour as it forms part of the major cost items. In this regard, for contractors to secure lower rates, they compromise on welfare facilities, protective equipment and a safe working environment for its workforce. Murie (2007) adds that low price culture in high competitive tendering does favour health and safety requirements. Furthermore, this encourages low wage payments of labourers, lack of safety equipment, lack of insurance coverage for accidents, and promotes an influx of informal workers for whom no tax or social security is paid (ibid).

The construction industry is characterised as one of the most accident-prone businesses (Othman, 2012). It is also defined as Dirty, Difficult & Dangerous (ILO,2001). Furthermore, labour rights issues are most striking in this sector as it relies heavily on human resources especially migrant labour and the workers are primarily unskilled, as a result, earn low-wages (Nieuwenkamp OECD, 2016). The industry is known to be a challenging regime in which to practice adequate health and safety (Bomel, 2001; Ishri, 2010). Construction activities take place in hazardous environments with exposures to heights, changing weather conditions and different locations with construction workers always expected to cope with changing environments and different scopes of works (ibid).

2.2 Improving Health and Wellbeing of Workers Through Construction Regulations

Primarily, major project parameters were defined as time, cost and quality (Smallwood & Haupt, 2006). However, increased health and safety awareness on project performance has been realised and has spawned the attention of different stakeholders (Smallwood & Haupt, 2006). In construction, an ideal project is a one completed within budget, time, quality and zero accidents (Davies & Tomasin, 1990). The principal objective of health and safety legislation is to prevent accidents within the workplace and to improve the sustainability of construction workers within the workplace (CIDB, 2009). This can be achieved through effective implementation of proper legislation (Ibid). The intended impacts of Construction Regulations have widely been spread. Furthermore, the increased awareness dominates, followed by stakeholders' awareness. This awareness significantly influenced the improvement of health and safety as well as increased financial provisions resulting in improved site conditions and fewer accidents (Smallwood & Haupt, 2006).

2.2 Impact of Construction Regulations Changes On the Wellbeing of Construction Workers

To address the challenges identified within the Construction Regulation 2003, Construction Regulations 2014 was drafted with a mandate to place more stringent rules and accountability to all key project stakeholders. The regulations state that any person failing to comply could face a 12 months' prison sentence or subject to a fine (Verwey, 2014; Construction Regulations, 2014). Additionally, the regulations aim is to close major linguistic loopholes in the old regulations, such as 'you shall' to 'you must' (Verwey, 2014). Prior to their implementation, studies indicated that there had been a staggering increase in the number of accidents despite the old regulations still being in place (ibid). Figure 1 indicates the top four most frequent accidents (excluding motor vehicle accidents) in the South African constructi ... here has been an increase i ... accidents caused by "Falls".

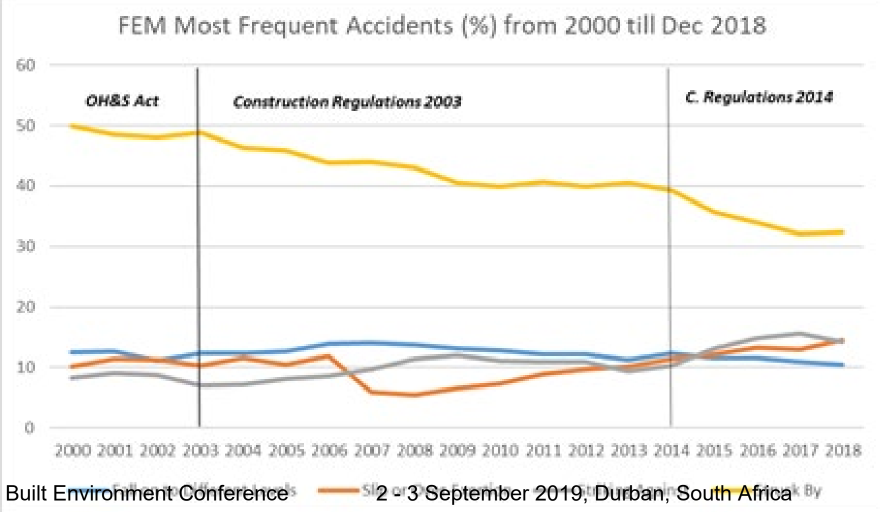

Figure 1: FEM most frequent accidents (2000 - 2018)

2.3 Contractors Attitude Towards the Construction Regulations

The identification of gaps within the 2003 Regulations led to the revision of these regulations in South Africa and the promulgation of revised ones in 2014 (Matete, Fidelis & Emuze, 2016). Under the new regulations, several clauses require contractors to comply with minimum safety standards to improve health and safety on site (Civin, 2014). Although contractors are obligated to apply for permit-to-work as a strategy to enforce commitment, the level of readiness of the Department of Public Works is still not clear (Matete et al., 2016). Contractors perceive these new regulations as an additional burden giving rise to unnecessary costs (such as the appointment of a competent H&S Agent from contractors' point of view), and as a result, contractors tend not to comply fully with the requirements of these regulations (ibid). Furthermore, contractors are not compelled by clients to notify Depart of Labour before the commencement of work (ibid).

Table 3.7: Contractors' perceptions related to the Construction Regulations

Statement	*MS*	*Rank*
The Construction Regulations should promote H&S compliance in the industry	4.63	1
Industry role players are relatively familiar with the Construction Regulations (2003)	4.17	2
Compliance with the Construction Regulations (2014) requires specific competencies	3.89	3
The Construction Regulations (2014) realised notable revisions and requirements	3.77	4
Industry role players are relatively familiar with the Construction Regulations (2003)	3.75	5
Permit-to-work system to be enforced by DoL in Au gust 2015 is based on the Construction Regulations (2014)	3.63	6
Industry role players are relatively familiar with the	2.93	7

Construction Regulations (2014

Adopted from (Matete, Emuze & Smallwood, 2016)

Based on the responses above, it can be concluded that the respondents are relatively familiar with the Construction Regulations 2014; however, the regulations have a far-reaching implication for implementation (Matete et al., 2016). Leshoedi (2016), highlights that the regulations are not improving health and safety in all project phases. Leshoedi (2016) also adds that it should be mandatory for all construction companies to become fully compliant on the clients' database and "not on paper only".

3. RESEARCH METHODOLOGY

An extensive literature review on the topic was done and questionnaires formulated from the literature to conduct a descriptive survey. Structured questionnaires were distributed to contractors registered with the Master Builders Association in the Kwa-Zulu Natal province to explore the constructs underlying the research topic. The sample size for the study was 40 contractors and contractors sampled using convenience sampling technique due to time constraints. The study employs a quantitative research approach and data were analysed using descriptive statistics on IBM SPSS v25. The study explored the impacts if any, of the construction health and safety legislation changes based on secondary and primary data collection methods.

4. RESULTS AND DISCUSSIONS

4.1 Profile of the Respondents

Table 4.1: Profile of Respondents

Gender		
		%
	Male	93.3
	Female	6.7
	Total	100.0
Qualifications		
		%
	Technical/Vocational	40.0
	University Degree	60.0
	Total	100.0
Position of Respondent		
		%
	Construction Manager	20.0
	Health and Safety Manager/officer	23.3
	Project Manager	6.7
	Quantity Surveyor	20.0
	Civil Engineer	26.7
	Structural Engineer	3.3
	Total	100.0

The findings in Table 4.1 indicate that males dominated employment in management roles within the construction companies. All the respondents obtained tertiary qualifications with 60% university qualifications, followed by technical/vocational institutions. The positions of respondents in descending order were civil engineers at 26.7%, health and safety managers/officers 23.3%, quantity surveyors 20%, construction managers 20%, project managers 6.7% and structural engineers 3.3%.

Table 4.2

Knowledge of H&S legislative framework			
	Mean	**SD**	**Rank**
Knowledge of OH&S Act 85 of 1993	3.70	1.24	1
Knowledge of Construction Regulations 2014	3.53	1.07	2
Knowledge of Construction Regulations 2003	3.47	1.17	3
Knowledge of COID Act 130 of 1993	3.33	1.29	4
Knowledge of SA Constitution	3.20	1.15	5

From Table 4.2, respondents were asked to rate their knowledge of H&S legislative framework based on a 5 point Likert scale (1=poor, 2=fair, 3=average, 4=good, 5=excellent). The knowledge of health and safety legislation with a mean score ranging from 3.2 to 3.7 indicated that respondents' knowledge was average.

Table 4.3

Impact of compliance with H&S legislative framework on workers wellbeing			
	Mean	**SD**	**Rank**
Impact of OH&S Act 85 of 1993 on workers' wellbeing	2.67	.60	1
Impact of COID Act 130 of 1993 on workers' wellbeing	2.63	.66	2
Impact of SA Constitution on workers' wellbeing	2.60	.62	3
Impact of Construction Regulations 2014 on workers' wellbeing	2.53	.62	4
Impact of Construction Regulations 2003 on workers' wellbeing	2.53	.62	5

The findings in Table 4.3 were based on a 3 point Likert scale (1=no impact, 2=some impact, 3=major impact). It seems that compliance with health and safety legislative and regulatory framework has an impact on construction workers' wellbeing with means ranging from 2.67 to 2.53.

Interpretation of scales for Tables 4.4 to Table 4.10:

Interval	**Frequency**	**Importance**
≤2.4	Low(L)	Low (L)
≥2.4≤3.4	Medium (M)	Medium (M)
≥3.51	High (H)	High (H)

The questions were based on a 5 point Likert scale measuring the level of agreement. The frequency scale was 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree and 5=Strongly Agree. For further ease of interpretations, the results are categorised into High, Medium and Low level of agreement. However, this does not reflect the reality of the finding for areas that need to be prioritised. Raw data is still used to interpret some findings

Table 4.4

Compliance with the Construction Regulations				
	Mean	**SD**	**Rank**	**Level**
Each project has a project-specific H&S plan in accordance with the requirements of the Construction Regulations 2014	4.50	.57	1	H
The application of Construction Regulations 2003 have a positive impact on the overall health and wellbeing construction labourer’s	4.03	.67	2	H
Contractors are fully committed to improving the health and safety of construction workers through Construction Regulations 2014	4.00	.74	3	H
The application of amended Construction Regulations 2014 have a positive impact on the overall quality of construction labourers’	3.97	.80	4	H
Contractors are applying all aspects of Construction Regulations to improve the health and wellbeing of construction workers’	3.97	.85	5	H
Construction Regulations clearly define legal parameters on how to improve workplace H&S for workers	3.93	.69	6	H
Construction Regulations 2014 establish a general awareness of the H&S of construction workers	3.86	.57	7	H
Department of Labour often ensures that contractors are fully compliant with the requirements of the Construction Regulations 2014	3.80	1.27	8	H
Contraction Regulations 2014 are perceived to have a positive impact on the reduction of construction workers fatalities	3.73	.94	9	H
Contractors comply with Construction Regulations 2014 only because its mandatory	3.53	1.14	10	H
Differences between Construction Regulations 2003 and Construction Regulations 2014	3.46	.73	11	M
Contractors register with COID because they care about labourers’ wellbeing	3.43	1.04	12	M
The impacts of construction regulations 2014 have not been determined to date	3.23	.77	13	M

The results in Table 4.4 suggest that there is overall high compliance with the construction regulations, especially in relations to satisfying the requirement of a site-specific health and safety plan. Both construction regulations 2003 and 2014 have are perceived to have an impact on improving the workers' quality of life or whether they clearly define the legal parameters on how to improve workplace safety. The findings further suggest that there is no clear distinction between the construction regulation 2003 and construction regulations 2014. Based on the medium level of response, it may be inferred that contractors do not register with COID to improve workers wellbeing.

Table 4.5

Management's Commitment				
	Mean	**SD**	**Rank**	**Level**
All workers possess medical certificates of fitness	4.67	.75	1	H
The firm employs trained H&S staff on site	4.63	.56	2	H
H&S inspections are done regularly and at least daily	4.33	.66	3	H
All workers medical certificates of fitness are valid	4.26	1.26	4	H
The head office management are intolerant of poor construction H&S	4.16	.83	5	H
The head office management ensures compliance with construction regulations 2014 to improve workers quality of life	4.03	.85	6	H
Implementation of construction regulations improve workers' performance and quality of life	4.03	.72	7	H
The head office management insists on the elimination of hazards by complying with construction regulations	3.86	.73	8	H
The construction workers' wellbeing is important to the head office management	3.66	1.21	9	H
The firm penalises workers for poor H&S practices on site	3.60	1.16	10	H
Management consults with the health and safety committee, representative union or representative group of employees, on the monitoring and reviewing of the risk assessments of a specific site	3.53	1.10	11	H
Standards set out in the construction regulations 2014 are often overlooked by management	3.03	1.16	12	M
Workers are rewarded for good H&S practices on site	2.46	.94	13	L
There is a general lack of proper supervision	2.20	.96	14	L

Findings in Table 4.5 suggest that workers possess valid medical certificates and firms employ qualified health and safety staff. The results suggest that regular inspections are conducted daily. Head office management also complies with construction regulations to improve workers' quality of life. However, the mean score of 3.8 suggests that management does not fully insist on the elimination of hazards by complying with the construction regulations. The health and safety of construction workers is regarded as less important. The means score of 3.6 highlights that poor health and safety practices of the construction workers are not dealt with accordingly. Findings further indicate that management does not engender full commitment in reviewing and assessing site-specific risk assessments. The findings indicate that standards set out in the construction regulations are overlooked by management. Moreover, workers are not rewarded for practising good health and safety. However, findings show that generally, there is supervision on-site with a mean score of 2.2.

Table 4.6

Health and Safety Training & Policies				
	Mean	**SD**	**Rank**	**Level**
All workers undergo orientation/induction before they are allowed to start work on site	4.56	.56	1	H
Workers are encouraged to report unsafe and unhealthy behaviour and working conditions	4.43	.77	2	H

Workers are trained in the proper care and use of PPE according the requirements of construction regulations	4.33	.88	3	H
More H&S education and training is needed	4.26	1.08	4	H
Health and Safety policies are written and in place	4.26	.74	5	H
We have regular H&S meetings	4.16	.83	6	H
Construction accidents are caused by workers non-compliance with construction regulations	3.96	.72	7	H

Findings in Table 4.6 suggest that workers undergo induction before working on-site, and health and safety meetings are held on a regular basis. However, it is further suggested that there is a need for more training as accidents are caused by non-compliance with construction regulations.

Table 4.7

Workers' Involvement				
	Mean	**SD**	**Rank**	**Level**
Workers are responsible for the H&S of their fellow workers	4.50	.57	1	H
Workers are responsible for their own H&S	4.36	.85	2	H
Workers have the right to refuse to work in unsafe conditions	4.36	1.24	3	H
Workers regularly report unsafe and unhealthy behaviour and working conditions	3.93	.82	4	H
Most workers on site view H&S as important	3.93	.86	5	H
Workers are involved with H&S inspections	3.60	1.03	6	H
Workers participated in the formulation of the H&S policy	3.20	.87	7	M
Workers are consulted when the H&S plan is compiled	3.16	1.26	8	M

The findings in table 4.7 indicate that workers are responsible for their health and safety on-site as well as that of their fellow workers. The results further indicate that workers have a right to refuse to work in unsafe conditions and workers usually report unhealthy behaviour and work conditions. However, based on the medium level of response, it may be inferred that workers are not consulted or involved in the formulation of H&S policies.

Table 4.8

Workers' Wellbeing				
	Mean	**SD**	**Rank**	**Level**
Workers worry about their job security	4.13	.89	1	H
The firm complies with prescribed working hours as per legislation	3.53	1.20	2	H
Workers are often stressed about work activities	3.36	1.06	3	M
The firm is only concerned with getting the job done as quickly as possible	3.00	1.36	4	M
Construction legislation and regulations in South Africa addresses workers psychological matters either directly or indirectly in the workplace	2.96	.61	5	M
Construction workers wellbeing and quality of life are often overlooked on site	2.76	1.28	6	M

The results in Table 4.8 suggest that workers worry about job security. Results further indicate that firms do not fully comply with the prescribed working hours as per legislation. Respondents disagreed that legislation addresses psychological matters in the workplace and also disagreed that workers wellbeing is overlooked on-site with a mean score of 2.76.

Table 4.9

Wellness Programs for Construction Workers				
	Mean	**SD**	**Rank**	**Level**
Workers are informed of any hazards, work-related measures and any control measures as per the risk assessment before work commences	4.00	.87	1	H
The company has medical surveillance programs to periodically identify workers for workplace related illnesses	3.80	1.10	2	H
Workers are incentivised for practicing good health and safety on site	3.10	1.30	3	M

The findings in Table 4.9 indicate that workers are informed about work-related hazards. However, the mean score of 3.8 suggests that medical surveillance programmes are not conducted periodically. Also, workers are not incentivised for practising good health and safety.

Table 4.10

On site Facilities				
	Mean	**SD**	**Rank**	**Level**
There is availability of clean drinking water for workers on site	4.70	.59	1	H
There are provisions for bathroom facilities on site	4.06	1.14	2	H
There are washing facilities for workers on site (for hands, PPE)	3.76	1.27	3	H
There are changing rooms for construction workers	3.70	1.32	4	H

Table 4.10 suggests that there is a provision for clean water and bathroom facilities on site. However, provision for washing facilities and changing rooms were sufficient.

5. CONCLUSION AND DISCUSSIONS

This study identified that although contractors are aware of the current health and safety legislation changes; the Construction Regulations 2014, construction workers are not the primary concern for compliance. Contractors comply mainly for profit maximisations and to avoid fines above improving construction worker' health and wellbeing. Most contractors cannot tell the differences between old regulation and amended ones. Moreover, the study identified that management is mainly concerned with compliance at the beginning of the project, but there seems to be a gap in monitoring compliance going forward and monitoring workers' health and safety performance. The study further identified that more health and safety training is required to improve awareness regarding construction regulations.

It is imperative to learn from other industries, such as manufacturing on how health and safety can be well administered. Moreover, wellness programs could be adopted and explicitly designed for construction workers well-being. Such could benefit the overall workforce and alleviate stress and improve workers' performance. The health of construction workers must be given more attention over and above their safety, and this must also address psychological health, which is often treated as taboo and given less attention in the current construction legislative framework. Furthermore, workers must be hands-on when it comes to legislative matters and be the key personnel advocating policy on sites instead of relying on top and middle management. The latter could be implemented through capacity building programs and training and must be a prerequisite. Although such interventions take place to mature, they have been proven to be most efficient and sustainable in the long run once effected. Technological advances can be used to improve workers' safety onsite and amendments must be done in current legislation to accommodate these advances. Improving construction workers well-being goes beyond just providing PPE, ticking checkboxes and securing projects. It must be seen more as a value!

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Process Health and Safety Management Deficiencies

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ABSTRACT AND KEYWORDS

Purpose:

The study aims to investigate existing process health and safety systems to identify deficiencies that require senior management's attention to improve process health and safety to a generative culture level.

Design/Methodology/Approach:

A quantitative research methodology and deductive research approach was used, and questionnaire survey to collect the data. The targeted population was 800 employees in one major petrochemical enterprise in the KwaZulu-Natal province of South Africa. The study was conducted by distributing 400 questionnaires manually to the randomly selected potential participants of which 259 were returned duly completed and used. They were statistically analysed using descriptive statistics (frequency of responses) in SPSS version 25. Ethical clearance to conduct the study was obtained from the University of KwaZulu - Natal Humanities and Social Sciences Research Ethics Committee (HSS/1094/018D).

Findings:

The results showed that the key process health and safety focus areas for an effective process health and safety management system are, namely, Effective handling of hazardous chemicals, Poor engineering design integrity, Poor controls when working at heights, Verifying energy isolation before start working on equipment, Fatigue management for both permanent employees and contractors, Poor controls when working with suspended loads, Poor housekeeping, Human error, Poor health and safety risk assessments, and Poor controls of source of ignition.

Research Limitations:

The study was conducted in South Africa (KwaZulu-Natal Province) and only the petrochemical industry was considered.

Value of Paper:

This study will assist senior management with a framework to reduce process health and safety incidents in the petrochemical industry.

Response to the Conference Theme:

Paper responds to Health and Safety.

Key words: Process Health and Safety Management Deficiencies.

1. INTRODUCTION

Many studies have been conducted on health and safety, attempting to improve health and safety in organisations. The workers in the oil and gas industry are exposed to many hazards, namely, physical hazards, chemical hazards, ergonomic hazards, psychosocial hazards and radiological hazards (Kim, 2016). The evolution of petroleum refining from simple distillation to today's sophisticated processes has created a need for health and safety management procedures and safe work practices (Kumar *et al.,* 2017). The International Labour Organisation (ILO) has estimated that 2 million workers die each year from work related injury and illness. According to Ezejiofor (2014) difficulties are encountered in obtaining information concerning occupational diseases and injuries in developing countries due to lack of comprehensive and harmonious data collecting systems. In 2002, in Sub-Saharan Africa alone, the ILO estimated more than 257,000 total work-related fatalities, including about 50,000 injuries. Previous studies have shown that the fatality rate in the petroleum industry is 2.5 times more than construction industry and 7 times more than general industry (Kulkarni, 2017).

The study aims to investigate the deficiencies in the existing process health and safety management systems that require senior management attention for the improvement of process health and safety systems in the petroleum industry. The research objective was to review the process health and safety management systems where hazardous chemical substances are being used and identify the major deficiencies.

2. COMPONENTS OF PROCESS HEALTH AND SAFETY MANAGEMENT SYSTEMS

There are several components that comprise the health and safety management systems used in the petrochemical industry. These components include leadership commitment and chemical exposure management, health and safety risk assessment and process hazard analysis, permit to work and operating procedures, training and competency, process health and safety information, control of confined space entry and ignition source. These are briefly discussed in the following sub-sections.

2.1 Leadership Commitment and Chemical Exposure Management.

According to Hardy (2013) it is recognised that leadership is important in the creation of a culture that supports and promotes a strong health and safety performance of an organisation Chemical process hazards at a chemical plant can give rise to accidents that affect both workers inside the plant and members of the public who reside nearby (Chen, 2016). The hazardous effect of chemicals comes through three ways, namely: fire, explosion and toxicity. The first essential step towards greater plant safety is being aware of the potentially dangerous properties of the substances, i.e. whether they are flammable, explosive or toxic (Almanssoor, 2008).

2.2 Health and Safety Risk Assessment and Process Hazard Analysis.

Risk assessment is the evaluation of hazards to determine their potential to cause an accident. According to Albert *et al.,* (2014) a critical component in safety risk management is to adequately identify hazards and mitigate its associated risk using safety program elements. According to Dabup (2012) the risk assessment provides a systematic approach for the identification, management and reduction of the risk to an acceptable level. According to Hardy (2013) process hazard analysis is defined as a systematic approach for identifying, evaluating and controlling the hazards of processes involving highly hazardous chemicals. A process hazard analysis must be conducted by a team with expertise in engineering and process operations, including at least one employee who has experience and knowledge on the system (Department of Labour [USA], 2016).

2.3 Permit to Work and Operating Procedures

The permit to work system has been widely used to ensure safety during maintenance and/or construction activities in almost every major hazard industry worldwide (Reddy and Reddy, 2015). According to Navadiya (2017) design of permit to work is very significant but most key thing is definition of roles and responsibilities of involved employees in procedure part and preparing checklist which is to be covered in synchronize way. The procedures should be formally reviewed and updated as necessary to assure that they are consistent with existing processes.

Training must accompany these operating procedures, with an emphasis on what employees should do in case of emergency (Hardy, 2013).

2.4 Training and Competency

Improving organisational knowledge and knowledge management capabilities is an important means to prevent chemical accidents and improve organisations safety level (Chen, 2016). According to Hardy (2013), training provides employees with the knowledge and tools to fully understand the risks in working with hazardous chemicals. Health and safety knowledge encompasses awareness of occupational health and safety risks, including an evaluation of occupational health and safety programmes in an organisation (Okoye *et al.,* 2016).

2.5 Process Health and Safety Information

According to Tzou *et al.,* (2004) managing safety related information inadequately has been cited as a significant factor to industrial accidents. Awareness on possible risk factors and knowledge on how to reduce these risk factors among workers and contractors will enhance site safety (Vitharana *et al.,* 2015).

2.6 Control of Confined Space Entry and Ignition Source

Confined spaces may contain hazardous atmospheres, including insufficient oxygen, toxic air, and an explosive atmosphere (Stojkovic', 2013). According to Karthika (2013) even though accidents can never be eliminated completely, employers can prevent many of the injuries and fatalities that occur each year. According to Puttick (2008) fire and explosion hazard assessment flammable and potentially flammable atmospheres must be identified and compared with the potential ignition sources present.

3. RESEARCH DESIGN AND METHODOLOGY

A quantitative research methodology and the deductive research approach in the form of questionnaire instrument was used to collect the data. According to Trochim (2006) quantitative research often translates into the use of statistical analysis to make the connection between what is known and what can be learned through research. The major advantage of this method is that it allows one to measure the responses of number of participants to a limited set of questions, thereby facilitating comparison and statistical aggregation of the data (Yilmaz, 2013). The deductive approach is concerned with developing a hypothesis (or hypotheses) based on existing theory, and the designing a research strategy to test the hypothesis. The study was conducted by distributing 400 questionnaires manually to the randomly selected potential participants within a single petrochemical organization and therefore considered to be a convenience sample. The targeted population was 800 employees. The employees to whom questionnaires were handed during health and safety talks and production meetings were then requested to remain behind for an explanation. The duly completed questionnaires were 259, and were analysed using descriptive statistics (frequency of responses) in SPSS version 25. The response rate was computed to be 64.75%. The observed variables was measure through a Likert scale where 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree and 5=Strongly Disagree.

4. FINDINGS

a. Demographics of Participants

Table 4.1 Age and Years of Service

	Minimum	Maximum	Median
Age	22	66	38
Years of Service	1	46	11

From Table 4.1 it is evident that the median age of participants was 38 with a minimum age of 22 years and a maximum age of 66 years. Further, the median number of years of service was 11 years with a minimum of 1 year and a maximum of 46 years. The participants were matured with considerable years of experience in the petrochemical industry. This aspect increases the reliability of the responses received from the participants in terms of their accuracy and completeness.

Table 4.2 Gender, Marital Status and Department

Gender	
	Percent
Male	80,6
Female	19,4
Total	**100,0**
Marital Status	
Single	37,2
Married	61,6
Divorced	1,2
Total	**100,0**
Department	
Health, Safety and Environment	8,2
Operations	50,6
Maintenance	24,1
Technical	12,5
Others	4,7
Total	**100,0**

Table 4.2 indicates that 80.6% of the participants were males, 61.6% were married and most of the respondents were from the Operations Department (50.6%), followed by the Maintenance Department (24.1%).The results show that the petrochemical industry in the case of the sample organization is still male dominated. Operations and maintenance generally have more employees that are exposed to health and safety risks in petrochemical industry.

Table 4.3 Latent Variables and Observed Variables Frequency Table

Latent Variables and Observed Variables	(Str Agree + Agree)%	Neutral%	(Str Disagree + Disagree)%
Leadership Commitment (LCH7) - Senior Management prioritises health and safety in my organisation.	93.4	4.3	2.3
LCH8 - Senior Management has an open door policy on health and safety issues.	88.4	9.3	2.3
LCH10 - Senior Management communicates Health and Safety policy to all employees.	96.9	1.9	1.2
LCH11 - Senior Management allocates enough time to address Health and Safety concerns.	88.4	9.3	2.3
LCH17 - Senior Management prioritises mechanical/asset integrity of our process plant	73.6	18.6	7.8
LCH38 - Poor housekeeping in my organisation is the cause for many health and safety incidents.	33.7	31.0	35.3
LCH40 - Audit compliance is an excellent practice to prevent most of health and safety incidents in the petrochemical industry.	87.3	9.3	3.4

Chemical Exposure Management (CEMH6) - My organisation has excellent chemical exposure management systems.	92.2	6.2	1.6
CEMH12 - Most employees are aware of hazardous chemicals in their work environment.	86.5	9.6	3.9
CEMH14 - Most permanent employees know how to handle hazardous chemicals in the work place.	84.9	12.8	2.3
CEMH15 - Contractor's on boarding appreciates all hazardous chemicals in my organisation.	62.4	32.1	5.5
CEMH16 - Most contractors know how to handle hazardous chemicals in my organisation.	43.8	40.3	15.9
CEMH30 - All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.	95.8	2.7	1.5
Health and Safety Risk Assessment (HSRAH9) - There are effective noise exposure management systems in my organisation.	88.8	8.5	2.7
HSRAH32 - Most of health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.	40.5	27.8	31.7
HSRAH33 - My organisation diligently manages fatigue in both permanent employees and contractors.	55.4	29.5	15.1
HSRAH34 - My organisation has all management systems in place to manage substance misuse.	88.0	8.5	3.5
HSRAH39 - Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry	46.1	22.1	31.8

Latent Variables and Observed Variables	(Str Agree + Agree)%	Neutral%	(Str Disagree + Disagree)%
Process Hazard Analysis (PHAH20) - In my organisation all engineering changes undergo a comprehensive management of change.	87.2	3.5	9.3
PHAH21 - The organisation does comprehensive process hazard analysis before engineering changes are made.	88.8	9.3	1.9
PHAH23 - Most of the health and safety incidents are due to poor engineering design integrity.	20.6	38.5	40.9
PHAH24 - In my organisation we have a comprehensive pre-activity start up review and pre-activity shutdown review.	93.8	4.6	1.6
Permit to Work (PTWH25) - Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights.	24.9	36.6	38.5
PTWH28 - All the work activities in my organisation are done after a valid permit to work has been approved by the authorities.	95.7	2.7	1.6
PTWH29 - In my organisation before you start excavation or entering a trench you need to obtain authorisation.	98.4	1.2	0.4
PTWH31 - In my organisation all safety critical equipment is disabled with permission from the authorities.	90.3	6.6	3.1
Training and Competency (TCH13) - Employees undergo comprehensive training on health and safety in my organisation.	86.1	9.7	4.2
TCH19 - The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite.	80.7	15.4	3.9
TCH35 - Most of the health and safety incidents are due to human error in my organisation.	55.0	32.2	12.8
Process Health and Safety Information (PHSIH18) - The organisation communicates effectively all lessons learned after the occupational health and safety incidents	88.0	6.6	5.4
PHSIH22 - The organisation has all process health and safety information available to all	90.0	8.1	1.9

employees.			
Control of Confined Space Entry (CCSEH36) - My organisation has effective management systems to manage working in confined space.	93.0	4.3	2.7
CCSEH37 - Most of the health and safety incidents are due to poor controls in place when working with suspended loads.	28.7	29.8	41.5
Operating Procedure (OPH26) - In my organisation all work activities have a detailed operating procedure or work instruction.	91.5	5.8	2.7
Control of Ignition Source (CISH27) - Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition.	34.1	31.4	34.5

The frequency of responses is shown in Table 4.3. These were used to determine the major deficiencies existing in process health and safety management systems when dealing with hazardous chemicals. The following formula was used to decide on main deficiencies (Strongly Agreed + Agreed < 60%, Neutral > 20% = Main Deficiencies). The cumulative percentages of both strongly agree plus agree and disagree plus strongly disagree were used to simplify the assessment of observed variables.

The key process health and safety management focus areas from Table 4.3 that have to be prioritized to minimise health and safety incidents are, namely, CEMH16 - Effective handling of hazardous chemicals (43.8%, 40.3), PHAH23 -Poor engineering design integrity (20.6%, 38.5%), PTWH25 - Poor controls when working at heights (24.9%, 36.6%), HSRAH32 - Verifying energy isolation before start working on equipment (40.5%, 27.8%), HSRAH33 - Fatigue management for both permanent employees and contractors (55.4%, 29.5%), CCSEH37 - Poor controls when working with suspended loads (28.7%, 29.8%),. LCH38 - Poor housekeeping (33.7%, 31.0%), TCH35 - Human error (55.0%, 32.2%), HSRAH39 - Poor health and safety risk assessments (46.1%, 22.1%), and CISH27 - Poor controls of source of ignition (34.1%, 31.4%). Participants in this study reported low levels of satisfaction with these observed variables of health and safety in the petrochemical industry.

According Zohrabi (2013) one of the main requirements of any research process is the reliability of the data and findings. The reliability and validity of the data are vital for a research study. The Cronbach's Alpha is a high-quality test widely used for reliability testing and an essential test for evaluating a questionnaire instrument. Cronbach's Alpha test is a widely-used method to test the internal consistency of measurement indicators, based on the correlations between indicators.

Table 4.4 Reliability Test for Constructs

Latent Construct	No of Observed Variables	Cronbach's Alpha
Leadership Commitment (LC)	7 (LCH7, LCH8, LCH10, LCH11, LCH17, LCH38, LCH40)	0.819
Chemical Exposure Management (CEM)	6 (CEMH6, CEMH12, CEMH14, CEMH15, CEMH16, CEMH30)	0.797
Health and Safety Risk Assessment (HSRA)	5 (HSRAH9, HSRAH32, HSRAH33, HSRAH34, HSRAH39)	0.435
Process Hazard Analysis (PHA)	4 (PHAH20, PHAH21, PHAH23, PHAH24)	0.776
Permit to Work (PTW)	4 (PTWH25, PTWH28, PTWH29, PTWH31)	0.718
Training and Competency (TC)	3 (TCH13, TCH19, TCH35)	0.481
Process Health and Safety Information (PHSI)	2 (PHSIH18, PHSIH22)	0.581
Control of Confined Space Entry (CCSE)	2 (CCSEH36, CCSEH37)	0.105
Operating Procedure (OP)	1 (OPH26)	N/A
Control of Ignition Source (CIS)	1 (CISH27)	N/A

Table 4.4 outlines the ten latent constructs with observed variables. Reliability test shows four latent constructs with acceptable Cronbach's alpha > 0.7 and four latent constructs with Cronbach's alpha < 0.7 and two latent constructs that were not computed due to one observed variable.

b. Principal Component Analysis

Confirmatory factor analysis was carried out to test whether the measure of latent construct correspond with the study of the nature of the individual factor. At this stage, the indicator elimination and model re-specification are performed for each latent construct. A common acceptable threshold value for a good indicator is having a loading higher than 0.5 (Rahman *et al.,* 2013).

Table 4.5 Principal Component Analysis

Rotated Component Matrix[a]					
Observed Variables	Latent Variables				
	PTW	PHA	LC	HSRA	CEM
Permit to Work (PTWH29)	0,779				
Permit to Work (PTWH28)	0,687				
Permit to Work (PTWH31)	0,661				
Permit to Work (PTWH36)	0,649				
Process Hazard Analysis (PHAH24)		0,630			
Process Hazard Analysis (PHAH22)		0,587			
Process Hazard Analysis (PHAH20)		0,564			
Process Hazard Analysis (PHAH21)		0,504			
Process Hazard Analysis (PHAH26)		0,586			
Leadership Commitment (LCH8)			0,726		
Leadership Commitment (LC10)			0,725		
Leadership Commitment (LCH11)			0,698		
Leadership Commitment (LCH7)			0,660		
Leadership Commitment (LCH13)			0,547		
Leadership Commitment (LCH9)			0,524		
Leadership Commitment (LCH17)			0,519		
Leadership Commitment (LCH6)			0,604		
Leadership Commitment (LCH40)			0,587		
Health and Safety Risk Assessment (HSRAH37)				0,833	
Health and Safety Risk Assessment (HSRAH32)				0,788	
Health and Safety Risk Assessment (HSRAH25)				0,785	
Health and Safety Risk Assessment (HSRAH27)				0,739	
Health and Safety Risk Assessment (HSRAH23)				0,690	
Health and Safety Risk Assessment (HSRAH38)				0,598	
Health and Safety Risk Assessment (HSRAH39)				0,573	
Health and Safety Risk Assessment (HSRAH33)				0,637	
Health and Safety Risk Assessment (HSRAH35)				0,769	
Chemical Exposure Management (CEMH30)					0,735
Chemical Exposure Management (CEMH16)					0,763
Chemical Exposure Management (CEMH15)					0,731
Chemical Exposure Management (CEMH14)					0,695
Chemical Exposure Management (CEMH12)					0,654
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.[a]					
a. Rotation converged in 6 iterations.					

Structural equation modelling combines multiple regression analysis and factor analysis together to analyse the relationship between measured variables and latent constructs or factors (Raykov, 2006). It provides a quantitative method to test a hypothesised model (Byrne, 2016). Structural equation modelling can be employed to capture complex relationships between one or more dependent variables that can be sourced from qualitative or quantitative data (Hox and Kleiboer, 2007).

According to Schreiber *et al.*, (2006) Confirmatory Factor Analysis and Structural Equation Modelling are statistical techniques that one can use to reduce the number of observed variables into a smaller number of latent variables by examining the covariation among the observed variables. In this research paper, there were three observed variables (OV) that were eliminated since the loading was less than 0.5 and they are namely, PHSIH18 - The organisation communicates effectively all lessons learned after the occupational health and safety incidents. TCH19 - The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite). HSRAH34 - My organisation has all management systems in place to manage substance misuse. Other observed variables were allocated to other latent variables after principal component analysis as indicated in Table 4.5.

Table 4.6 Reliability Test after Principal Component Analysis for Constructs

Latent Construct	No of Observed Variables	Cronbach's Alpha
Leadership Commitment (LC)	9 (LCH6, LCH7, LCH8, LCH9, LCH10, LCH11, LCH13, LCH17, LCH40)	0.867
Chemical Exposure Management (CEM)	5 (CEMH12, CEMH14, CEMH15, CEMH16, CEMH30)	0.781
Health and Safety Risk Assessment (HSRA)	9 (HSRAH23, HSRAH25, HSRAH27, HSRAH32, HSRAH33, HSRAH35, HSRAH37, HSRAH38, HSRAH39)	0.829
Process Hazard Analysis (PHA)	5 (PHAH20, PHAH21, PHAH22, PHAH24, PHAH26)	0.810
Permit to Work (PTW)	4 (PTWH28, PTWH29, PTWH31, PTWH36)	0.749

The five latent constructs for process health and safety culture in this study are, namely, Leadership Commitment (0.867), Chemical Exposure Management (0.781), Health and Safety Risk Assessment (0.829), Process Hazard Analysis (0.810) and Permit to Work (0.749), they all have Cronbach’s Alpha > 0.7, and that confirms reliability of the data.

5. CONCLUSION AND RECOMMENDATIONS

The study investigated existing process health and safety systems by surveying a sample of employees in a petrochemical business enterprise in KZN province to identify deficiencies that required senior management’s attention to improve process health and safety to a generative culture. It can be concluded that senior management has to increase attentiveness to handling of hazardous chemicals, engineering design integrity, controls when working at heights, verification of energy isolation before start working on equipment, fatigue management, controls when working with suspended loads, housekeeping, human error, health and safety risk assessments and controls of ignition sources to improve health and safety culture. It is recommended that industry develop process health and safety elements from the focus areas and to enforce compliance and intervention timely when there is non-compliance. It is recommended that the next phase in this study be to determine the key drivers to generative health and safety culture within the petrochemical industry.

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The challenges of professional women in a male-dominated construction industry

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ABSTRACT AND KEYWORDS

Purpose of this paper
This study adopted a qualitative investigative perspective to explore and clarify the challenges experienced by professional women in the South African construction industry.

Design/methodology/approach
This is an exploratory qualitative study from a constructivist grounded theory perspective. A purposive sampling technique of ten professional women based on in-depth unstructured interviews was engaged. This sample is delimited to professional women, who are architects, civil engineers, construction managers, electrical engineers and quantity surveyors. In order to maintain a central practice and the relationship between the subject of the research and the researcher, a purposive sampling technique has been used, which yielded only 10 women in various professions of the construction industry. Gender diversity has been key to this discourse

Findings
The study revealed that gender diversity is identical to business intelligence in the South African construction industry. In addition, the co-existence of the two genders in the construction domain has the implications of rivalry perpetuated by patriarchy controls, ineffective implementation of gender policies and lack of understanding regarding effective development strategies.

Research limitations/implications
This study measured only the South African professional women, in particular in the Eastern Cape Province, who renders professional services in the construction industry. Based on the fact that Eastern Cape Province is mostly rural with patriarchy and economic rivalry that violate human rights, there is a deficiency in studies that explicitly regulate the practice of dialects such as such as Queen Bee, Window Dressing, Fronting, and Quid Pro Quo which have a bearing on the performance of this industry on both genders of the construction industry.

Practical implications
The study has the potential to influence the construction industry and the South African government in imposing measures regarding the application of professional ethics concerning accommodating professional women in the built environment fraternity.

What is original/value of paper?
This study portrays the operational gaps, in line with diversity, that exists pertaining to synchronizing women's rights in the construction industry and generating ideas to benefit construction business growth in diversity.

Keywords: Built Environment, Construction, Eastern Cape, Gender, Policies, Professional women, South Africa

1. INTRODUCTION

Gender equality has been a hope for most of our contemporary humanity; however, discrimination based on one's gender remains an issue (Valji, 2007:3). The culture of patriarchy is the architect of gender inequality that starts at the girl-boy childbirth segregation phase (Buthelezi, 2012:22). Gender transformation and equity are not implemented effectively in the South African construction industry (Hicks, 2012). Women are restricted to domestic work and subordinated by their culture (Mba, 2015:446). In addition, women are still on the periphery of the economy and they remain marginalized (SAWIC, 2014:15). The male-dominated construction industry culture is known to pay lip service to gender empowerment policies and continues to marginalise women (Hicks, 2012). This situation is perceived by the fact that the South African construction industry is the most untransformed sector and highly gender-active. Moreover, men have difficulty in accepting women in the construction industry (English *et al*., 2006, Haupt and Madikizela, 2009).

The predominant societal settings strengthen the exclusion of professional women on the basis of masculine and feminine occupations, which dates back from the beginning of the 18th centuries (Simpeh, 2011). The gender imbalances practised in construction industry imitate what is happening in the societal, political and economic circles (Valji, 2007:3). In addition, arrogant behaviour and insensitivities are evident obstacles aimed at women in all occupations, in particular the construction industry profession (Worrall *et al.,* 2010:279).

Though gender imbalances have been researched diversely based on the economic sphere and the male dominance (Ozumba & Ozumba, 2012), the focus has been on western behaviour (Amaratunga *et al.*, 2006). Agherdien and Smallwood (2013), in their paper on women in the South African construction industry, revealed a number of concerns, such as low representation. These revelations ratified the promotion of a cultural shift and the improvement of the overall image of the construction industry. In addition, Ozumba and Ozumba (2012) probed the performance of the South African construction industry with regard to its feminine footprint. Their conclusions indicated that South Africa is behind the set goals of women representation in the construction industry. Moodley's (2012) study focused on the challenges that South Africa women face in the broader perspective of performing various roles. Nevertheless, she did not reveal the extent of these challenges but instead deliberated more on women entrepreneurs in the construction industry as a whole, together with the recommendations of more local studies in the context of women in the construction industry. In their study based on influences on women's professions, Haupt and Madikizela (2010) highlighted the preferences in the South African construction industry, which served to confirm the gender bias and the malfunctioning of existing legislation. However, this study did not consider the overall image of the industry. Mjoli-Mncube (2005) analysed the opportunities for women in housing and construction while Mahlobo (2006) looked at the challenges faced by women contractors in housing construction. Both these studies were tailored to one construction section, with no intent to investigate from the perspective of professional women themselves. Other studies include Mathur-Helm's (2005) study on women and affirmative action and that of Verwey (2005), who studied a comparative analysis between South African and American women entrepreneurs in construction.

However, not much emphasis was placed on the fundamental feminist models in addressing these inequalities and improving women's prerogatives and abilities to participate in the sector that is traditionally believed to be masculine and male-dominated (Moshupi, 2013). In addition, none of these studies emphasised the great challenge of matching statutes, policy and practice. It is evident that the common conclusion of all the studies is the negative image posed by the construction industry. It is within these confines that this paper has concentrated on the construction industry, which has not widely explored the importance of diverse professional genders within the construction industry. The study pursues the comprehensive concern experienced by women who are working as professionals within the construction industry in the Eastern Cape, South Africa. Importance

This study adopted an investigative perspective to explore and clarify the challenges experienced by professional women in the South African construction industry. The primary aim is to examine the gender imbalances that promote the marginalisation of professional women in the South African construction industry. The objectives are restricted to the following:

- To identify perceptions allied to professional women in the construction industry;
- To identify the mental encumbrances and physical strains endured by professional women in the South African construction industry; and
- To explore the contemporary state of professional women in a male-dominated industry in the Eastern Cape of South Africa.

The construction industry is an ideal setting for ethical dilemmas perpetuated by a lack of attitude and fierce rivalry (Moshupi, 2013). Furthermore, it is very hectic, with a complex scope of activities (Nkomo and Thwala, 2014). It is difficult to maintain discipline between the two genders, even at the professional level (Chittibabu, 2007).

From the South African perspective, the study undertakes a qualitative motive, to imposing measures regarding the application of professional ethics towards professional women in the built environment fraternity. In addition, it will determine the operational gaps that exist in synchronizing women's rights in the construction industry and offer ideas to benefit construction business growth in diversity. Recommendations and conclusions are guided by a literature review relevant to this paper and the findings from data collected.

2. LITERATURE REVIEW

The literature review is structured according to headings which reflect perceptions about professional women, their encumbrances and their contemporary status.

2.1 The basics of professional competence

The basis of professionalism is the control of a body of specialised knowledge, that when shared with character, affords authority upon its possessor (Greenhalgh, 1997). Co-operatively, a profession is portrayed to be a cluster of specialised knowledge in the interests of a culture based on a supposed association (Simpeh, 2011). Moreover, competence is a capability to perform well through a strategic analysis of a dilemma, which can be observed and judged by others (Simpeh, 2011:4). This implies that construction professionals apply their knowledge, with the support of a code of ethics (Toor & Ofori, 2010). The restrictions conveyed by Bowen *et al*. (2014:1273) that not all individuals can participate in the construction industry owing to physical strength as a prerequisite, regardless of age, suppress professional women who are regarded as the weaker gender by the construction industry (Nkomo and Thwala, 2014).

In the South African context, women are restricted to domestic work and expected to be obedient to their social culture (Mba, 2015:446). This provides proof of injustice leading to necessary reforms of the construction industry practice (Cha, 2013).

2.2 Outlook of the construction industry of professional women

The construction industry is a very busy sector with a complex scope of activities (Nkomo & Thwala, 2014). Therefore, it is difficult to maintain discipline between the two genders even at a professional level (Chittibabu, 2007). Hence gender issues perpetuate imbalances through supremacy by direct career opportunity (Simpeh, 2011).

Culture appreciation assists in clarifying several perplexing issues (Schein, 2010:7) and an appreciation of culture is crucial for the construction industry (Tijhuis and Fellows, 2012:52). Additionally, the "tokenism" approach must be circumvented (Gurjao, 2006) in order to change from conditions of labour resource crises and skill deficiencies to expanding equal opportunities for men and women (Amaratunga *et al*., 2006).

The questioning of professional women's competence and their gender-role beliefs undermine their self-esteem, deterring them from realising their potential within the male-dominated industry (Damaske, 2011; Hicks, 2012). Consequently, it is evident that professional women's ability is not commensurately rewarded (Jaafar *et.al.,* 2014). Therefore, women seem caught between resisting and accommodating masculine politics (Davey, 2008).

2.3 The strength of professional women in a male-dominated space

It is imperative to consider the barriers women face when rendering services. These barriers are culture, gender imbalances, poor working conditions, and the insensitivity of the construction industry (Amaratunga *et al.,* 2006:562).

Layne (2010) indicates the implementation of gender equality and affirmative-action legislation as having inequality deficiencies. Although national legislation is in favour of women, there is a non-existent correlation between policy and practice (Mathur-Helm, 2005: 62-63). A study by Jaafar *et.al.* (2014) revealed that the South African construction industry is trailing behind regarding modern human resource practices.

3. METHODOLOGY

The purpose of this paper is to reflect the classification to which professional women in the construction industry are defined based on being women, through the literature review.

The model to various philosophies, methodologies and other properties is derived through an onion layer illustration (Saunders *et al*., 2009). This study embraces constructivist grounded theory which offered clear strategies that have a potential flex ability in order to inspire improvement (Charmaz, 2008: 397). Contradictorily, these strategies offered some researcher's satisfactory trend to rule out qualitative studies (Charmaz, 2008: 397). The outlook is that qualitative research methods are ideal for retrieving knowledge about reality. This study is primarily qualitative, and it employs comprehensive dialogue to produce the data, which has been helpful in studying the topic problem.

From this perspective, this study undertakes a descriptive and exploratory research design, which was used to undertake preliminary investigations into construction industry research zones (Jaafar *et.al*., 2014)

3.1 Data collection

The population of this study was Eastern Cape Province in the construction industry with their details attained from the CIDB, the Treasury Department and professional bodies' websites. Regarding the selection of particular informative elements of this paper's population, a total number of thirty professional women were given interview questionnaires (Creswell, 2009). These questionnaires had semi-structured questions where unstructured questions were used during follow up questions. However, only ten agreed to undergo interviews upon completion, of which a purposeful sampling was assumed, which complied with the sample frame (Moodley, 2012).

The description of the research participants is tabulated in Table 3.1 below:

Table 3.1: Participant demographic details

Research participant (Rp)	Profession	Education level	Race	Age	Year with the company
Rp1	Architect	Master's Degree	Black	40>	7<
Rp2	Architect	National Diploma	Black	35>	4>
Rp3	Construction manager	BTech	Black	48>	10<
Rp4	Construction manager	National Diploma	White	40>	7>
Rp5	Civil engineer	Master's Degree	White	38<	6<

Rp6	Civil engineer	National Diploma	White	37<	6<
Rp7	Electrical engineer	BTech	Black	40>	6<
Rp8	Electrical engineer	BTech	Black	39>	6<
Rp9	Quantity surveyor	BTech	White	30<	5<
Rp10	Health & safety advisor	National Diploma	Black	30<	3<

3.2 Observation

During the interview sessions and on interviewee's workplace, field notes were taken throughout the observations and they focused on what was perceived such as facial expressions, interaction with colleagues etc. The recorded notes assisted in determining what the observed events meant and provided support for responding to the research questions through data analysis (Moodley, 2012). The researcher was conscious of obtrusiveness by ensuring that participants become accustomed to having the researcher and a recording device present. This has limited the pre-visit exercise as observation in qualitative research usually involves spending a protracted amount of time.

3.3 Interviews

The privacy with the backing of a digital recorder format was the most appropriate for this study. Hence, notes were jotted down immediately after the interview, including the occurrences happening on site which was allied to the subject matter. To keep track of what was expressed in the interview, a recording device was engaged as a secondary service. The highly structured format was used primarily to gather socio-demographic information and for the most part was more open-ended and less structured (Moodley, 2012). In maintaining consistency, the interviewer asked the same questions of all the participants: the order of the questions and the wording did not change, and but the type of follow-up questions varied considerably. The researcher started by asking easy questions and then proceeded with more difficult and sensitive questions.

The researcher was very aware of being empathic and relaxed with the respondents to engender trust in the researcher. Without trust they would not open up and describe their true feelings, thoughts and intentions. The interviewer was alert to both verbal and nonverbal messages and was flexible in rephrasing and pursuing certain lines of questioning. The interviewer used words that are clear and meaningful to respondents.

3.4 Ethical considerations

A code of conduct and all the associated research ethics were taken into consideration by the researcher. Hence, the researcher ensured that there was no susceptibility or risk from the participants' viewpoint.

Two informed consent forms were distributed to participants for them to accept the use of data in this paper, both for the survey and for conducting and recording the interview. The consent forms included an outline of what the study entailed, the protection of participants' confidentiality and the five-year period of data keeping. Although the researcher's profession is affiliated to the subject matter, autonomy and honesty are maintained.

3.5 Research bias

It is obligatory to declare the inherent bias of the researchers as males with direct experience of the challenges faced by women in the construction industry. This influenced the choice of the study problem and the establishment of the research questions. Every effort was made to maintain academic objectivity during the different stages of the research. This study highlighted a qualification that males tend to destroy women's self-esteem deliberate and or accidentally through their actions in the construction industry.

4. RESULTS, ANALYSIS AND DISCUSSION

4.1 Results

The study sampled ten professional women to answer questions pertaining to the challenges they face. The literature review indicated that professional women might experience discrimination due to male chauvinism. Consequently, this could hamper their prospects in their profession.

In addition, the dominance of male in this industry is prominent; hence, it is vital to confirm that there are interventions by means of government initiatives in terms of professional women in the construction industry.

In view of the qualitative nature of this paper, a comprehensive survey was undertaken. The raw data was analysed into themes that were further compared to the literature review and analysed to achieve the objective of this research. The outcomes were then presented through extracts after the interview that exemplified variations of these themes.

It is acknowledged that participation was voluntary, hence the 33% response rate is accepted as due to circumstances such as the participants' time constraints and the data saturation was achieved still. Nonetheless, a total of ten (10) respondents is respectable and manageable for this paper. Furthermore, the qualitative study emphasis is more on the depth and quality of data than the quantity. An added advantage to this smaller number is that there is more time spent with the respondents, recording their experiences at a deeper level.

The data which had been collected were grouped into themes. This enabled the findings of the literature review and the participants' responses to be linked to the research objectives. The following themes were identified:

- Theme one related to the demographics of the participants. The responses were analysed according to demographical status: race, age and experience.
- Theme two was the impact of a patriarchal culture in relation to the model-driven revelation of survival tactics by professional women in the construction industry of South Africa. The responses are analysed according to the mental tactics used to discredit professional women and the physical aspects of belittling professional women.
- Theme three presented the perceived core impact of the construction industry growth. The theme is based on the status core of the entire construction industry in line with professional women.

4.2 Analysis and discussion

Through broad demographical questions, the researcher probed the participants in terms of ideal values for professional women in order to establish whether the demographics influence discrimination which is assumed one of the challenges faced by women in the industry.

The study understood this as a form of masculine perception. The following extracts illustrate this theme:

A question posed to participants: "How has the reaction been since your appointment to this position?"

Participant: "………I have experienced varied feedbacks [sic] on both genders. This has happened regularly, and I never took it personal [sic]".

The above reply is in line with researchers' findings (Haupt and Madikizela, 2009; Amaratunga and Haigh, 2007), namely that the South African construction industry is the most untransformed sector and highly gender conscious, challenging the survival of women in the industry. These assertions also

validated the fact that the existence of both genders in the construction industry is similar to subjective judgments when promoting the female gender in this sector (Agapiou, 2002:704).
Participant: ''…………there are always beliefs [sic] to put extra effort in order to prove my capabilities [sic] match my skills."
The above assertions contradict the findings of Wangle (2009:20) and Bowen *et al*. (2014:1273), namely that not all individuals can participate in the construction industry owing to physical strength being a prerequisite, regardless of age and gender. However, Buthelezi's (2012:1) finding that worksite environments and executive positions embrace anti-women attitudes is confirmed.

The probed on the impact of a patriarchal culture that encompasses mentally and physically challenging, is the scope of this theme. All ten participants indicated their observations on this theme. This has been quantified by compelling ambiguities that exist between policies and practice, in particular concerning feminine diversity. The following extracts were observed:
A question posed to participants: Do you desire to champion an executive/professional position in this construction industry?
Participant: "…No. I was actually in a senior management position before I requested demotion."
These contentions are allied to scholars' (Powell *et al.*, 2009; Watts, 2009; Kyriakidou, 2012) revelations that …"women working in the construction industry are forced to either incorporate and or conform to the existing masculine culture or become marginalised, discouraged, and possibly expelled from the industry". On the other hand, the request for demotion can be interpreted as professional women lacking professionalism and competency.
A question posed to participants: Is the construction industry depicting professional women's rights?
Participant: "….Absolutely yes, with the right perspective, mixed authority with minimal recognition by men, the image has changed to adopt us."
Assertions are allied to the confirmation by Moshupi (2013) that the rights of women are viewed as human rights. The participant's statement is also contrary to that of Mathur-Helm (2005) that women have not been benefiting from government policies and legislation.

The probe on this theme was to establish status core and present prominence of professional women in the hostile male-dominated construction industry. These prominences are challenges and strategies for acquiring an identity in the male-dominated domain. The shared perspective indicates that there is no contemplative and incremental development within the construction industry for professional women. The objective of this concern was to establish whether the transformation "window dressing" persists.
A further question posed to participants was: Is the construction industry transformation ideal to develop professional women?
Participant, "Yes. There are many professional women in both public sector and private…however implementation on some parts of [the] construction industry for women is still sluggish."
The scholars (Hicks, 2012; Nkomo & Ngambi, 2009) support the view of the participant, who indicated that the empowerment of women is supported by legislation and other government initiatives.
Participant: "No…transformation is imaginary…. legislation and policies are just as good as the paper they are written on; many policies need measures to see their effectiveness in the industry."
This view echoed Valji's (2007:3) assertions of the generality of the gender imbalance evident in many societal, political and economic circles. Hence it is common with women working in the construction industry to assume administrative duties Flood, 2005).
Participant: "…. policies are a lot of hogwash…people just go on with their way of doing business."
The participant indicated a non-existent correlation between policy and practice (Mathur-Helm, 2005: 62-63). Consequently, professional women often know what they should be doing, but experience difficulties putting it into practice (Jahn, 2009).

5. CONCLUSIONS

The study found that there is a necessity for diversity within the construction industry executives so as to take advantage of the benefits and insights offered by a variety of diverse perspective and capabilities. This will assist the industry to produce preferred synchronised, objective and effective governance with clear roles and responsibilities. An ideal synthesis of expertise provides effectiveness to business strategy. Definitely, this validates the view that professional women in the construction industry are emotionally discriminated against and obstructed from identical prospects and acknowledgement for what they accomplish when compared to men.

The co-existence of the two genders in this domain has the implications of rivalry perpetuated by patriarchy controls and ineffective implementation of gender policies that are different from the definition of professionalism. Also at the executive level, there is no physical manifestation of strength on gender and or age. Although these behaviours are not enforced, women are still not treated equally to men. However, the current state of professional women in a male-dominated industry in the Eastern Cape demonstrates a growth in their numbers.

6. RECOMMENDATIONS

It is evident that in the construction industry there is an ignorance of gender diversity as well as the potential value of women professionals in the construction industry. Furthermore, culture in the construction industry is the origin of these manifestations.

The South African government is striving to eliminate poverty through gender equality. Globally, women in professions survive although gender equality is not prioritised. Difficulties in realising equality cannot be defendable through resource deficiencies but require adequate policies. Therefore, it is appropriate to pursue an in-depth balance between professional women, equity and policies (in terms of economic transformation).

Professional women in the construction industry have to maintain confidence and take charge in order to rise from subordinate levels of society in which men are recognised as superior.

There are also dialects, mostly found in construction industry studies, such as Queen Bee, Window Dressing, Fronting, and Quid Pro Quo which have a bearing towards the performance of this industry on both genders of the construction industry. These intimidating dialects sound innocent enough yet they are associated with the rivalry that goes against human rights. There is no study that explicitly points to the regulation of the practice of these dialects.

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The Effects of Late Payments on Contractors Within the South African Built Environment

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ABSTRACT AND KEYWORDS

Purpose of this paper
Late payment practices within the construction industry create a series of chain reactions that have undesirable effects that begin with the main contractor, subcontractors, suppliers, and eventually the community. The study investigated the effects that late payments have on contractors in KwaZulu-Natal, and the Eastern Cape.

Design/methodology/approach
The empirical study adopted a quantitative approach and entailed the distributing of self-administered research questionnaires to civil and building contractors. The analysis of the data entailed the computation of frequencies, and a measure of central tendency in the form of a mean score (MS) to enable the ranking of variables.

Findings
The salient findings are as follows: clients are the main cause of late payment to contractors followed by principal agents; delaying the submission of a payment certificate produces undesirable effects on the cash flow of contractors; poor financial management by contractors results in constrained cash flows, forecasting is important in managing cash flows on construction projects; labour productivity is greatly affected by absenteeism; time delays / overruns are attributable to rework; site abandonments are attributable to clients paying late; political interference, and irregular payment patterns significantly tarnish the image of the construction industry.

Research limitations/implications
The study was limited to civil and building contractors.

Practical implications
The study investigated an issue that has been cited in the media, and which has resulted in much angst. It is concluded that the late payment of contractors is a multi-stakeholder issue, and requires a range of interventions, most of which are contractor-related.

What is original/value of paper?
The recommendations include: policy with respect to clients' payment practices needs to be evolved; optimum cash flow forecasting, and mitigation of accidents, poor productivity, rework, and cost and time overruns are critical; contractors must finalise their payment claims accurately and timeously; clients must pay promptly, and government authorities must mitigate political interference on construction projects.

Response to the Conference Theme
The paper responds to the conference theme given that prompt payment of contractors promotes the sustainability of the built environment.

Keywords: Built Environment, Contractors, Construction, Payments, Projects

1. INTRODUCTION

The construction industry is an important contributor to employment and growth in South Africa (PWC, 2016: 3). It is therefore important for the industry to be supported by all major stakeholders such as the government and the professional bodies that regulate the industry. Late payment to contractors has been identified as a hindrance to infrastructure delivery within the public sector (cidb, 2009: 2). Furthermore, late payment negatively affects the growth of emerging contractors, who are particularly vulnerable to negative cash flows. Construction is a demanding process, and Sambasivan and Soon (2007: 526) advise construction businesses to be circumspect when deciding on undertaking construction work, which they are not accustomed to, and that effective planning should be a priority in preparing their work schedule.

Although late payment has been flagged as a major cause of the failure of contractors, research has not been conducted to interrogate the issue in a holistic manner, which includes all stakeholders, especially the role of contractors – the research gap.

Given the aforementioned, a study was conducted to determine:

- The extent to which twelve stakeholders contribute to contractors experiencing late payment(s);
- The extent to which eight factors contribute to contractors experiencing constrained cash flow during construction;
- The extent to which eleven factors contribute to site abandonment;
- The extent to which ten factors negatively impact the image of the construction industry, and
- The extent to which late payment by the client negatively impacts contractor performance in the construction industry.

2. REVIEW OF THE LITERATURE

According to Stats SA (2018: 9), the construction industry's growth in 2017 was -0.3% as compared to a GDP of 1.3% of the same year. Furthermore, a growth rate of -2.7% was recorded for the third quarter of 2018 versus a GDP of 2.2%, which indicates an inadequate growth projection for the construction industry. This means that contractors ought to keep abreast of the prevailing market conditions, and ensure that measures are put in place to combat the challenges of the economy, while remaining competitive in the market.

2.1 Contractors are not paid in accordance with their agreed terms

According to Godwin (2013: 3), a contract is an agreement between two or more parties, which gives rise to rights and obligations, therefore, construction works are mostly undertaken in terms of an agreement between two or more parties, namely the contractor and the client, typically under a well-defined contract. A contract is binding and any deviations from the contract may result in a dispute between the contracting parties. Cook (2014: 57) states that not fulfilling any part of a contract can be considered a breach of contract, and furthermore, remedies are prescribed in a contract to resolve the breach or breaches of a contract. This is important to state, as this means that the contractor or the client can seek recourse in resolving dissatisfaction.

The cidb (2004: 15) states that one of the criteria for acceptable forms of construction works contracts in South Africa is to include a clearly defined period for which interim payment certificates are to be made out to all parties, failing to do so results in an automatic right to compensation by the affected party, with higher interest. This is to discourage slow payment. It is a common occurrence in the construction industry for the contractor to await payment by the client (Badroldin et al., 2016: 798), and contractors may jeopardise the chance of receiving repeat work from the same client if a late payment challenge is lodged.

Ye and Rahman (2010: 503) postulate that late payment is considered a major problem in the construction industry. The problem of late payment in the construction industry affects the entire stakeholder chain beginning with the main contractor, to subcontractors, suppliers, and the community at large.

2.2 Contractors experience negative cash flow during construction projects

Cash flow is at the heart of a contractor's survival in the construction industry. Cash flow impacts the ability of the contractor to continually meet contractual obligations. It is further compounded when the contractor has more than one project that is being undertaken. The factors which influence negative cash flow according to Harris and McCaffer (2006: 247) are:

- Duration of new projects;
- Profit margins on projects;
- Conditions pertaining to retention;
- Late payment by the client;
- Supplier credit arrangements, and
- Late settlement of outstanding claims.

Mutti and Hughes (2002: 31) determined the major causes of failure of construction firms are poor management, and bad cash flow management, which could be avoided in most cases. Furthermore, cash flow forecasting and modelling are important to re-evaluate the construction firm's cash flow management to make optimum decisions regarding finance.

2.3 Labour productivity on construction projects is low

The quality of construction work is largely dependent on the work done by the labour force. Joseph et al. (2017: 4) indicate that the total project cost attributed to labour in India for construction projects is between 30% and 40% of the total project cost. Therefore, improving productivity will have a positive impact on the long-term sustainability of the construction industry, and sustain the growth of a nation (Bierman et al., 2016: 44).

2.4 Completion of construction works is delayed

Famiyeh et al. (2017: 192) state that delays in the payment of contractors contributes to time overruns for construction projects in Ghana. The construction industry is susceptible to changes in the economy, more so during recessionary periods in the economy because of the high capital outlay, cost elasticity of resources and the general competitiveness of the industry, which limits the pricing variance, (Purnus & Bodea, 2015: 1217). Furthermore, the changes in the business environment are often associated with limited funding, volatility of the exchange rate, and political instability, which increases the financial risk profile of undertaking construction projects.

2.5 Construction site abandonments

Site abandonment is a serious breach of contract of the contractor, which enables the client to pursue legal options to recover any loss that they incur. Doraisamy et al. (2015: 979) postulate that if projects are to be executed, then planning is the most crucial aspect. Furthermore, the successful completion of a project depends on adequate financial planning. Both Yap et al. (2010: 1) and Doraisamy et al. (2015: 981) state that abandoned construction sites are a waste of useful resources, and are deemed to be uneconomical, furthermore, site abandonments result in illegal activity, which subsequently leads to exposure of people to health and safety hazards, and the undermining of the wellbeing of the community.

2.6 The image of the construction industry is tarnished

The cidb (2016: 7) note in their construction industry indicators report that prompt payment to contractors has been deteriorating from 2012 to 2015. A poor or diminished image of the construction industry can lead to a decrease in investor confidence, which will likely have a bearing on infrastructure investment. According to the National Planning Commission (2012: 44), a GDP target of 30% of capital spending on infrastructure is required by the year 2030 to attain growth and sustain household services in South Africa. This target depends on large sums of investment capital being available, however, this often hinges on investor confidence and the rating of ratings agencies. This in turn can deter prospective contractors entering the industry, especially those with limited resources and tight profit margins.

3. RESEARCH

3.1 Research method

The study was conducted using a quantitative approach which was perceived to generate an accurate representation of the construction industry. The research method entailed a survey, and the primary data was secured using structured questionnaires which consisted of close-ended questions. Building and civil engineering contractors registered with the Construction Industry Development Board (cidb) in the Kwazulu-Natal province that were recorded as 'active' on the online register of contractors, and which had phone numbers were identified, and contacted per phone, and requested to provide their e-mail addresses. This resulted in a sample of eighty-eight (88) contractors, which were surveyed per e-mail. Thirty-seven (37) responses were returned, which equates to a 42.1% response rate. The analysis of the data entailed the computation of frequencies, and a measure of central tendency in the form of a mean score (MS) to enable the interpretation of percentage responses to a five-point Likert scale questions, and the ranking of factors.

3.2 Research findings and discussion

The results presented in Table 1 indicate the extent to which twelve stakeholders contribute to contractors experiencing late payment(s) in terms of percentage responses to a scale of 1 (minor) and 5 (major), and a MS between 1.00 to 5.00. It is notable that only 2 / 12 (16.7%) MSs are > 3.00, which indicates the stakeholders contributed a major as opposed to a minor extent. It is notable that client (4.05) predominates, followed distantly by the principal agent (3.19). Given that the client MS is > 3.40 ≤ 4.20, clients can be deemed to make between a contribution and a near major / near major contribution to contractors experiencing late payment(s). The stakeholders ranked second and third, namely principal agent, and quantity surveyor, have MSs > 2.60 ≤ 3.40, which indicates a near minor contribution to a contribution / contribution. This finding is underscored by Ye and Rahman (2010: 503) who postulate that late payment is considered a major problem in the construction industry – the client, principal agent , and quantity surveyor are primarily responsible for expediting the payment of contractors.

Table 1: The extent to which twelve stakeholders contribute to contractors experiencing late payment(s)

Stakeholder	Response (%)						MS	R
	Un-sure	Minor …………………………Major						
		1	2	3	4	5		
Client	0.0	8.1	8.1	2.7	32.4	48.6	4.05	1
Principal Agent	0.0	10.8	21.6	21.6	29.7	16.2	3.19	2
Quantity Surveyor	0.0	25.0	19.4	19.4	27.8	8.3	2.75	3
Subcontractor(s)	0.0	38.9	25.0	19.4	13.9	2.8	2.19	4
Construction Project Manager	2.8	30.6	30.6	19.4	13.9	2.8	2.17	5
Construction Manager / Site Agent	0.0	47.2	25.0	22.2	2.8	2.8	1.89	6
Owner of construction firm	5.6	50.0	19.4	13.9	5.6	5.6	1.81	7
Estimator	2.9	62.9	17.1	11.4	5.7	0.0	1.56	8
Civil Engineer	5.9	47.1	38.2	2.9	5.9	0.0	1.54	9
Structural Engineer	8.3	47.2	36.1	2.8	5.6	0.0	1.50	10
Mechanical Engineer	11.4	48.6	37.1	0.0	2.9	0.0	1.34	11
Labour	11.4	65.7	14.3	5.7	0.0	2.9	1.26	12

Table 2 indicates the extent to which eight factors contribute to contractors experiencing constrained cash flow during the construction phase of projects, in terms of percentage responses to a scale of 1 (minor) and 5 (major), and a MS between 1.00 to 5.00. It is notable that 5 / 8 (62.5%) MSs are > 3.00, which indicates the factors contributed a major as opposed to a minor extent. The factors ranked first to fourth have MSs > 3.40 ≤ 4.20, which indicates that the extent is between a contribution to a near major / near major contribution - delayed submission of payment certificate (3.94), , followed by poor financial management, submitting an inaccurate claim, and procurement of materials and services in cash. The factors ranked fifth to eighth have MSs > 2.60 ≤ 3.40, which indicates the extent is between a near minor to some contribution / contribution - access to finance (3.31) is near the upper end of this range, and is followed by lack of forecasting tools, procurement of new plant and equipment, and limited number of skilled staff. Clearly, many of the factors are within the control of contractors, and are function and process-related and are underscored by Mutti and Hughes (2002: 31) who determined the major causes of failure of construction firms to be poor management (all encompassing), and bad cash flow management, which could be avoided in most cases.

Table 2: The extent to which eight factors contribute to contractors experiencing constrained cash flow during construction

Factor	Response (%)						MS	R
	Un-sure	Minor …………………………Major						
		1	2	3	4	5		
Delayed submission of payment certificate	0.0	5.6	11.1	13.9	22.2	47.2	3.94	1
Poor financial management	0.0	11.4	11.4	11.4	22.9	42.9	3.74	2
Submitting an inaccurate claim	0.0	8.3	16.7	11.1	36.1	27.8	3.58	3
Procurement of materials and services in cash	0.0	8.1	10.8	29.7	24.3	27.0	3.51	4
Access to finance	0.0	11.4	17.1	20.0	31.4	20.0	3.31	5
Lack of forecasting tools	0.0	13.9	25.0	25.0	22.2	13.9	2.97	6
Procurement of new plant and equipment	0.0	17.6	20.6	26.5	23.5	11.8	2.91	7
Limited number of skilled staff	0.0	22.2	25.0	22.2	16.7	13.9	2.75	8

Table 3 indicates the extent to which eleven factors contribute to site abandonment in terms of percentage responses to a scale of 1 (minor) and 5 (major), and a MS between 1.00 to 5.00. It is notable that only 2 / 11 (18.2%) MSs are > 3.00, which indicates the factors contribute a major as opposed to a minor extent. Only 1 / 11 (9.1%) factors have a MS > 3.40 ≤ 4.20, which indicates that 'late payment by client' contributes between some extent to a near major / near major extent. The factors ranked second to fifth (34.4%) have MSs > 2.60 ≤ 3.40, which indicates they contribute between a near minor extent to some extent / some extent - civil unrest (community), strike action (legal or illegal), client administrative procedures, and negative cash flow. The factors ranked sixth to eleventh (54.5%) have MSs > 1.80 ≤ 2.60, which indicates they contribute between a minor to near minor extent / near minor extent - access to finance, vandalism, poor financial management, cash on hand, theft of material, and H&S non-compliance. The first four factors are largely out of the control of contractors, although they can mitigate strike action (legal or illegal), especially if it is legal. Negative cash flows, ranked fifth, in turn could be induced by late client payments.

These findings are underscored by Mutti and Hughes (2002: 31) who determined the major causes of failure of construction firms to be poor management (all encompassing), and bad cash flow management, which could be avoided in most cases.

Table 3: The extent to which eleven factors contribute to site abandonment

Factor	Response (%)						MS	R
	Un-sure	Minor …………………………Major						
		1	2	3	4	5		
Late payment by client	2.7	8.1	8.1	8.1	18.9	54.1	3.95	1
Civil unrest (community)	8.1	13.5	13.5	16.2	24.3	24.3	3.08	2
Strike action (legal or illegal)	5.6	27.8	11.1	8.3	25.0	22.2	2.86	3
Client administrative procedures	2.8	16.7	19.4	25.0	30.6	5.6	2.81	4
Negative cash flow	5.7	25.7	14.3	5.7	34.3	14.3	2.80	5
Access to finance	5.6	27.8	19.4	13.9	25.0	8.3	2.50	6
Vandalism	5.6	27.8	16.7	22.2	16.7	11.1	2.50	7
Poor financial management	5.7	28.6	20.0	17.1	14.3	14.3	2.49	8
Cash on hand	5.6	27.8	25.0	19.4	8.3	13.9	2.39	9
Theft of material	5.6	22.2	25.0	25.0	19.4	2.8	2.39	10
H&S non-compliance	8.3	38.9	33.3	5.6	5.6	8.3	1.86	11

Table 4 indicates the extent to which ten factors contribute to site abandonment in terms of percentage responses to a scale of 1 (minor) and 5 (major), and a MS between 1.00 to 5.00. It is notable that 9 / 10 (90.0%) MSs are > 3.00, which indicates the factors contribute a major as opposed to a minor extent. Only 1 / 10 MSs is > 4.20 ≤ 5.00, which indicates that political interference (Corruption) contributes between a near major to major / major extent. 5 / 10 (50.0%) factors have a

MS > 3.40 ≤ 4.20, which indicates that irregular payment patterns, non-achievement of quality, time overruns, inadequate transfer of skills, and rework contribute between some extent to a near major / near major extent. Clearly, the first two factors are beyond the control of contractors. However, non-achievement of quality, time overruns, inadequate transfer of skills, and rework are largely within their control.

The factors ranked seventh to tenth (40.0%) have MSs > 2.60 ≤ 3.40, which indicates the factors contribute between a near minor extent to some extent / some extent - site abandonment, client dissatisfaction, insufficient employment, and harm to the environment.

These findings are underscored by Mutti and Hughes (2002: 31) who determined the major causes of failure of construction firms to be poor management (all encompassing), and bad cash flow management, which could be avoided in most cases.

Table 4: The extent to which ten factors negatively impact the image of the construction industry

Factor	Response (%)						MS	R
	Un-sure	Minor …………………………Major						
		1	2	3	4	5		
Political interference (Corruption)	2.7	0.0	2.7	24.3	8.1	62.2	4.22	1
Irregular payment patterns	0.0	0.0	8.1	16.2	40.5	35.1	4.03	2
Non-achievement of quality	0.0	5.6	5.6	11.1	44.4	33.3	3.94	3
Time overruns	0.0	5.4	13.5	21.6	32.4	27.0	3.62	4
Inadequate transfer of skills	0.0	0.0	16.7	25.0	47.2	11.1	3.53	5
Rework	0.0	8.1	13.5	32.4	18.9	27.0	3.43	6
Site abandonment	0.0	13.9	13.9	25.0	19.4	27.8	3.33	7
Client dissatisfaction	0.0	11.1	16.7	30.6	13.9	27.8	3.30	8
Insufficient employment	0.0	11.1	11.1	38.9	36.1	2.8	3.08	9
Harm to the environment	0.0	13.9	30.6	27.8	11.1	16.7	2.86	10

Table 5 indicates the extent to which respondents agree that ‘late payment by the client negatively impacts contractor performance in the construction industry in terms of percentage responses to a scale of strongly disagree and strongly agree, and a MS between 1.00 to 5.00. The MS of 4.65 indicates that the respondents agree to strongly agree / strongly agree with the statement as the MS is > 4.20 ≤ 5.00. This finding is underscored by Ye and Rahman (2010: 503) who postulate that late payment is considered a major problem in the construction industry.

Table 5: The extent to which ‘late payment by the client negatively impacts contractor performance in the construction industry’

Response (%)						MS
Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agrre	
0.0	0.0	2.7	2.7	21.6	73.0	4.65

4. CONCLUSIONS

Given that the client and principal agent predominate among twelve stakeholders in terms of stakeholders contributing to contractors experiencing late payment(s), it can be concluded that contractors are largely dependent upon other stakeholders, especially two, in terms of timeous payment. However, the other stakeholders do contribute to contractors experiencing late payment(s), albeit to a lesser extent, and therefore it can be concluded to be a multi-stakeholder issue.

Given that delayed submission of payment certificate predominates among eight factors contributing to contractors experiencing constrained cash flow during construction, and that the others contribute, albeit to a lesser degree, it can be concluded managing cash flow is largely within contractors’ control.

Late payment by client predominates in terms of the extent to which eleven factors contribute to site abandonment, therefore it can be concluded that contractors are largely dependent upon clients in terms of sustainability. This conclusion is reinforced by second ranked civil unrest (community), and fourth ranked client administrative procedures. However, although the other factors contribute to a lesser extent, most are contractor-related, and therefore it can be concluded that mitigating site abandonment is largely within contractors' control.

Given that the top two ranked variables in terms of the extent to which ten factors negatively impact the image of the construction industry are political interference (corruption), and irregular payment patterns, it can be concluded that clients play a major role in terms of optimising the image of construction. However, quality, rework, skills, and time-related factors are largely contractor-related, and therefore it can be concluded that optimising the image of construction is to a degree within contractors' control.

Given that the extent to which 'late payment by the client negatively impacts contractor performance in the construction industry' is between agree to strongly agree / strongly agree (MS = 4.65 / 5.00), it can be concluded that late payment is a major issue in construction. Furthermore, it underscores the prior conclusions.

The research findings have addressed the research gap, namely the role of contractors in their being paid late.

5. RECOMMENDATIONS

Policy needs to be evolved with respect to clients' payment practices, and clients should make payments timeously to promote the sustainability of contractors. However, contractors must finalise their payment claims timeously and ensure that they are always accurate.

Government authorities must mitigate political interference, and community / civil unrest with respect to construction projects.

Contractors must ensure that skilled labour is used to mitigate cost overruns, poor productivity, rework, and late completion. Productivity can in turn be engendered by providing satisfactory working conditions with respect to labour, and addressing health and safety to mitigate accidents. Furthermore, contractors must ensure that wages are paid in full and timeously. These interventions will in turn promote positive cash flows. However, optimum financial management, characterised by structured cost control, and cash flow forecasting is a further pre-requisite for liquidity and solvency.

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Workplace stress experienced by construction professionals – managerial status differences

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ABSTRACT AND KEYWORDS

Purpose of this paper:
Modern definitions of stress all recognise that it is a personal experience caused by pressure or demands on an individual, which impacts his or her perceived ability to cope. Workplace stress occurs when employees are unable to manage or control the job demands of their work environment. The purpose of the research was to establish the differences in experienced stress levels and psychological well-being between managerial level and employee level construction professionals.

Design/methodology/approach:
The most common approach used in workplace stress studies is self-reported survey. This study employed the psychometrically validated ASSET scale, a model of workplace well-being. Supplementary questions, designed to gather demographic information, respondents' characteristics, and details of employment, were also included in the survey. The ASSET model employed in the current study included the *6 Essentials* scale and the *Psychological Well-being* scale. The participants were members of the Chartered Institute of Building (CIOB), globally. The data were collected by means of a web-based survey. The usable sample size was 790.

Findings:
At the level of the *Composite 6 Essentials* scale, which measures the fundamental influences over sources of stress and potential alleviators thereof, it was found that employees were significantly more stressed than were managers. At the level of the *Composite Personal Psychological Well-being* scale, which measures positivity and a sense of purpose, it was found that managers experienced positive emotions significantly more often than did employees and that they also enjoyed a greater sense of purpose than did employees. Analysis of the subscales revealed that employees were more concerned than were managers about several issues, including lack of information about what is going on in the organisation, account not being taken of their suggestions and ideas about their jobs, and lack of influence over performance targets. Managers were less concerned than were employees about feeling isolated at work, that their bosses' expectations of them were unclear, that others were taking credit for their achievements, and that their work performance was being monitored too closely. Employees were found to not enjoy their jobs as much as did managers, who were more inclined to experience the positive emotions of happiness and contentedness. Suggestions of what organisations might do to improve the situation are made in the Discussion.

Practical implications:
Organisations should be concerned about the mental health of all employees. In the absence of formal workplace stress audits and interventions, they do not know enough about whether they have a problem, and if so, what it is. This study tested for whether or not there are differences between managers and employees regarding the causes of workplace stress and their state of psychological well-being. Further, it elaborated which aspects of stress and psychological well-being give rise to the differences. This knowledge may be used to inform appropriately targeted interventions.

Original / value of paper:
A great number of workplace stress studies have been conducted on samples of construction professionals. However, the majority of them have not used psychometrically validated scales. The ASSET model is psychometrically-validated and has not previously been applied to a sample of construction professionals. The findings provide valuable pointers for improving construction

professionals' mental well-being, with specific reference to the differences between managers and employees.

Keywords: ASSET model; workplace stress; psychological well-being; construction professionals; managers; employees.

1. INTRODUCTION

A great many studies of perceived stress levels have been undertaken over the past four decades, in a variety of contexts. The purpose of many such studies is to audit stress levels, with a view to identifying areas in need of intervention or management. Several of these studies have focussed on the construction sector, including both the professions and the trades (Bowen, Govender, & Edwards, 2014; Bowen, Govender, Edwards, & Cattell, 2014; Leung, Bowen, Liang, & Famakin, 2015; Leung, Liang, & Olomolaiye, 2016; Love, Edwards, & Irani, 2010; Ng, Skitmore, & Leung, 2005). It is common for such studies to adopt a focus, for example: gender (Loosemore & Waters, 2004), culture (Chan, Leung, & Yuan, 2014; Leung & Chan, 2008), and occupation (Bowen, Cattell, & Edwards, 2013; Leung, Ng, Skitmore, & Cheung, 2005; Love & Edwards, 2005).

An interesting yet under-explored focus in workplace stress research is differences between how managers and non-managers experience stress. Many studies focus on occupations that are defined in terms of management, e.g. project managers and construction managers, but it cannot be assumed that every individual in these professions performs a management role. Further, the professions of architecture and civil/structural engineering usually involve management, but, similarly, it cannot be assumed that every individual in those occupations performs this role. Thus, if we wish to understand how managers experience stress differently compared with non-managers (i.e., employees), we should identify them in terms of how they describe their roles. This paper addresses the question of how managers and employees experience stress differently, using a recent survey of construction professionals, described in section 3 below.

2. LITERATURE REVIEW

Managers shoulder considerable responsibility, often have to make unpopular decisions, and are the focus of attention (Skakon, Kristensen, Christensen, Lund, & Labriola, 2011). The central question is whether performing this role leads to high levels of stress. Many sources suggest that this is so (Bass, 2008; Bech, Andersen, Bech-Andersen, Tønnesen, Agnarsdottir, & Borg, 2005; Bernin, 2002; Burke, Burgess, & Fallon, 2006; Løkke & Madsen, 2014; Lu, Siu, Au, & Leung, 2009; Meško, Erenda, Videmšek, Karpljuk, Štihec, & Roblek, 2013; Tengelin, Arman, Wikström, & Dellve, 2011; Yong, Nasterlack, Pluto, Lang, & Oberlinner, 2013). Bech et al. (2005) found managers' perceived stress to be detrimental to their well-being; Jenkins and Palmer (2004) studied National Health Service managers in the UK, concluding that they were exposed to levels of strain that could lead to mental ill-health and reduced well-being; and the UK study by McLean and Toby (2000), which focussed on social workers and their managers, found a clear correlation between increasing stress levels and lower job commitment, satisfaction and control, but no significant differences between managers and employees.

Wilkes, Stammerjohn, and Lalich (1981), however, found higher levels of perceived stress among employees relative to their managers, in a study involving production line work, where they defined 'managers' as "supervisory staff". The occupational group that perceived the highest job stress were production line workers, who also received the least social support and scored highest in experience of psychological and behavioural strain. Skakon et al. (2011) similarly found that managers reported lower levels of stress than did employees. They studied managers and employees in three Danish organisations, from the same worksites. Using four scales to measure emotional, somatic, behavioural, and cognitive stress (Setterlind & Larsson, 1995), Skakon et al. (2011) found that managers tended to experience lower levels of cognitive, emotional and behavioural stress compared to employees, but that the difference was only statistically significant in the case of emotional stress. Managers reported significantly higher levels of perceived management quality, influence (authority regarding major decision-making), control and freedom at work, better levels of skills development, and better appreciation of their work. They also enjoyed better access to information and greater predictability. Bivariate analyses of associations between stress and psychological factors showed that management quality, freedom at work, appreciation of work, and support from peers, information and predictability, and authority at work, were negatively correlated to stress - indicating that higher levels of these factors will reduce stress. The factors that showed positive correlation with stress levels were the amount of work required from an individual, and conflicts in the workplace. High levels of these factors will increase perceived stress. Since management quality, freedom at work, appreciation of the work, support from peers, information/ predictability, and authority at work were found to be higher amongst managers, it was concluded that, overall, managers enjoyed greater control with higher job demands, and perceived their working conditions and environment more positively (Skakon et al., 2011). This, in turn, caused managers to perceive lower stress levels than did the employees with whom they worked.

Yong et al. (2013) found that different occupational groupings within an organisation perceived workplace stressors differently. They studied staff in an organisation that also involved production line work - but with ‘manager’ defined more broadly to include “professional and managerial staff”. The study measured perceived stress using seven questions regarding “*Concern about safety at the workplace, Self-rated health status, Stress symptoms, Unrealistic job demands, High degree of time pressure, Thinking over the problems in the workplace, and Work life imbalance”* (Yong et al., 2013, p. 350) in conjunction with the Work Ability Index (Tuomi, Ilmarinen, Jahkola, Katajarinne, & Tulkki (1998). Frontline operators (which included ‘supervisors’) were more concerned than were other categories of staff about conditions in the workplace, but managers perceived higher levels of tension, time pressure and poor work-life balance than did the other occupational groupings.

The studies reviewed above all relate to contexts other than construction and conclude, variously, that employees experience significantly higher job stress than do managers, or the opposite (that managers do more so than employees), or that there are no significant differences between the two. Despite an exhaustive search, very few studies were found that report on manager vs. employee perceptions of workplace stress, particulalry so in the context of the construction industry.

3. METHOD

The survey population consisted of corporate members of the Chartered Institute of Building (CIOB), worldwide. Psychological well-being specialists Robertson Cooper Ltd. assisted in the collection of the data. The study received full ethics clearance from the University of Cape Town. CIOB members were emailed details of the URL for the ASSET model questionnaires and asked to participate. The psychometrically-validated ASSET scales (Faragher, Cooper, & Cartwright, 2004) are a model of workplace well-being and in the current study we used the ‘core’ *6 Essentials* and *Psychological Well-being* scales (see Figure 1).

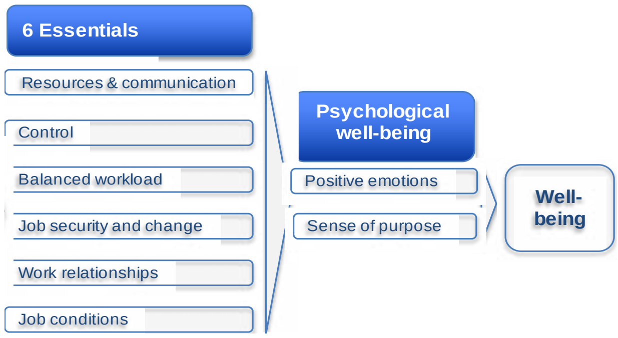

Figure 1 The core scales of the ASSET model

The majority (83%) of respondents were from Europe, and the remaining 17% collectively came from Africa, Asia, Australia and North America. The total number of responses received was 918, of which 790 were suitable for analysis after elimination of missing values cases. Missing data were missing completely at random (MCAR). This represents 2.2% of the total professional membership of the CIOB. Respondents variously described their job functions as construction management (34%), project management (29%), quantity surveying (16%), architecture (2%), engineering (3%), and 'other' (16%). Forty-two per cent were Chartered Builders, and 58% were Chartered Construction Managers. Dual membership of CIOB and other professional bodies was reported as follows: Royal Institution of Chartered Surveyors (RICS) (21%); Institute of Civil Engineers (ICE) (4%), Royal Institute of British Architects (RIBA) (1%), and 'other' (75%). Presumably, such 'other' affiliations related to membership of non-UK professional bodies.

Respondents described their roles in organisations as partners/owners/ directors (52%), registered professional employees (26%), and employees (22%). The analysis presented in this paper defines the 52% partners/ owners/directors as "managers" and the remaining 48% as "employees". Most participants were male (93%), with almost two-thirds (62%) aged between 41 and 60 years old. The median age was between 41 and 50 years old, and the majority of respondents (88%) were either married or living with a partner. Whilst the mother tongue of respondents was mostly English (85%), followed by 'other' (8%), Cantonese (2%), Arabic (2%), and Mandarin (1%), the *language of work* was predominantly English (97%). Most respondents lived in Europe (83%), followed by Asia (9%), Africa (6%), Australia/Oceania (2%), and North America (1%). The majority (79%) reported working in their country of citizenship. Slightly more than half of the respondents (57%) had industrial experience in excess of 25 years. The majority (86%) were full-time employees and 7% were employed on a fixed-term contract basis. Only 14% of respondents worked 40 hours per week or less. More respondents (45%) reported working 41-50 hours per week than longer or shorter durations, but 29% and 13%, respectively, reported working 51-60 hours and exceeding 60 hours per week. Working hours per week may be influenced by travelling time and in this regard, 50% reported spending less than one hour travelling to and from work each day, but 44% reported this as 2-3 hours.

4. FINDINGS

4.1 The 6 Essentials scale

The 6 Essentials scale comprises the subscales: *Resources and communication, Control, Job security and change, Balanced workload (Work-life balance and Workload), Work relationships,* and *Job conditions*.
Combining the items in all of these subscales into a new *Composite 6 Essentials* scale, the mean of the raw scores is positioned approximately midway in the range, indicating a normal distribution (N = 775,

M = 112.53, *SD* = 32.73). Significant differences were found between the stress levels of managers (*M* = 106.63, *SD* = 31.68) and employees (*M* = 118.83, *SD* = 32.83; *t* (773) = -5.26, *p* = 0.00, two-tailed), with employees being more concerned than managers about the issues referred to in the scale items. Employees were thus more stressed than were managers.

If we examine the individual subscales, the main causes of these differences become clear. Since a 6-point rating scale was used for all items in all of the subscales, means of less than 3 represent disagreement and means exceeding 3 represent agreement. Significant differences between managers and employees can therefore include contexts where both disagree, both agree, or one agrees and the other disagrees. Only the latter are reported below.

Of the four items in the *Resources and communication* subscale, two indicate significant differences. They are: *lack of information about what is going on in the organization*, where managers (*M* = 2.99, *SD* = 1.57) disagreed and employees (*M* = 3.58, *SD* = 1.52; *t* (785) = -5.35, *p* = 0.00, two-tailed) agreed; and *lack of equipment/resources to do the job*, where, similarly, managers (*M* = 2.71, *SD* = 1.37) disagreed and employees (*M* = 3.17, *SD* = 1.43; *t* (786) = -4.60, *p* = 0.00, two-tailed) agreed with it.

Two items from the *Control* subscale show significant differences. The first is *account not being taken of staff ideas/suggestions about the job*, where managers (*M* = 2.78, *SD* = 1.40) disagreed with the statement and employees (*M* = 3.30, *SD* = 1.39; *t* (785) = -5.21, *p* = 0.00, two-tailed) agreed with it. The second is *lack of influence over performance targets*, where, similarly, managers (*M* = 2.80, *SD* = 1.41) disagreed and employees (*M* = 3.42, *SD* = 1.46; *t* (785) = -5.99, *p* = 0.00, two-tailed) agreed with it.

None of the items in the *Work-life balance* subscale revealed significant differences between managers and employees. In three of the four items, however, the means for both groups exceeded 3, which indicates that *long hours*, *excessive travel time,* and *work interfering with home/personal life* affected both groups negatively, but they were not significantly different.

All of the items in the related subscale *Workload* revealed both groups to be negatively affected (by *unrealistic deadlines, unmanageable workloads,* and *lack of time* – all with significant differences, but with all means greater than 3, so not reported here*),* or unaffected (*technology overload* – significantly different, but with both means lower than 3, so not reported here).

Two of the five items in the *Job security & change* subscale indicate significant differences. Firstly, managers (*M* =2.75, *SD* =1.49) disagreed with *organization changes for change's sake* being a cause of concern, but employees (*M* =3.43, *SD* = 1.51; *t* (784) = -6.39, *p* = 0.00, two-tailed) did find it concerning. Secondly, managers (*M* =2.83, *SD* =1.37) did not find the prospect of their *jobs changing in the future* concerning, but employees did (*M* = 3.19, *SD* = 1.36; *t* (786) = -3.66, *p* = 0.00, two-tailed).

Three of the eight items in the *Work relationships* subscale reveal significant differences, as follows. First, managers (*M* = 2.77, *SD* = 1.45) were not concerned about *isolation at work,* but employees (*M* = 3.15, *SD* = 1.47; *t* (785) = -3.61, *p* = 0.00, two-tailed) were. Second, managers (*M* = 2.64, *SD* = 1.36) were not concerned about the item *unclear what boss expects*, but employees (*M* = 3.07, *SD* = 1.37; *t* (785) = -4.50, *p* = 0.00, two-tailed) did find this troubling. Finally, managers (*M* = 2.79, *SD* = 1.46) were not concerned about the item *others taking credit for my achievements*, but employees (*M* = 3.12, *SD* = 1.45; *t* (785) = -3.14, *p* = 0.02, two-tailed) found this troublesome.

Two of the eight items in the *Job conditions* subscale were responded to with significant differences, as follows. Managers (*M* = 2.58, *SD* = 1.30) were not concerned about *work performance being closely monitored*, but this did trouble employees (*M* = 3.03, *SD* = 1.38; *t* (786) = -4.70, *p* = 0.00, two-tailed). Managers (*M* = 2.99, *SD* = 1.57) disagreed with the item *lack of enjoyment of job*, but employees (*M* = 3.41, *SD* = 1.58; *t* (786) = -3.69, *p* = 0.00, two-tailed) agreed with the statement.

4.2 The Psychological well-being scale

The *Psychological well-being* scale comprises the subscales: *Positive emotions* and *Sense of purpose*. Combining all of the items in these subscales into a new *Composite Personal Psychological Well-being* scale, the mean of the valid responses is slightly higher than midway in the range, indicating that the level of personal psychological well-being is generally better than average (N = 780, M = 39.7, SD = 9.26). Significant differences were found between managers (M = 41.05, SD = 9.18), who experienced *positive emotions* and a *sense of purpose* more so than did employees (M = 38.25, SD = 9.14); t (778) = 4.28, p = 0.00, two-tailed).

An examination of the individual subscales reveals the main causes of these differences. A 5-point rating scale was used for the *Positive emotions* scale and a 6-point rating scale was used for the *Sense of purpose* scale. For the 5-point scale, a mean of 3 = "moderately", a mean lower than 3 = "very slightly/not at all" or "a little", and a mean higher than 3 = "quite a bit" or "very much", referring to how frequently the emotion was experienced. For the 6-point scale, means of less than 3 represented disagreement, and means exceeding 3 represented agreement. As noted above, only cases where managers or employees agree and the other disagrees are reported below.

Only two of the seven emotions/conditions in the *Positive emotions* subscale, revealed significant differences. First, managers (M = 3.1, SD = 1.08) experienced the emotion *happy* moderately, while employees (M = 2.90, SD = 1.12; t (785) = 2.56, p = 0.01, two-tailed) said they experienced it a little. Second, managers (M = 2.99, SD = 1.22) experience the state *contented* moderately, but employees (M = 2.69, SD = 1.14; t (783) = 3.45, p = 0.01, two-tailed) experienced it a little.

None of the significant differences in the *Sense of purpose* subscale had means greater than 3, so are not reported here.

4.3 Summary

The differences in workplace stress levels, measured by the *6 Essentials* scale, were due to the following. *Resources and communication* (employees more worried about lack of feedback on performance and not being informed about what is going on in the organisation), and *Control* (employees more worried that they lack control over aspects of the job and are not being involved in decisions affecting their jobs). Further, differences related to *Job security and change* (employees more worried about the job changing for change's sake and insecure jobs), *Work relationships* (employees more worried about other people not pulling their weight and not receiving the support they would like), and *Job conditions* (employees more worried about not getting the same pay and benefits for the same work as colleagues and the unlikelihood of their jobs changing in the future). Differences in *Psychological well-being*, measured by the *Sense of purpose* and *Positive emotions* subscales, were due to managers enjoying a greater *sense of purpose* (committed to achieving job goals), and feeling *positive emotions* (determined, alert, enthusiastic) more frequently than did employees.

5. DISCUSSION

The finding that employees were significantly more concerned than were managers about being kept informed about what goes on in their organisations, coupled with the feeling that they were not properly resourced or equipped to do their work, should be of concern to employers. Feelings of mistrust, exclusion, and marginalisation are strains that are likely to increase employees' perceived stress (Bakker, Demerouti, & Euwema, 2005; Faragher et al., 2004). This condition is aggravated by the finding that employees lack control, compared with managers. Control is what they need to counter strains. Thus, the feeling that their ideas about how to influence their jobs are not valued, together with their exclusion from decisions about the appropriateness or manageability of their performance targets, creates additional strain in the very area, i.e. control, that could be used to diminish strain (Faragher et al., 2004). The implication for employers is that they should actively adopt attitudes and/or develop processes that build trust and reduce employees' feelings of exclusion or marginalisation.

Although no significant differences were found between managers and employees regarding work-life balance, it should be noted that both groups were negatively affected by long working hours, excessive travel time, and work interfering with their personal lives – all of which increase strain and perceived stress. Similarly, both groups reported being affected by unrealistic deadlines, unmanageable workloads, and lack of time. These, too, clearly increase strain and, therefore, perceived stress (Bowen, Govender, & Edwards, 2014). Work-life imbalance is a common problem in the construction and project management industries (Turner, Lingard, & Francis, 2009). The implication of this finding, at the level of the organisation, is that employers should be mindful of the imbalance and plan to allocate sufficient personnel to work functions and provide relief to those most adversely affected.

Stability in work environments is important, because instability is a source of strain. The finding that managers were not concerned, but that employees were worried about the prospect of their jobs changing in future, combined with their interpretation that change might be unnecessary, means that they perceive their work environments and jobs to be less secure than they would like them to be. This is a source of increased strain, which may be related to the finding reported above regarding perceptions about lack of information about what is going on in the organisation (Davis, 1996). The implication for employers is that they could address this issue, by realising the importance of communicating openly and regularly about what they are planning, and why.

Relationships at work are very important in that social support can alleviate stress. Lack of clarity about what is expected of employees increases worry and strain (Faragher et al., 2004), which will be aggravated by their perceptions that they cannot trust colleagues to be honest regarding taking credit for achievements and will be further aggravated by feeling isolated at work. The finding that managers do not share these perceptions might cause them to be unaware of the problem at the employee level. Organisations can diminish the potential for this kind of strain, particularly in the area of clarity about expectations. The implication of this is that employers should consider adopting procedures that require expectations to be formally documented. The findings regarding job conditions are related. Employees' perceptions that their work is too closely monitored implies that they do not feel trusted, which, together with the finding that they do not enjoy their jobs, suggests that this is a constant source of strain that managers do not experience to the same degree. Both of these stressors could be addressed by employers and appear to be related to other issues, like influence over performance targets and taking employees' opinions about the job into account. The implication is that employers should evaluate whether strict control/ monitoring of employees' work is necessary and relax this if it is not. If applicable they should also actively investigate why their employees do not enjoy their jobs, with a view to addressing the causes of the problem.

Positive psychology and the construct of psychological well-being assume that positive emotions make a difference to individuals and those with whom they work (Campbell-Sills, Cohan, & Stein, 2006). The finding that employees experienced the emotions of 'happiness' and 'contentment' "a little", significantly less so than did managers, tends to reflect the findings regarding stressors and strain discussed above. Given that positivity is a personal trait, the implication for employers is that they should ensure that their recruitment procedures are capable of profiling applicants sufficiently well for them to know whether the individual experiences a high level of positive emotions, or not.

The findings of the current study support the hypothesis that managers experience lower levels of workplace stress and higher levels of psychological well-being compared to employees. This supports the earlier findings of Skakon et al. (2011) and Wilkes et al. (1981) as they relate to employees experiencing higher levels of job stress but contradicts the Yong et al. (2013) finding that managers perceive themselves to be under greater stress compared with employees.

6. CONCLUSION

At the level of the *Composite 6 Essentials* scale, which measures the fundamental influences over sources of stress and potential alleviators thereof, it was found that employees were significantly more stressed than were managers. At the level of the *Composite Personal Psychological Well-being* scale, which measures positivity and sense of purpose, it was found that managers experienced positive emotions significantly more often than did employees and that they also enjoyed a greater sense of purpose than did employees. Details about the causes of these significant differences were discussed above, along with suggestions of what organisations could do to improve the situation. The solutions to the problem of high levels of stress and an imbalance between how managers and employees experience it can only be developed from a position of knowledge. In this paper, we have provided knowledge of what the problems are, in the hope that concerned organisations might use it to evaluate how best to intervene in improving their employees' experience of workplace stress relative to managers.

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A Development Framework for 'Niche Markets' in Real Estate Development

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ABSTRACT AND KEYWORDS

Purpose of this paper
The study addressed strategic planning and management techniques in order to generate success within the Real Estate sector.

Design/methodology/approach
The study was conducted by means of a review of the related literature and by conducting an empirical study. The empirical study was conducted using a quantitative statistical approach by distributing research questionnaires to members falling within the sample population.

Findings
The salient findings suggest that the development of a 'Niche Market' and through careful planning and management techniques, the success rate of Real Estate Development Firms may be significantly increased.

Practical implications (if applicable)
Strategic planning plays an integral role in Real Estate Development, as strategic planning may prevent unwanted outcomes in the future. Strategic planning may also provide developers with the leading edge associated with developing a 'Niche Market' in Real Estate.

What is original/value of paper?
This study contributed a framework that could be of assistance in guiding real estate developers carve a successful market niche in the South African property market. It identified factors that have direct and indirect positive influence on the perceived success of 'Niche Markets' in Real Estate Development:

Keywords: **Niche Markets, Real Estate, Real Estate Development, Strategic Planning**

1. INTRODUCTION

Real Estate markets may be dived into five major categories namely; residential, office, commercial, industrial, and land (Peiser and Hamilton, 2012). Each category is different in its own respect and has specific aspects that influence the cost to purchase, modify or rent Real Estate which include factors such as area and location (Peiser and Hamilton, 2012). Real Estate is comprised of land, buildings, the air above it and the ground below it, that is immovable by legislation (McKenzie, Betts and Jensen, 2011). Therefore, Real Estate owners acquire the right to make decisions regarding the Real Estate owned (McKenzie, Betts and Jensen, 2011).

Real Estate markets may attract different types of people and thus segmenting a market through consumer behaviour, demographics, the way people live their lives and their specific characteristic (Thilmany, 2008). The segment formed, not only deviates from the rest of the population but also incorporates different characteristics into their lives thereby creating a 'Niche Market' (Thilmany, 2008). Reed and Sims (2015) explain that through careful planning and management techniques and a thorough understanding of Real Estate development, a positive cash flow or profit may be achieved effectively.

2. LITERATURE REVIEW

a. Niche Markets

A Niche Market is an attractive market, which targets a specific group, in order to be profitable (Thilmany, 2008). Thilmany (2008) explains that 'Niche Markets' provide smaller enterprises the opportunity to enter complex markets and compete with larger firms, as they provide products or services that are tangible to the buyer. Furthermore, target markets are a segment of an entire population, which are targeted by entrepreneurs to generate their desired 'Niche' by public desirability (Thilmany, 2008).

b. Strategic Planning and Techniques

For an organisation to be successful it needs to have a clear vision, goals and objectives and this is achieved through strategic planning and management techniques (Gates, 2010). Gates (2010) explains that it is essential in the process of planning that the organisation looks ahead of its current status, to foresee future outcomes in order to be successful.

c. Real Estate and Regulatory Bodies

Real Estate can be an extremely difficult market to interpret and modify and this is why it is essential to have regulatory bodies and laws in place to protect both the consumer and the developer, thus giving rise to improved growth and performance across the Real Estate sector in years to come (KPMG, 2016). In order to ensure that laws are followed and not deviated from a Real Estate Developer will have to deal with up to 40 regulatory bodies over the life cycle of Real Estate Development project (KPMG, 2016).

d. Real Estate Markets and Trends

Kohlhepp (2012) explains that for a development to be successful, the developer needs to have a clear understanding of the present market and the future market conditions and trends in order to market the development accordingly. Furthermore, Kohlhepp (2012) suggests that breaking down the process of marketing Real Estate into categories is called a 'marketing mix and this allows firms to gain a better understanding of the marketing process. PWC (2013) suggests that entering new markets requires great knowledge and understanding of how that market works and the way in which the local people operate. It is important to have legislation and systems in place to govern people and firms to ensure they operate correctly and efficiently, without difficulty, and avoid the risks that could be felt due to the location of the market (PWC, 2013).

e. Construction Costs

Construction costs are largely determined by the supply and demand of predetermined factors in the construction industry such as plant, equipment, materials, labour and interest rates (Mallick, 2011). Furthermore, interest rates have a significant effect on the economy as a whole (Mallick, 2011). With the construction industry being a significant contributor to the economy of a country, increased construction costs may have negative consequences for investors and Real Estate developers (Mallick, 2011).

f. Population and Real Estate

According to PWC (2015), the youth of Africa will be the major driving force behind urbanisation across the whole of Africa. Furthermore, the constant need for major city hubs and Real Estate, be it residential, industrial or commercial, means that there will always be a need for development (PWC, 2015). PWC (2015) suggests that another contributing factor to the stimulation of Real Estate in Africa is the influx of migrant workers looking for employment. Consequently, the lack of strategic planning by local authorities' places large amounts of stress on the population as there is an insufficient supply of housing for these migrants which inflates Real Estate prices (PWC, 2013).

g. Political Influences

According to Filipovic (2005), privatisation takes place when a country aims to expand and grow the economy by relocating assets from the public sector and making them available to the private sector to invest in and purchase. Filipovic (2005) suggests that with the private sector investing in the public sector, more capital gets injected into the market which reduces the governmental influence over the market.

h. The Stock Market and Real Estate

Areiqat and Zamil (2011) state that Real Estate markets and the stock markets are large contributors to the success of a country's economy as a whole. According to Sebastian and Zhu (2012), to a greater extent, people are investing in securitised Real Estate around the world, as Real Estate investors have numerous options to invest in, such as: residential, industrial, commercial and the retail sector. Sebastian et al. (2012) further suggest that investing in Real Estate compared to investing in the stock market is profusely different, as Real Estate investments are not in essence as quick as the stock market.

3. Research Methodology

The table below outlines the sample strata selected for the purposes of the research study as well as the response rate for the issued questionnaires. Table 1 presents a summary of the sample stratum in terms of the number of questionnaires circulated, the number returned, the number of questionnaires that were not returned, as well as the response rate.

Table 1: Response rate

Sent	Returned	Not Returned	Response Rate
144	32	112	22%

The design of the research questionnaires formed an integral part of the study. The research questionnaire was developed based on the statement of the problem, related sub-problems and hypotheses. The majority of questions presented within the research questionnaire were closed-ended questions. The closed-ended questions consisted of a five-point Likert type scale to ensure ease of answering. These questions also provided for an 'unsure' response. Open-ended questions included in the questionnaire were minimised and answers were brief in order to reduce the time required to complete the questionnaire.

The following terms were used when discussing the data:

Minority – 33.3% and less
Half – 50%
Majority – 66.7% and more, but less than 80%
Most – 80% and more, but less than 100%
All – 100%

To describe the findings in more detail, the following terms were used when analysing the weighted MSs:

≥ 1.00 to ≤ 1.80 - minor to near minor extent
- strongly disagree to disagree
> 1.80 to ≤ 2.60 - minor to near minor / near minor extent
- strongly disagree to disagree / disagree
> 2.60 to ≤ 3.40 - near minor extent to some extent / some extent
- disagree to neutral / neutral
> 3.40 to ≤ 4.20 - some extent to a near major / near major extent
- neutral to agree / agree
> 4.20 to ≤ 5.00 - near major to major / major extent
- agree to strongly agree / strongly agree

The results pertaining to the demographic profile revealed that the average age of respondents was 42 years of age. It is important to note that the majority (81%) of respondents had a qualification equal to or higher than a diploma and the majority (94%) of respondents are worked in Real Estate or on Real Estate development projects. Majority (78%) of respondents occupied a managerial position and the majority (94%) of respondents were registered with professional/regulatory bodies. The average amount of experience for the respondents was 12 years and 5 months in Real Estate or Real Estate development.

4. RESEARCH FINDINGS

Table 2: The extent to which certain factors influence strategic planning

Factor	**Response %**						**MS**	**RANK**
	U	**Minor.................................Major**						
		1	**2**	**3**	**4**	**5**		
Leadership	0.0	3.1	0.0	6.3	15.6	75.0	4.59	3=
Management	0.0	3.1	0.0	12.5	21.9	62.5	4.41	8
Communication	0.0	0.0	0.0	3.1	12.5	84.4	4.81	1
Goal Setting	0.0	0.0	0.0	0.0	28.1	71.9	4.72	2
Company Vision	0.0	0.0	0.0	12.5	25.0	62.5	4.50	5=
People skills	0.0	0.0	0.0	9.4	21.9	68.8	4.59	3=
Timeframes	0.0	0.0	0.0	6.3	37.5	56.3	4.50	5=
Budgeting	0.0	0.0	0.0	9.4	31.3	59.4	4.50	5=

Table 2 indicates the extent to which certain factors positively influence strategic planning in terms of percentage responses to a range of 1 (Minor) to 5 (Major). MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. MSs > 3.00 indicate that respondents perceive that the extent to which certain related factors positively influence strategic planning is major as opposed to minor as in the case of a MS < 3.00. It is notable that all of the MSs > 3.00. Communication, goal setting, leadership, people skills, company vision, timeframes, and budgeting have MSs > 4.20 to ≤ 5.00, indicating that these factors positively influence strategic planning between a near major to major / major extent.

Table 3: The extent to which the following market trend factors influence the development of 'Niche Markets' in Real Estate Development

Factor	Response %						MS	RANK
	U	Minor...............................Major						
		1	2	3	4	5		
Seasonal fluctuations	9.1	9.4	10.0	26.7	30.0	23.3	3.47	7=
Supply of Real Estate	2.3	0.0	6.5	12.9	35.5	45.2	4.19	2=
Demand of Real Estate	2.0	0.0	3.2	16.1	29.0	51.6	4.29	1
Micro - Economics	40.0	0.0	0.0	37.0	48.1	14.8	3.78	6
Macro - Economics	17.8	0.0	0.0	25.9	40.7	33.3	4.07	4=
Financial analysis	10.7	0.0	7.1	21.4	28.6	42.9	4.07	4=
Timeframes	9.1	9.4	10.0	26.7	30.0	23.3	3.47	7=
Budgeting	2.3	0.0	6.5	12.9	35.5	45.2	4.19	2=

Table 3 indicates the extent to which market factors influence the development of ‘Niche Markets’ in Real Estate Development, in terms of percentage responses to a range of 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. MSs > 3.00 indicate that respondents perceive that the extent to which certain market factors influence the development of ‘Niche Markets’ in Real Estate Development is major as opposed to minor as in the case of a MS < 3.00. It is notable that all of the MSs > 3.00. Demand of Real Estate is rated first based on a MS of 4.29, which indicates that the demand of RE is perceived to influence the development of ‘Niche Markets’ in Real Estate Development to a near major / major extent than other related factors. Supply of Real Estate, budgeting, macro – economic, financial analysis, micro – economics, seasonal fluctuations and timeframes have a MS > 3.40 to ≤ 4.20, indicating that these factors affect the degree of the development of ‘Niche Markets’ in Real Estate Development between some extent to a near major / near major extent.

Table 4: The extent to which the following demographical factors influence the development of ‘Niche Markets’ in Real Estate Development

Factor	Response %						MS	RANK
	U	Minor...............................Major						
		1	2	3	4	5		
Tourism	0.0	0.0	6.3	21.9	40.6	31.3	3.97	6
Growth Patterns	5.3	0.0	6.7	10.0	43.3	40.0	4.17	3
Property Cycles	2.3	0.0	0.0	12.9	41.9	45.2	4.32	1
Global Trends	8.0	0.0	6.7	33.3	33.3	26.7	3.80	8
Individual Income	2.5	0.0	0.0	16.1	41.9	41.9	4.26	2
Individual Expenditure	2.5	0.0	3.2	19.4	35.5	41.9	4.16	4
Political Factors	5.3	0.0	0.0	26.7	33.3	40.0	4.13	5
Social Media	0.0	6.3	28.1	28.1	28.1	9.4	3.06	9
Gross Domestic Product	9.6	3.1	6.9	17.2	37.9	34.5	3.93	7

Table 4 indicates the extent to which demographical factors influence the development of ‘Niche Markets’ in Real Estate Development, in terms of percentage responses to a range of 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. MSs > 3.00 indicate that respondents perceive that the extent to which certain demographical factors influence the development of ‘Niche Markets’ in Real Estate Development is major as opposed to minor as in the case of a MS < 3.00. It is notable that all of the MSs > 3.00. Property cycles is ranked first based upon a MS of 4.32, which indicates that property cycles are perceived to influence the development of ‘Niche Markets’ in Real Estate Development to a near major to major extent and individual income has a MS of 4.26, which indicates to a near major to major extent. Growth patterns, individual expenditure, political factors, tourism, GDP and global trends have a MS > 3.40 to ≤ 4.20, indicating that these factors affect the degree of the development of ‘Niche Markets’ in Real Estate Development between some extent to a near major / near major extent. Social media has a MS of 3.06, which indicates that social media is perceived to influence the development of ‘Niche Markets’ in Real Estate Development between near minor extent to some extent / some extent.

Table 5: The extent to which the following stock market factors influence the development of ‘Niche Markets’ in Real Estate Development

Factor	**Response %**						**MS**	**RANK**
	U	**Minor.................................Major**						
		1	**2**	**3**	**4**	**5**		
Investments	5.3	6.3	3.3	16.7	33.3	40.0	3.97	3
Privatisation	12.0	6.3	13.8	24.1	27.6	27.6	3.55	6
Real Estate Cycles	2.7	0.0	3.2	16.1	41.9	38.7	4.16	2
Political	2.1	3.1	0.0	12.9	35.5	48.4	4.26	1
GDP	13.7	3.1	3.4	20.7	48.3	24.1	3.86	4
Global Trends	13.7	6.3	3.4	27.6	37.9	24.1	3.69	5

Table 5 indicates the extent to which stock market factors influence the development of ‘Niche Markets’ in Real Estate Development, in terms of percentage responses to a range of 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. MSs > 3.00 indicate that respondents perceive that the extent to which certain stock market factors influence the development of ‘Niche Markets’ in Real Estate Development is major as opposed to minor as in the case of a MS < 3.00. It is notable that all of the MSs > 3.00. The political factor is ranked first based upon a MS of 4.26, which indicates that politics is perceived to influence the development of ‘Niche Markets’ in Real Estate Development to a near major to major extent. Real Estate cycles, investments, GDP, global trends and privatisation have a MS > 4.20 to ≤ 5.00, which indicates that Real Estate cycles, investments, GDP, global trends and privatisation are perceived to influence the development of ‘Niche Markets’ in Real Estate Development between some extent to a near major / near major extent.

Table 6: The extent to which the following factors influence the perceived success of development of 'Niche Markets' in Real Estate Development

Factor	**Response %**						**MS**	**RANK**
	U	**Minor..................................Major**						
		1	**2**	**3**	**4**	**5**		
Strategic Planning	1.6	0.0	6.5	9.7	19.4	64.5	4.42	1
Government Structures	4.0	0.0	16.1	19.4	38.7	25.8	3.74	5
Market Trends	4.9	0.0	0.0	20.0	36.7	43.3	4.23	2
Demographics	0.0	0.0	3.1	28.1	28.1	40.6	4.06	4
Construction Costs	0.0	0.0	3.1	18.8	31.3	46.9	4.22	3
Regulatory Bodies	8.0	6.3	9.4	34.4	18.8	25.0	3.50	8
Professional Bodies	8.0	6.3	6.3	37.5	34.4	12.5	3.42	7
Stock Markets	12.0	3.1	12.5	21.9	28.1	25.0	3.66	6

Table 6 indicates the extent to which certain factors influence the perceived success of the Development of 'Niche Markets' in Real Estate Development in terms of percentage responses to a range of 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. MSs > 3.00 indicate that respondents perceive that the extent to which certain factors positively influence the perceived success of development of 'Niche Markets' in Real Estate Development is major as opposed to minor, as in the case of a MS < 3.00. It is notable that all of the MSs > 3.00. Strategic planning is ranked first based upon a MS of 4.42, which indicates that respondents perceive strategic planning to positively influence the perceived success of development of 'Niche Markets' in Real Estate Development on a more major scale than the other related factors. Market trends and construction costs have MSs > 4.20 to ≤ 5.00, indicating that respondents perceive them to positively influence the perceived success of the development of 'Niche Markets' in Real Estate Development which is between near major to major / major extent. Demographics, government structures, stock markets, professional bodies and regulatory bodies have MSs of > 3.40 to ≤ 4.20, indicating that respondents perceive these factors to positively influence the perceived success of the development of 'Niche Markets' in Real Estate Development between some extent to near major / near major extent.

Table 7: Respondents rating of the extent of which inadequate planning and management techniques affects the failure rate of Real Estate development

Response %						
U	Strongly Strongly Disagree.. Agree					MS
	1	2	3	4	5	
0.0	0.0	0.0	9.4	50.0	40.6	4.31

Table 7 indicates the respondents rating of the extent to which inadequate planning and management techniques affect the failure rate of Real Estate developments in terms of percentage responses to a range of 1 (Strongly Disagree) to 5 (Strongly Agree), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00.

The MS of the respondents rating of the extent to which inadequate planning and management techniques affects the failure rate of Real Estate development is > 4.20 to ≤ 5.00, which indicates that respondents agree to strongly agree / strongly agree that inadequate planning and management techniques affect the failure rate of Real Estate.

Table 8: The extent to which respondents agree with the statement, “Numerous Real Estate Developers lack sufficient planning and management techniques in order to effectively manage the development process”.

Response %						
U	Strongly Strongly Disagree.. Agree					MS
	1	2	3	4	5	
8.0	0.0	15.6	15.6	37.5	25.0	3.77

Table 8 indicates the extent to which respondents agree with the statement “Numerous Real Estate Developers lack sufficient planning and management techniques in order to effectively manage the development process” in terms of percentage responses to a range of 1 (Strongly Disagree) to 5 (Strongly Agree), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. The MS of 3.77 is > 3.40 to ≤ 4.20, therefore, the occurrence can be deemed to be between neutral to agree / agree. However, it should be noted that 3.77 is above the lower end of the range, namely 3.40. Given that the MS > 3.00, the respondents can be deemed to agree as opposed to disagree with the statement.

Table 9: The extent to which respondents agree with the statement, “There is a positive relationship between the implementation of effective Strategic Management Plan and the Development of ‘Niche Markets’ in Real Estate Development”.

Response %						
U	Strongly Disagree..			Strongly Agree		MS
	1	2	3	4	5	
10.7	0.0	0.0	12.5	50.0	28.1	4.17

Table 9 indicates the extent to which respondents agree with the statement, “There is a positive relationship between the implementation of effective Strategic Management Plans and the Development of ‘Niche Markets’ in Real Estate Development” in terms of percentage responses to a range of 1 (Strongly Disagree) to 5 (Strongly Agree), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. The MS of 4.17 is > 3.40 to ≤ 4.20, therefore, the occurrence can be deemed to be between neutral to agree / agree. However, it should be noted that 4.17 is considerably above the lower end of the range, namely 3.40. Given that the MS > 3.00, the respondents can be deemed to agree as opposed to disagree with the statement.

5. EMPIRICAL FRAMEWORK

The empirical framework is presented graphically according to the factor loading of the variables MS’s. According to the research results and the testing of the hypotheses, all variables have a positive influence on the perceived success of niche markets in real estate development. Furthermore, variables were presented (see figure 1) based on factor loading of the MSs relative to the dependent variable namely, the perceived success of niche markets in real estate development.

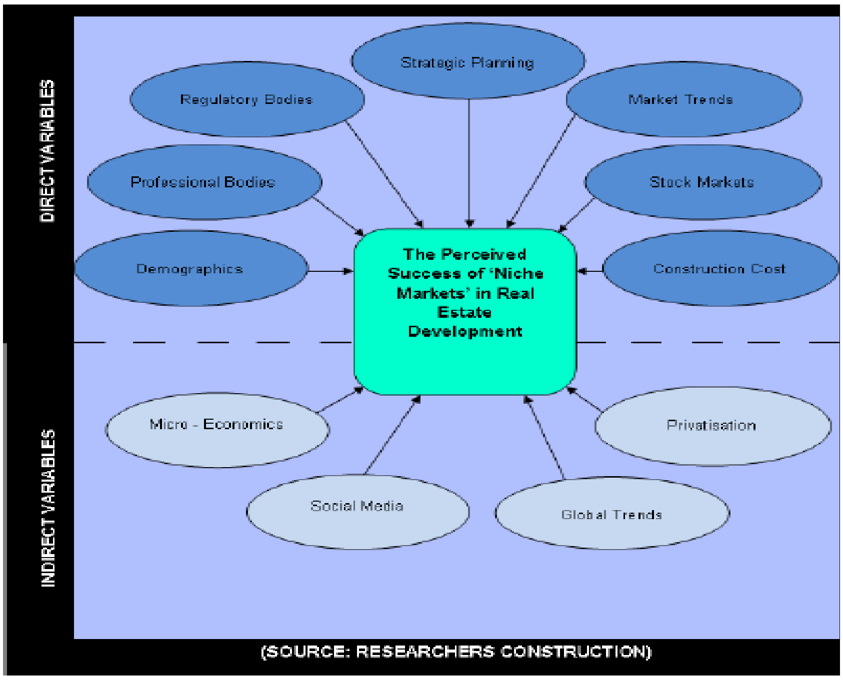

Figure 1: An Empirical Framework for ‘Niche Markets’ in Real Estate Development

The following variables have a direct and positive influence on the perceived success of 'Niche Markets' in Real Estate Development:

- Strategic Planning;
- Market Trends;
- Construction costs;
- Demographics;
- Government Structures;
- Stock Markets;
- Professional Bodies, and
- Regulatory Bodies.

The following variables have an indirect albeit positive influence on the perceived success of 'Niche Markets' in Real Estate Development:

- Micro – Economics;
- Social Media;
- Global Trends, and
- Privatisation.

6. CONCLUSION

Real Estate Development is complex and requires an in-depth understanding of the contributing factors associated with the development of a 'Niche Markets' within the in Real Estate sector. There is sufficient evidence from the literature review and the empirical research findings to suggest that it is essential for Real Estate Development firms to implement effective planning and management techniques to increase their success rate from inception to completion. With the required knowledge, expertise and skills regarding Real Estate and Real Estate Development, professionals may develop positive outcomes when developing 'Niche Markets' in Real Estate Development.

7. RECOMMENDATION

In an effort towards the successful development of 'Niche Markets' in Real Estate the following parameters must be addressed; Strategic planning, market trends, construction costs and demographics. Furthermore, government structures, stock markets, professional bodies and regulatory bodies should form an integral part of the development process. As a result, the empirical framework should provide a guideline for Real Estate developers to be successful within the realm of Real Estate.

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An Exploration of Delay Factors in South African Electrical Modification Projects

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ABSTRACT

Purpose of this paper
This paper explores the major determinants leading to the delays in the modification projects in a South African power station and demonstrates how the identified delay factors are interlaced.

Design/methodology/approach
The research adopts a soft systems approach called Interactive Management (IM) to construct a model displaying the aggravating relationship between the identified delay factors in the South African power station. The identity of the organization is not disclosed for confidentiality reason. The IM inquiry mainly comprises four phases: idea generation, idea clarification, idea structuring, and interpretation of the structured ideas. The Interactive Management methodology enables the relevant stakeholders to interactively design a system and enhance continuous learning through an emancipatory way.

Findings
The model generated through the IM session is a digraph showing the ‘aggravate’ relationship between the identified delay factors. The digraph reveals that the main driver leading to the modification project delays is the ’proficiency of a project manager’.

What is original/value of paper
The model serves as a starting point for the power station to revisit its strategy in dealing with project delays to generate the greatest leverage in the intervention process.

Keywords: Interactive Management, Project Delays, Systemic Thinking

1. INTRODUCTION

Project delays are common problems in the global construction industry. They affect the development of construction industry and the overall economy of a country (Luu *et al.* 2015). The delays in a project could result in increased costs and the reduction of income (Mulla and Waghmare 2015). In fact, some projects become uneconomical due to the time and cost overruns. Cruywagen (2012) supports this view and argues that, for the owner and contractor, delays could result in missing new opportunities due to unavailability of capital and resources to exploit them.

Eskom is the major electricity supplier in South Africa. It supplies electricity for industrial, commercial, and domestic use. However, South Africans have been subjecting to load shedding resulted from limited generating capacity and the increasing demand for electricity. Eskom, with the governmental support, has implemented various projects to tackle this problem. These projects include building new power plants and refurbishing existing plants through modification projects to ensure adequate and uninterrupted supply of electricity to the country. Despite the concerted efforts in resolving the energy crisis, these projects continue to experience severe delays which exacerbate the crisis. The project delays also occurred in the modification projects.

Some authors, such as Durdyev et al. (2017), Zewdu (2016) , Kim et al. (2016), Bagaya and Song (2016), Mulla and Waghmare (2015), Albogamy *et al.* (2012), Sunjka and Jacob (2013), and Luu *et al*. (2015), conducted studies on identification of delay factors in different projects. The prevalent approach used by these researchers was the questionnaire method. Baloyi and Bekker (2011) said that the research anchored in questionnaires or interviews has been a proven application in identifying major delay factors.

Different from the common approaches, this paper recognizes the systemic relationship among the project delay factors. The systemic nature means that the delay factors are interdependent. Besides, structuring the interrelationships between the system elements is a subjective process. With this idea in mind, structuring the relationship between the delay factors may reveal the holistic picture regarding how the project delay factors are interlaced. Through this way, the significance among the project delay factors can be determined. Once the cause and effect between the delay factors are identified, a solution may be applied to focus on the drivers of delay. This paper adopts Warfield's Interactive Management (IM) to model the factors causing untimely delivery of modification projects in a South African power station". Warfield and Cardenas (2002) define IM as "a system of management invented explicitly to be applied intermittently in organizations to enable those organizations to cope with issues or situations whose scope is beyond that of the normal type of problem that organizations can readily solve". IM echoes systemic thinking. It is designed to deal with complex problems and embrace democracy in the inquiry process.

This paper starts by providing an overview of the backgrounds to the untimely delivery of projects in South African power stations. Following the backgrounds to the study, the IM inquiry process will be briefly described. The last part demonstrates how IM was used to structure the delay factors in the modification projects in a South African power station.

2. BACKGROUNDS TO THE STUDY

South Africans were subjected to load shedding which came as a result of limited generating capacity and the increasing demand for electricity. The lack of electricity supply and interruption of supply have been increasingly recognised as a serious constraint on sustainable economic growth, given the wide consensus on the links between electricity and economic development (Fedderke *et al.* 2006). Therefore, timely completion of projects by South African power station is of paramount importance in ensuring the continuous and uninterrupted supply of electricity. To address the electricity energy challenge, various projects are initiated in South Africa. These projects include building new power plants and refurbishing existing plants through modification projects to ensure adequate and uninterrupted supply of electricity to the country. Despite the concerted efforts in resolving the energy crisis, these projects continue to experience severe delays which exacerbate the crisis.

The timely delivery of projects in South African power station is crucial as unplanned unavailability of a power station has the following knock-on effects:

- disrupting the maintenance shutdown (outage) projects schedule of other power stations;
- affecting electricity capacity of the national grid;
- possible load-shedding restricting supply to domestic, commercial, and industrial consumers; and
- detrimental consequences to the country's economic activities.

Given these effects, modification projects and outage projects are still challenged to be completed within the targeted period. This results in clients' loss of income. Conflicting views existed among the South African power station personnel regarding the reasons why some projects are not delivered on time. Some team members believed that the planning strategy is a major contributing factor to project delays. On the other hand, some team members believed that the lack of accountability and the commitment to adhere to the established time schedules were the causes for the project delays. The debacle of project delays and the dissonance between the relevant stakeholders inspire the study to explore why projects are not delivered on time in this South African power station.

This research adopts IM to identify the drivers leading to the project failure as IM is designed to deal with complex situations through a disciplined procedure. The output of IM is an archival digraph showing the interrelationships between the system elements. The next part briefly describes the IM process.

3. INTERACTIVE MANAGEMENT METHODOLOGY

The IM methodology has been used to investigate various problems, e.g. the factors impeding organizational effectiveness (Tuan, 2004), the process of conducting classification (Tuan, 2010), the factors hindering the performance of basic education in Lesotho (Nthunya *et al.* 2017), and the exploration of AIDS epidemic (Tuan, 2018). In this study, three major steps of IM methodology were adopted to investigate the delay factors. The three steps are briefly described below.

The idea writing technique and the nominal group technique are both discussed under this section as one technique. The idea writing is seen as an extension of nominal group technique. Warfield and Cardenas (2002) describe nominal group technique as a process of generating ideas, clarifying ideas, doing a preliminary partitioning of the set of generated and classified ideas, based on the criterion of relative saliency, and helping to build a spirit of participation and teamwork or group morale. On the other hand, idea writing is described as an efficient idea generation process for eliciting the ideas relevant to a stated issue from one or more small groups (Warfield and Cardenas 2002). The idea writing and nominal group technique processes are initiated by carefully formulating a triggering question (Warfield and Cardenas 2002). The triggering question used for identifying modification project delay factors is 'which factors influence plant system modification projects and lead to the delay of project delivery'? The triggering question motivates the participants of IM workshop to generate their ideas regarding the issue in question. The facilitator of IM process collates the generated ideas and present them to the group. Following the idea writing, the group clarified the generated ideas and selected the ideas that each participant deemed essential.

The next step is idea structuring. This step involves answering a series of questions about determining whether the relationship of interest exists between a pair of posed elements. The participants collectively decided whether the relationship exists between the posed two elements. A contextual question is needed for the group to determine whether the relationship exists. The contextual question used for this study is 'does delay factor A significantly aggravate delay factor B'. The computer software 'Concept Star' was used for structuring the project delay model. When the group answer a series of posed questions, a binary matrix is gradually filled in. Upon the group complete all of the questions, a digraph can be extracted from the binary matrix. Warfield (1976) explains the algorithm of extracting the digraph. However, the algorithm of extracting the digraph is not in the scope of this paper.

The third step is the interpretation of the produced model. The model reveals how the systems elements are interlaced. In this study, the model can show the sources of delay factors. The established model is amenable to change. If the group feel that they need to revisit certain decisions, they may discuss the decisions made before and make changes if necessary. After all, IM is not aimed at establishing universal laws. Its inquiry process is aimed at enhancing learning and consensus.

4. RESEARCH FINDINGS AND DISCUSSIONS

The South African power station management team, comprising senior members from various departments, had vested interest in the delay of modification projects. The department managers from the Outage Management Department, the Project Management Department, and the Plant Engineering Department were also considered to participate in the study of identifying the factors causing modification project delays in this South African power station.

Warfield and Cardenas (2002) consider the following participants to be adequate for achieving a successful IM workshop:

- between 6 and 12 participants;
- experienced group leader;
- a computer operator; and

- possibly other staff available to document key comments by the participants.

The required number of participants corresponds to the number of representative set up for a committee, organized to review certain issue(s), evaluating available options, and making collective decisions based on the majority rule. A questionnaire was prepared and sent to the participants as the starting point of this study. The number of participants involved in generating ideas was deliberately increased above the recommended maximum number of 12 participants recommended by Warfield and Cardenas (2002) to 18 participants. The objective of the extension of the number of participants was to assess whether a perception of a multitude of common factors causing modification project delays existed among a bigger population. The idea was not to have all eighteen participants present for the IM workshop, but rather to expand the spectrum and get more ideas with regard to factors causing modification project delays in the South African Power Station.

A total of 92 factors were identified by the participants through the idea generating technique. Through consultation with the participants, the list of 92 modification delay factors was reduced by merging, splitting and deleting certain factors. Furthermore, the voting by participants reduced the number to 21 project delay factors which were the significant factors causing modification project delays in the South African Power Station, shown in Table 1.

Table 1 Identified delay factors and voting results

Project Delay Factors		**No. of Votes**
1	Poor leadership	2
2	Top management decision	1
3	Poor co-ordination	2
4	Delayed delivery of materials/spares	2
5	Insufficient risk management in terms of risk analysis, response and control	3
6	Lessons not learnt	1
7	Poor scope management/definition	1
8	Scope creep	1
9	Bureaucratic commercial and investment processes	3
10	Inaccuracy of execution duration on the plan	1
11	Cross-functional structure is not effective	2
12	PM does not fully understand how modification project fits into the outage project	3
13	Lengthy project management process with multiple departments involved	1
14	Delayed regulatory approvals	1
15	Resource constraints	2
16	Lack of discipline in executing the plan	2
17	Poor communication	2
18	Project cost underestimation	2
19	Outage project strategy, goals	1
20	Poor planning	4

Project Delay Factors		No. of Votes
21	Proficiency of a project manager	5

These factors were used for the model structuring phase to assess the interrelationships among the 21 identified significant delay factors. Six participants were involved in the model structuring phase. The decisions made by the participants regarding whether the aggravating relationship exists between a pair of posed elements are shown as Figure 1.

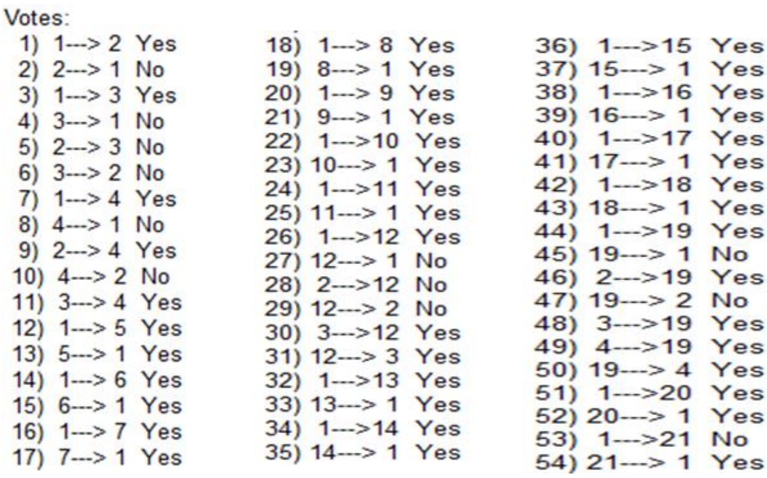
Votes:
1) 1---> 2 Yes
2) 2---> 1 No
3) 1---> 3 Yes
4) 3---> 1 No
5) 2---> 3 No
6) 3---> 2 No
7) 1---> 4 Yes
8) 4---> 1 No
9) 2---> 4 Yes
10) 4---> 2 No
11) 3---> 4 Yes
12) 1---> 5 Yes
13) 5---> 1 Yes
14) 1---> 6 Yes
15) 6---> 1 Yes
16) 1---> 7 Yes
17) 7---> 1 Yes
18) 1---> 8 Yes
19) 8---> 1 Yes
20) 1---> 9 Yes
21) 9---> 1 Yes
22) 1--->10 Yes
23) 10---> 1 Yes
24) 1--->11 Yes
25) 11---> 1 Yes
26) 1--->12 Yes
27) 12---> 1 No
28) 2--->12 No
29) 12---> 2 No
30) 3--->12 Yes
31) 12---> 3 Yes
32) 1--->13 Yes
33) 13---> 1 Yes
34) 1--->14 Yes
35) 14---> 1 Yes
36) 1--->15 Yes
37) 15---> 1 Yes
38) 1--->16 Yes
39) 16---> 1 Yes
40) 1--->17 Yes
41) 17---> 1 Yes
42) 1--->18 Yes
43) 18---> 1 Yes
44) 1--->19 Yes
45) 19---> 1 No
46) 2--->19 Yes
47) 19---> 2 No
48) 3--->19 Yes
49) 4--->19 Yes
50) 19---> 4 Yes
51) 1--->20 Yes
52) 20---> 1 Yes
53) 1--->21 No
54) 21---> 1 Yes

Figure 1 The group's decision records

In Figure 1, the arrow linking two elements means the posed contextual question about whether the relationship exists between the two elements. For example, '1→2 Yes' means that the group debated the question 'does element 1 (poor leadership) significantly aggravate element 2 (top management decision) and the group decided 'Yes'. Upon all of the computer posed questions completed by the group, a digraph is extracted from the binary matrix, shown as Figure 2.

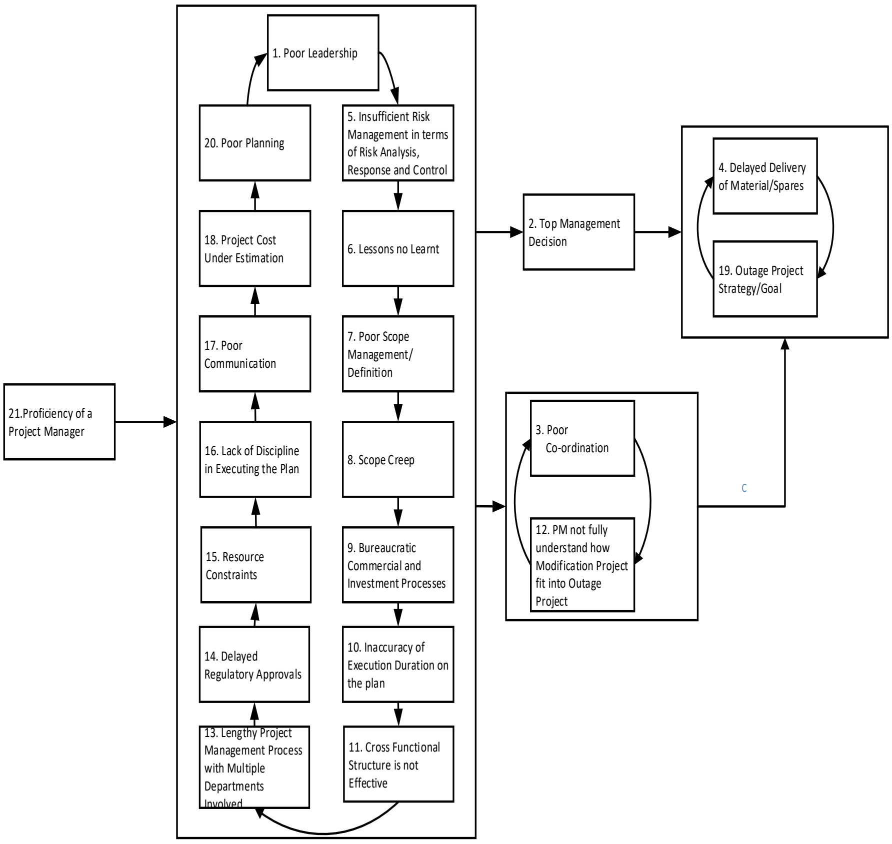

Figure 2 The aggravating relationship between the delay factors

In Figure 2, all arrows mean 'significantly aggravate'. Figure 2 reveals that "proficiency of a project manager" is the major determinant leading to the modification project delay. The delay factor "proficiency of a project manager" appears to be the driver of all other 20 project delay factors identified through the nominal group technique. It appears that the 'proficiency of a project manager' significantly aggravates the big loop lying in the second stage, comprised of fifteen elements. The two elements lying in the rightmost stage have no power to influence others. They are actually aggravated by the leftmost stage driver, i.e. the proficiency of a project manager. To eradicate the project delays in the South African power station, the power station needs to address how to equip the project manager with the skills needed for managing projects.

It is noteworthy, despite that the ranking in Table 1 also shows that element 21 (proficiency of a project manager) is the major problem, the elements in the big loop in Figure 2 don't receive the same votes shown in Table 1. However, their power of influencing the right stage elements is equivalent from a systemic point of view. When the group adopts the systemic approach, they see the problem in a different way.

5. CONCLUSION

The proficiency of a project manager has been identified as the major determinant resulting in modification project delays in the South African power station. It is recommended that the South African power station to focus its effort to address the first level drivers (i.e. "proficiency of a project manager"). It is believed that if this driver is addressed, modification project delays in the South African power station will be significantly mitigated.

However, the IM inquiry is not aimed at establishing universal laws. In other South African power stations, the driver causing delays might be different. In other countries, the participants of IM workshop might produce a very different model about their project delays. Even if the South African group runs the IM workshop again, they might generate a different conclusion. Human perceptions might change over time. The output from the first workshop paves the path for the iterative learning. The purpose of learning is to enhance consensus among the relevant stakeholders to take actions to deal with an undesirable situation. It is recommended to embrace more stakeholders from different power stations to participate in the IM workshop to establish broader consensus on the factors causing delays in the electrical modification projects in South Africa.

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An Investigation of the Strategies for Managing Extension of Time on Construction Projects in Zimbabwe

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ABSTRACT AND KEYWORDS

Purpose of this paper

This study explores the major causes of extension of time on construction projects and strategies being employed by Small and Medium Enterprise (SME) contractors, including the effectiveness of such strategies in managing extension of time (EoT) in the context of the construction industry in Zimbabwe.

Design/methodology/approach

The study adopted a mixed method design approach. Twelve completed projects, twelve SME Contractors and thirty-eight registered consultants were purposively sampled for the study. Content analysis was conducted on archived project information for the twelve completed projects. The selected SME contractors and consultants were each requested to complete a questionnaire with both closed-ended and open-ended questions. Thereafter, follow up interviews were conducted. The samples were drawn from SME contractors and registered consultants comprising architects, quantity surveyors and engineers, whereas a sample for construction projects were drawn from those that were completed by year 2012.

Findings

Responses were that client related delays such as variations, late issuance of instructions and financial constraints were major causes of extension of time in Zimbabwe. Further, the research identified six main strategies of managing EoT by SME Contractors namely progress reporting, control and review, procurement management, proper planning, contractor's diligent operation, appropriate standard form of contract and effective site supervision. Additionally, the study also noted that most SME contractors and consultants used irrational methods when claiming and evaluating claims for EoT. Further, the research observed a weak correlation between extension of time and additional cost.

Research limitations/implications

The sample is drawn from only SME contractors and consultants based in three major cities in Zimbabwe. More so, the hyperinflationary environment that prevailed in Zimbabwe between 2000 to 2012 precludes the study from being generalized to other settings without caution.

Practical implications

This study highlights strategies that SME contractors could adopt in ensuring effective mitigation of EoT on construction projects in Zimbabwe.

Original/value of paper.

The experiences presented in this study could be adapted to capacitate SME contractors with skills to effectively manage extension of time and consequently attain sustainable construction.

Keywords:
SME contractors, Construction Projects, Mitigation, Extension of Time, Scheduling, Zimbabwe

1. INTRODUCTION

Project completion time is one of the essential parameters that determine the success of any construction contract (Kaming et al., 1997; Yogeswaran et al., 1998; PMI, 2000; Kheng, 2003). Contrarily, the construction industry has been marred by myriad of inefficiencies that have resulted in unprecedented time and cost overruns. Harmon (2004) claimed that the only project that portrayed a miracle of efficiency is when God created the world in seven days. Harmon's analogy relates perfectly to the situation prevailing in most developing countries. The argument is further entrenched by studies conducted in Nigeria (Aibinu and Jagboro, 2002), Thailand (Toor and Ogunlana, 2008) and Libya (Tumi et al., 2009) where most construction projects were completed beyond the original contractual practical completion period.

Previous research in developed countries have also revealed similar patterns of delayed construction projects. For instance, Bordoli and Baldwin (1998) cited Onyango (1993) who claimed that 52% of all completed projects in United Kingdom suffered completion delays. The recorded statistics and current status quo in both developed and developing countries attest to the serious challenges that the construction industry is facing in its quest to attain a sustainable built environment.

To address the mentioned challenges in the construction industry, it is important to unearth the source of the challenge, including the key players involved therein. Several studies cited client related delays (variations, late issuance of instructions by client's agent), extraneous delays (force majeure, inclement weather conditions) and contractor related delays as factors that affected timely completion of construction projects (Bordoli and Baldwin, 1998 ; Aibinu and Jagboro, 2002; Toor and Ogunlana, 2008). The moment project completion is delayed, Aibinu (2009) argued that there is an inextricable link with additionally costs, apart from deprivation of the client to enjoy use of the facility. As a result, sustainable built environment is compromised due to untimely completion of projects and absence of value for money to clients. However, if effective and efficient mitigating measures are put in place by key players in the construction to curb the mentioned challenges, it is feasible to create a sustainable built environment.

Most of the projects that have suffered completion delays are those that were being executed by Small and Medium Enterprise (SME) contractors (Tumi et al., 2009; Toor and Ogunlana, 2008; Aibinu and Jagboro, 2002). According to Paramasivan and Selvam (2013); Fening (2012) and Ahmed and Chowdhury (2009), SME contractors have been viewed as a backbone at all levels of economic development, particularly in developing countries. Nonetheless, several studies highlighted numerous challenges faced by SME contractors which include inadequate technical capacity, lack of managerial skills and financial constraints (Mofokeng and Twala, 2012; Fening, 2012; Ahmed & Chowdhury, 2009). However, it is undoubted that sustainable infrastructure development could be realized through indigenized solutions. One such step is to capacitate SME contractors with requisite skills to drive the construction industry in a more effective and efficient manner (Dalrymple, 2004). As noted by Mofokeng and Thwala, attempts to develop SME contractors have been made by several developing countries. However, more effort needs to be done in that regard if meaningful transformation is to be witnessed in the construction industry in developing countries.

Considering the impact of EoT on the successful completion of construction projects, there is urgent need to address the phenomenon. Kendrick (2010) and Orr (2007) recommended the use of traditional time management techniques such as Gantt Chart, Program Evaluation and Review Technique (PERT) and Critical Path Methods (CPM). The mentioned techniques are believed to have been developed between 1900 and 1950 according to Marais and Martin (2008) and Bordoli and Baldwin (1998). More so, modern standard forms of contract such as FIDIC (1999); JCT(1998); NJPC (2000) and Agreement and Schedule of Conditions of Building Contract (2009) highlight obligation of parties and the need for contractors to implement reasonable measures to mitigate any delays that can result in extension of time of construction projects. However, the use of the stated time management techniques and full comprehension of the standard forms of contract by SME contractors to effectively mitigate completion delays remain debatable.

It is against the above backdrop that this research sought to explore major causes of extension of time and the strategies used in managing EoT on construction projects by SME contractors, in the context of the construction industry in Zimbabwe. The research also assessed the effect of extension of time on overall construction cost. Further, the research evaluated the effectiveness of the strategies used by SME contractors in mitigating completion delays and cost overruns , in view of the unprecedented hyperinflationary environment that marred Zimbabwe between 2000 to 2010 as noted by Biti (2012).

The findings of the research formed the basis for the formulation of measures deemed more effective in mitigating EoT on construction projects by SME contractors. The envisaged suggestions anchor on the premise that if SME contractors are capacitated with the relevant skills, it becomes easier to attain sustainable built environment even in exceptional economic environments such as that prevailed in Zimbabwe.

2. METHODOLOGY

The study used a mixed design approach. The research sought to explore the main causes of EoT on construction projects , determine strategies that are being used to manage EoT on construction projects by SME Contractors and evaluate the effectiveness of the strategies used to manage EoT on construction projects, in terms of timely completion of projects and cost overruns in Zimbabwe. The study considered civil and building projects located in three major cities of Zimbabwe namely Harare, Bulawayo and Gweru. Harare was selected because of it being the capital city with high economic activities, then Bulawayo is the second largest which is located at the southern part of the country, and Gweru is the third largest city which is centrally located, geographically. These are also the areas with high level of construction activities compared to other smaller cities. Projects were further categorised into three strata namely commercial, residential and public utility buildings. More so, only projects with contract value or market value of above Two Hundred Thousand United States Dollars (US$200,000.00) were considered for the study basing on the assumption that EoT occurs mostly on complex projects. Basing on a research carried by Yogeswaran et al. (1998) in Hongkong and Tumi et al. (2009) in Libya, it is difficult to have a clear baseline of the total number of construction projects that are on-going or have been completed within a specific period from which a sample can be drawn since such data is not often stored at a central place. As such, the research purposively sampled twelve completed projects and conducted content analysis on archived project information in a bid to investigate all the three objectives. Further, a questionnaire survey was administered to twelve SME contractors and thirty-eight consultants who were randomly sampled from Zimbabwe Institute of Quantity Surveyors, Zimbabwe Institute of Architects, Zimbabwe Institute of Engineers. The sample frame for the targeted consultants was 140. The questionnaire survey consisted of both open and closed ended questions which sought to address all the three objects. Thereafter, unstructured follow-up interviews were conducted to probe more data where responses from questionnaire survey were ambiguous or inadequate.

Variance analysis in terms of time and cost on selected projects was also done and results were measured against internationally acceptable benchmarks. Some grouped data which were categorised on a 3-point scale High, Moderate and Low, with weighting of 3, 2 and 1 respectively, were analysed by calculation of Importance Index.

3. RESULTS AND DISCUSSION

The collected data were analysed to highlight the causes of extension of time on construction projects and mitigation strategies. Fifty respondents comprising twelve contractors, twelve quantity surveyors, twelve architects, fourteen engineers were selected and given questionnaires. Of the fifty targeted respondents, only thirty respondents completed the questionnaires, thus represented 60% response rate. This was considered adequate for analysis according to Aibinu and Jagboro (2002) citing Moser and Kalton (1971) who claimed that the result of a survey could be considered as biased and of little value if the return rate was lower than 30-40%. The research had also targeted sixteen construction experts for in-depth interviews but managed to interview fifteen, thus 94% response rate hence acceptable for analysis as well.

3.1 Causes of extension of time on construction projects

From the data collected through questionnaires, 92% of the respondents indicated that they had experienced extension of time on at least one of the projects they worked on whereas 8% asserted that they had never experienced extension of time. The results also show that 16 causes of extension of time claims were identified from those who had experienced extension of time on their projects. From the sixteen identified causes, variation orders (57%), late payments by clients (48%), adverse weather conditions (43%), and unrealistic scheduling of works by the contractor (38%), client financial constraints (34%) and procurement challenges (33%) were cited as the major causes of EoT.

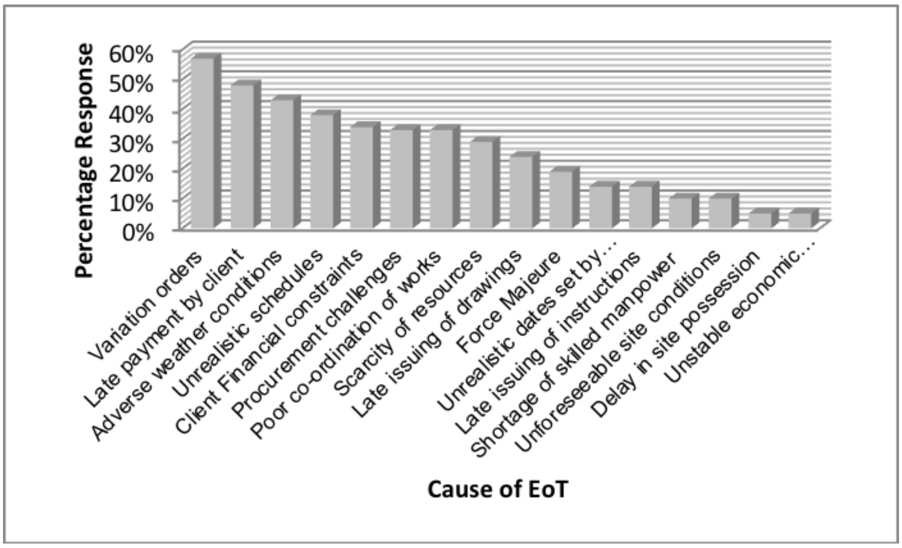

Figure 3.1 Causes of extension of time on construction projects

In addition to the above, three major causes of EoT identified on the twelve studied completed construction projects were client financial constraints, variation orders and suspension of projects. The findings described above were similar to those found in Indonesia (Kaming et al., 1997), Nigeria (Aibinu and Jagboro, 2002), Thailand (Toor and Ogunlana, 2008) and Libya (Tumi et al., 2009). Moreover, approximately 95% of the identified causes were also stipulated in various standard forms of contract such as Agreement and Schedule of Conditions of Building Contract (1980), FIDIC (1999) and NJPC (2000). However, the aforesaid standard forms of contract did not stipulate late payment by clients and unrealistic scheduling as basis for awarding EoT claims. Late payment by clients was handled in the aforesaid contracts in two ways that include contractor's claim for interest on late payment and or termination of the contract by the contractor, whereas unrealistic scheduling was considered an inexcusable delay that should be borne by the contractor.

Further, the study assessed the prevalence in the construction industry of extraneous related delays and client related delays that had been identified through literature search. The prevalence level was categorised on a 3-point scale of High, Moderate and Low with weighting of 3; 2; and 1 respectively. Then each respondent was asked to express its opinion by ticking the appropriate category. The data were then analysed through calculation of importance index as indicated on Table 3.1 and 3.2.

Table 3.1 Extraneous related delays (excusable-non-compensable delays)

Item	Type of delay	Importance Index	Rank
1	Exceptional inclement weather	37.60	1
2	Change in statutory requirements or the carrying out of work by local authority	33.60	2
3	Civil commotion, riot, strike or lockout by persons other than the contractors' personnel	24.80	3
4	Natural catastrophes such as earth quakes, hurricane, typhoon or volcanic activity	23.20	4
5	War, explosive materials, ionising radiation or contamination of radio activity which are not attributable to the contractor	20.80	5
	Average Importance Index	**28.00**	

The most prevalent extraneous related delays were exceptional inclement weather (37.60), change in statutory requirements or the carrying out of work by local authority (33.60) and civil commotion, riot, strike or lockout by persons other than the contractors' personnel (24.80).

Table 3.2 Client related delays (excusable-compensable delays)

Item	Type of delay	Importance Index	Rank
1	Late payment by client which directly affects contractor's operations on site	66.40	1
2	Architect's instructions	59.20	2
3	Late issuing of instruction to the contractor	56.00	3
4	Delay by Nominated-Subcontractor	48.00	4
5	Client's direct interference with works or interim payment certificates	47.20	5
6	Delay by Nominated-Supplier	44.00	6
7	Delay on the part of other contractors or tradesmen engaged by the client in executing work not forming part of the main contract	40.00	7
	Average Importance Index	**51.54**	

The results on Table 3.2 showed that late payment by clients (66.40), variation orders (59.20) and late issuing of instructions to contractors (56.00) were the most prevalent excusable-compensable delays.

By comparing results in Table 3.1 and Table 3.2, the research found that client related delays were more prevalent on construction projects in Zimbabwe, compared to extraneous delays. The results were supported by Aibinu (2009) who claimed that there is a strong link between extension of time and additional costs. This assertion emanates from the fact that, if client related delays are more prevalent, they would result in the project being extended with related costs.

3.3 Establishing relationship between extension of time and cost

To establish the extend of the relationship between EoT and additional costs, the research conducted statistical analysis by calculating correlation coefficient of data of ten (10) projects where EoT was granted against related additional Cost using the equation 3.1.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[\,[n\sum x^2 - (\sum x)^2\,] - [n\sum y^2 - (\sum y)^2]\,]}} \tag{3.1}$$

Table 3.3 Overview of EoT granted versus related additional costs

Project Code	EoT Granted (Months)	Awarded Additional Cost (USD)
A	2	0.00
C	12	69,000
D	12	4,430,000
F	3	70,000
G	5	45,000
H	1.5	1,560,000
I	0.8	0.00
J	15	75,000,000
K	3	404,000
L	1	120,000

From statistical analysis of data collected from ten completed projects as indicated in Table 3.3, the research found a correlation coefficient of 0.6. Accordingly, Plooy-Cilliers et al. (2014: 215) stated that if the value of correlation coefficient falls within the range of 0.4 to 0.7 it implies a weak positive correlation between the independent and dependent variable. As such, the results indicated existence of a weak positive relationship between EoT and additional costs. Thus, if a project's duration is extended, there are moderate chances of incurring additional costs hence budget overruns. The weak positive relationship could be attributed to some EoT claims that could be awarded to contractors basing on extraneous delays or ex-gratia which do not directly result into additional cost. The findings do not entirely support Aibinu (2009)'s grant claim that extension of time is inextricably linked to additional cost, though true to a greater extent.

3.3 Strategies used in managing extension of time

The research identified six main strategies namely progress reporting, control and review; procurement management, proper planning, contractor diligent operations, use of appropriate contract and effective site supervision. These strategies were similar to some of the strategies highlighted by Passenheim (2009) and Kendrick (2010).

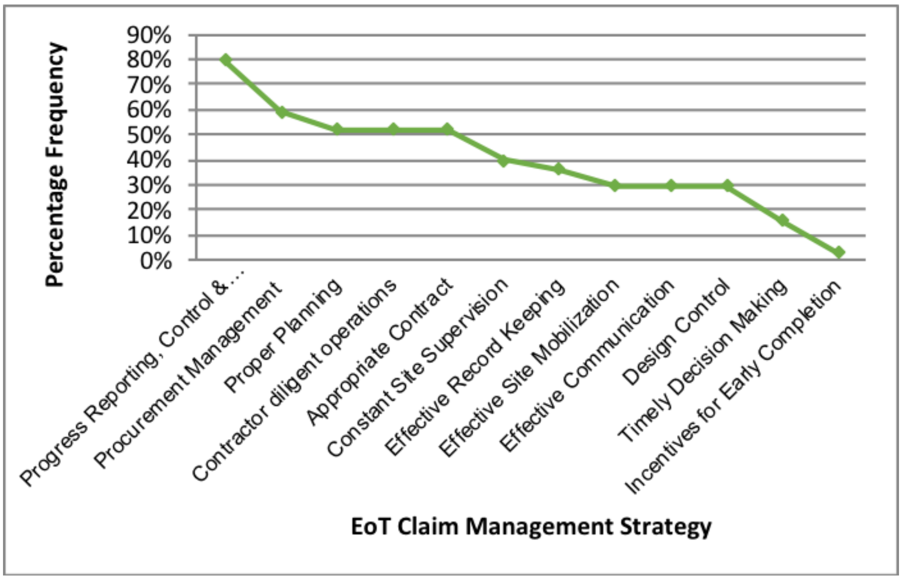

Figure 3.2 Strategies used in mitigating extension of time (EoT)

3.4 Effectiveness of the strategies used in managing extension of time on Construction Projects in Zimbabwe

The research further investigated the effectiveness of the strategies listed in figure 3.2 in three -fold: firstly, in terms of evaluating projects which were completed on time due to implementation of mitigating measures, then secondly, in terms of EoT claims which contractors submitted and managed to be granted EoT and thirdly, in terms of impact of EoT granted on construction cost. The results showed that EoT was granted on ten projects (83%) and rejected on two projects (17%). However, from the ten projects that contractors were granted EoT, the research found that the number of days granted to contractors were on average 27% lower than the number of days indicated on their claims. Further, the research found that construction cost on the studied twelve projects increased by an average of 460%, thus 4.6 times the original contract. This is unprecedented increase due to a hyperinflationary environment that prevailed in Zimbabwe in the last two decades. As such, the fact that 83% of the completed projects suffered completion delays, it implied that mitigating measures were not adequately implemented by SME contractors. Additionally, the results showed that most SME contractors had difficulties in preparing EoT claims and lacked knowledge of rational delay analysis techniques including essential steps advocated by Levin (1998) and Badman (2007).

4. CONCLUSIONS AND RECOMMENDATIONS

Basing on the findings from the study, the research concluded that, EoT on construction projects in Zimbabwe is mainly caused by client related delays such as variation orders, late issuance of instructions by client's agent and client financial constraints. Generally, client related delays were more dominant compared to extraneous delays. Pertaining to the impact of EoT on construction cost, the results showed a weak positive correlation between EoT and additional cost, implying that even though it is not automatic that EoT results in additional cost, there are moderate chances to incur additional costs whenever a project is extended in Zimbabwe. More so, the research noted that hyperinflationary environment that prevailed in Zimbabwe for the past two decades negatively impacted on construction costs hence impeded sustainable built environment. Additionally, the research found several EoT mitigating measures used by SME contractors and practitioners in the industry namely progress reporting, control and review; procurement management; proper planning; contractor diligent operations, use of appropriate standard form of contract and constant site supervision. However, the results also showed that most SME contractors lacked expertise in implementing those measures hence made such strategies ineffective in ensuring timely completion of construction projects which are also within budget in the context of Zimbabwe.

Basing on the conclusions drawn from the research findings, the research recommends adoption of an integrated approach encompassing appropriate and comprehensive standard form of contract, project management techniques and negotiations. Secondly, contractors and consultants are advised to use well-defined procedures and rational delay analysis techniques such as CPM schedule analysis methods during preparation and evaluation EoT claims. Thirdly, there is a serious need for the training of SME contractors in the construction industry in Zimbabwe to equip them with skills to effectively mitigate EoT, which in turn curbs cost overruns and late completion of projects, thus enhancing sustainable built environment.

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Barriers Hindering the Implementation of the System for Infrastructure Procurement and Delivery Management

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ABSTRACT AND KEYWORDS

Purpose:
Poor service and infrastructure delivery are still experienced in public sector construction projects within the South African built environment. These challenges include delays in the completion of public sector projects from inception through to close out. Government has developed and implemented numerous policies and frameworks over the years to address the challenges of service delivery in the construction industry. With the implementation of the most recent framework in 2017, the System for Infrastructure Procurement and Delivery Management (SIPDM) it is evident that service delivery challenges are still present. This study investigated the challenges hindering the implementation of the SIPDM.

Design/methodology/approach:
This study was executed based on a qualitative approach which was included data collection via semi structured interviews. A sample of 15 professionally registered construction project managers (CPM) to determine whether they are aware of the SIPDM and to identify the challenges hindering its implementation including the tools and techniques they can utilise towards improving service delivery in the public sector. The data output was analysed thematically in order to pinpoint examine and record themes within the data.

Findings:
This study found that CPM's are aware of the SIPDM and are utilising the framework in current public sector projects. From the study it was evident that there are challenges hindering the implementation of the SIPDM which results in service delivery challenges. The study further showed that CPMs believe that the tools and techniques provided through project management knowledge and expertise can enhance service delivery of construction projects.

Research limitations:
This study was limited to professionally registered Construction Project Managers (CPMs) involved in public sector projects based within the province of KwaZulu-Natal, South Africa.

Originality/value:
This research establishes a link between the barriers hindering the implementation of the SIPDM and identifies the tools and techniques that CPMs can utilise towards improving service delivery through the successful delivery of construction projects in the built environment.
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Keywords: Built Environment, Construction Project Management, Public Sector, Service Delivery, SIPDM

1. INTRODUCTION

The construction industry contributes significantly to employment and growth in South Africa (PwC Report: SA Construction, 2016). Construction usually involves the interpretation of the Client's brief into a design and then translation into reality. This translation requires a design or consultant team selected by the client/ employer. More specifically, some of the major consultant team members consist of land surveyors, engineers, quantity surveyors, fire protection engineers, planning consultants, architects, construction project managers, health and safety specialists and construction project managers (Davies, Nikolas and Jokiniemi, 2008). Construction consultants play a multifaceted role in construction projects and are usually involved from project inception to completion (Clark and Wilson, 2008). More specifically, consultants involved in public sector projects are usually employed through the sectors procurement policy for the specific duration of the project (National Treasury Supply Chain Management Guideline, 2004). However, measuring performance is critical for enhancing service delivery in the construction industry.

There are numerous performance indicators regarding service delivery in the construction industry. Chan and Ada, (2004) highlighted time, cost and quality as the three most commonly cited performance indicators in construction projects. Other critical performance indicators include, safety, functionality, human resourcing, procurement, communication, integration, satisfaction and the environment. Furthermore, Ali *et al*. (2010) argued that consideration must be given to four constraints in construction, these are scope, cost, time and quality. This is further supported by Endut *et al*. (2009) who revealed that time overruns are higher when compared to cost overruns. Baloyi and Bekker (2011) noted that client mandated scope changes and inadequate planning leads to delays. Late award of contracts also emerged as one of the factors causing delays in construction projects. Therefore, emphasising that time is one of the most important factors taken into consideration regarding the successful delivery of construction projects in the industry.

Other critical challenges identified by Aibinu and Jagboro (2002) that hinder the successful delivery of services in the public sector include:

- Cost overruns and time delays resulting from design errors, scope change, inappropriate and inadequate procurement, and complexity of the project,
- Client financial difficulties and payment delays,
- Incompetent project team,
- Lack of skills in the government fraternity,
- Lengthy government planning processes resulting in delays (Aibinu and Jagboro, 2002).

Service delivery dissatisfaction is more widespread and not restricted only to municipalities. The slow pace and poor quality service delivery is evident through the violent protests carried out by community members all over the country which has brought local governments under the spotlight (Managa, 2012). As a result of these challenges, government through the years have developed and released numerous policies and frameworks to assist in the eradication of service delivery challenges.

Studies conducted by government from 2002 to 2016 were undertaken to determine the issues and gaps in the delivery of infrastructure through the years (CIDB Building and Construction Sector Report, 2017). Most of these studies reported that there was a shortfall in effective and systematic delivery systems including a shortfall of skills. Some of the programme's developed by government over the years were: Infrastructure Delivery Improvement Programme (2004), this programme led to the development of the Infrastructure Delivery Management System in 2006. In 2011 the National Planning Commission published a detailed report that set out the key challenges that confront the South African construction industry, amongst the challenges identified, poor service delivery in public sector projects was highlighted. This was further reinforced in the National Development Plan released in 2012 where it became clear that an infrastructure delivery system was needed, focusing on prioritising, planning, allocating and measuring. Based on this, the National Treasury developed the Infrastructure Delivery Management System (IDMS) as a model for best practice delivery of infrastructure management within the public sector. Collectively these processes and systems, together with a performance management system, established the institutional system for infrastructure delivery. In 2017, National Treasury released an updated policy, the SIPDM for implementation. Professionals who may participate in infrastructure procurement and delivery management as regulators, clients, consultants and contractors, are expected to facilitate the effective implementation of the SIPDM (SIPDM, 2016).

This research aimed to investigate the barriers hindering the implementation of the SIPDM in the public sector and identify the tools and techniques that CPMs can utilise towards improving service delivery through the successful delivery of construction projects in the built environment.

2. THE SOUTH AFRICAN BUILT ENVIRONMENT & PUBLIC SECTOR

The built environment is a material, spatial and cultural product of human labour that combines physical elements and energy in the forms of living, working and playing (Bartuska and McClure 2007). The South African built environment which comprises the construction industry plays an integral role in the national economy. The construction industry provides infrastructure which is fundamental to the continuous development of the country (South African Government News Agency, 2017). The built environment is a key stimulator of the built environment (National Treasury, 2015). The industry contributes to economic development through demand and supply of construction goods and services.

The public sector in South Africa refers to the part of the economy concerned with providing basic government services such as the police, public roads, public transit, education and healthcare, services which benefit society rather than individuals who use the service (Lane, 1995).

In addition, South Africa is a constitutional democracy with a three-tiered system of government (national, provincial and local) that functions in an 'interdependent and interrelated' way (Stats SA, 2016). Municipalities are the most basic units of government in the country and are tasked with providing basic services and fostering development in the regions they control. Local government in South Africa is largely understood in terms of service delivery and the South African constitution (Act No. 108 of 1996) assigns municipalities the role to mobilise economic resources towards the improvement of the lives of all citizens (Stats SA, 2016). The Human Sciences Research Council further reinforces that local government is the key site of delivery and development and is central to the entire transformative project of the new South Africa." This means that local government is the sphere that engages with communities and tends to their needs, in an endeavour to resolve service delivery challenges (Human Sciences Research Council, 2016). Schiller (1993) noted that the roots of governments success or failures lies in the economic policies and decisions around appropriate economic mix on how best the government is able to produce optimal output.

As a result, the intervention of the government should be to address failures which include but is not limited to services and infrastructure delivery. South Africa has made remarkable progress in reducing poverty and inequality, but still faces tremendous shortfalls in economic and social infrastructure (Financial and Fiscal Commission Report, 2017). The South African government's infrastructure development plan and the Presidential Infrastructure Coordinating Commission which were set up to coordinate infrastructure expenditure between the three different spheres of government, are highlighted as positive signals for future growth in the industry (PwC Report: SA Construction, 2016).

3. SERVICE DELIVERY AND ITS CHALLENGES

Service delivery in the South African construction industry post 1994 has seen its challenges over the years. The government has through the years developed and implemented numerous policies and frameworks to facilitate service delivery in the construction industry. To date, there are still unresolved challenges. As a result, government through National Treasury has released the System for Infrastructure Planning and Delivery Management (SIPDM) as an initiative towards ensuring a systematic and structured approach for infrastructure procurement and delivery management for the successful delivery of construction projects (SIPDM, 2016).

One of the fundamental challenges of the South African government is service delivery in the construction. Some of these challenges are highlighted by the SA Government New Agency Report (2017) as:

- delays and disruptions during construction,
- poor site management,
- time and cost variations,
- skills and competence issues,
- lack of quality improvement processes,
- a lack of worker participation and
- more specifically to this research are delays in the completion of public sector projects from project inception through to completion and close out.

The Africa Institute of South Africa (2012) supports this and identifies that other major challenges facing local government which are hampering performance are:

- Acute problems of institutional capacity – lack of expertise has left many municipalities inadequately staffed, resulting in deteriorating service delivery over the years and leaving many communities with inadequate access to basic services.
- Mismanagement of funds – due to the lack of quality service provision, many municipalities are unable to supplement the budgetary allocation with rate payments to assist in rendering the services required.
- High levels of corruption – the extent and nature of corruption is rooted in the countries bureaucratic traditions, political development and social history. Africa's Public Service Delivery and Performance Review (2012) further highlight that in spite of positive strides made towards democratising local government, poor service delivery and perceived corruption still result in municipalities being dysfunctional.
- A lack of public participation – protestors have expressed dissatisfaction and frustration because of their exhaustion from local decision making and accountability by the municipal officials who represent them in wards.

The Constitution outlines a developmental mandate of local government. Within this mandate the executive authority of a local municipality needs to determine the best way, using partnerships, programmes and services to render services to the maximum benefit of the community. Quality service delivery and monitoring standards are therefore critical components of an effective and responsive local government (APSDPR, 2012).

Governments inability to provide basic services promised post 1994 to all citizens with specific reference to those previously disadvantaged by the apartheid regime has resulted in communities displaying their frustrations and impatience over slow and poor service delivery in the form of protests, strikes, boycotting and petitions characterized by violence, vandalism, looting, bloodshed and looting (Clark ,2011; Zubana, 2011). The provision of basic service delivery in most municipalities has been very slow and has failed to meet the expectations of the majority of people. As a result, public service delivery protests have been rife in municipalities across South Africa (Clark, 2011).

Although government should be acknowledged for major infrastructure development initiatives, numerous reports on service delivery indicate that progress has been uneven across the country with different issues facing different areas, reflecting variable socio-economic conditions and municipal competence (SA Government New Agency Report, 2017).

However, the infrastructure drive in the country is propelled by economic growth imperatives and broader social concerns such as the elimination of poverty and reduction of inequality by 2030. In other words, the country faces a triple infrastructure challenge:

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1. To provide infrastructure that stimulates economic growth and job creation,
2. To maintain existing infrastructure,
3. To provide infrastructure and services to the poor in order to eradicate poverty (Financial and Fiscal Commission Report, 2017).

While it is evident that there are challenges, the government's contribution to the industry plays a vital role in meeting the demands of infrastructure requirements, housing, clinics, hospitals and schools to under developed areas of the country. Kaul (1998) supports this role by indicating that since the transformation of the government in 1994, government has implemented numerous key turn-around strategies towards improving service delivery within the country such as:

- Collaborations/partnerships also known as Public Private Partnerships (PPPs),
- Black Economic Empowerment (BEE),
- the Preferential Procurement Policy Framework Act (PPPFA),
- the Infrastructure Delivery Management System (IDMS) and
- the Accelerated and Shared Growth Initiative of South Africa,
- the National Skills Development Strategy and
- the Employment Equity Programme to name a few (SIPDM, 2016).

Since then, the government through National Treasury has implemented the National Treasury Standard for Infrastructure Procurement and Delivery Management (SIPDM) which forms an integral part of the Model Supply Chain Management (SCM) Policy issued in terms of the Municipal Finance Management Act (MFMA). The issuing of the Model SCM Policy accordingly enables implementation of the SIPDM through the MFMA (SIPDM, 2016).

However, a study conducted by Khumalo, Choga and Munapo (2017) identified that the infrastructure delivery model requires a new trajectory in tackling the under-development and triple challenges of poverty, unemployment and slow economic growth. The study further highlighted that government as a public entity has a lack of systems for monitoring and checking resulting in no strict ownership of whatever processes that take place.

4. THE SYSTEM FOR INFRASTRUCTURE PLANNING AND DELIVERY MANAGEMENT (SIPDM)

In 2011 the National Planning Commission published a detailed diagnostic report that set out the key challenges that confront South Africans in fighting poverty and inequality and in achieving the Constitutional objectives. The implicit conclusion of this report was that a business-as-usual approach will result in South Africa failing to meet a great many of its objectives. With the publication of the National Development Plan 2030: Our future – make it work in 2012 it became clear that an infrastructure delivery system was needed which focused on prioritising, planning, allocating and measuring. Given this thought process, National Treasury developed the Infrastructure Delivery Management System (IDMS) as a model for best practice delivery of infrastructure management within the public sector (SIPDM, 2016).

The SIPDM establishes control frameworks for the planning, design and execution of infrastructure projects and infrastructure procurement requirements for a number of matters as applied to the supply chain management system for infrastructure procurement and delivery management, and minimum requirements for infrastructure procurement. This standard enables the separation of the supply chain management requirements for general goods and services from those for infrastructure. Underlying the separation of the supply chains is the notion that the effective and efficient functioning of the supply chain management system for infrastructure procurement and delivery management will realise value for money and good-quality service delivery. Value for money may be regarded as the optimal use of resources to achieve the intended outcomes. Underlying value for money is an explicit commitment to ensure that the best results possible are obtained from the money spent or maximum benefit is derived from the resources available (SIPDM, 2016).

There is a relationship between socio-economic growth, development and infrastructure delivery. The delivery of basic public services depends as much on the people and the institutions delivering the services as on the physical works they use. It is not enough just to have money. It is one thing to build a clinic, but quite another to build the right clinic within budget, on time and to the required quality, and be able to maintain it. As a result, the issuing of the Treasury Instruction in terms of the Public Finance Management Act (PFMA) and the issuing of the circular for the Model SCM Policy for Infrastructure Procurement and Delivery Management establishes a common approach to infrastructure delivery across all organs of state in all spheres (SIPDM, 2016).

Government has highlighted that the infrastructure plan for expenditure over the next 3 years (2019 – 2022) is positive for South Africa. Key areas of focus for infrastructure spending will be building and construction, energy, transport interventions, strengthening capacity to deliver infrastructure projects and creating new infrastructure funding streams. As a result, government needs to ensure that they are geared up and ready to implement public sector expenditure in order to roll out the plan for infrastructure development (SA Budget Review, 2019).

However, the SIPDM in its infancy of implementation from July 2017 has not seen its implementation efficiently and effectively as set out in its policy regulation guidelines. To date (2019), infrastructure delivery in the South African construction industry faces the same challenges regarding poor service delivery of public sector construction projects (SA Budget Review, 2019).

5. THE CONSTRUCTION PROJECT MANAGEMENT PROFESSION

Construction Project Management (CPM) is defined by the South African Council for the Project and Construction Management Profession (SACPCMP) in terms of the Project and Construction Management Professions Act (2000) as the management of projects within the Built Environment from conception to completion, including the management of related professional services.

In construction, experience has shown that the selection of the CPM is a key appointment which can influence the success or failure of the project. As the single point of responsibility, it is the CPM who integrates and co-ordinates all the contributions and guides them to successfully complete the project (Burke, 2013). The CPM works with the project team and other stakeholders to determine and use appropriate good practices for each project. Determining the appropriate combination of processes, inputs, tools, techniques including outputs and the life cycle phases to manage a project (PMBOK, 2017)

The PMBOK (2017) states that project management requires the project manager to adopt and show expertise in the following areas of knowledge, commonly known as The Ten Project Management Knowledge Areas. These areas of expertise are project integration, scope, cost, resource, schedule, quality, communications, risk, procurement, stakeholder management.

Project management can and should be applied throughout the project lifecycle, from the earliest stages of concept definition into operations and maintenance. It comprises the management of all that is involved in achieving the project objectives safely and within agreed time, cost, technical, quality and other performance criteria. Project management provides the “single point of integrative responsibility” needed to ensure that everything on the project is managed effectively to ensure a successful project deliverable (APM PMBOK, 2000).

Papke-Shields, *et al*. (2012) suggested that there is a positive relationship in project management practices and project success, implying that project management practices or standards inherently increase prospects of project success. This was also supported by Ika (2009) who noted that use of project management tools remains imperative in today’s environment.

During construction projects, there are many opportunities for the CPM to implement tools and techniques that will have a positive impact on the project from inception to completion. As a result, this research aimed to investigate the barriers to efficient and effective implementation of the SIPDM in the South African Public Sector and identify the tools and techniques that CPM’s can utilise towards improving service delivery through the successful delivery of construction projects in the built environment.

6. RESEARCH METHODOLOGY

The research methodology designed for this study entailed a literature review of the South African built environment and public sector, service delivery and its challenges, the SIPDM and the construction management profession. Thereafter a qualitative study through semi structured interviews were conducted with a sample of 15 professional CPMs registered with the South African Council for Construction and Project Management Profession (SACPCMP) in KwaZulu-Natal (KZN). These registered CPMs were identified from the Professions and Projects Register (2019).

The semi structured interviews aimed at investigating whether CPMs are aware of the SIPDM and to identify the challenges hindering its implementation including the tools and techniques they can utilise towards improving service delivery in the public sector. The data was analysed thematically with the NVIVO software package. More specially, the thematic analysis involved becoming familiar with the data, generating initial codes, searching for themes, reviewing the themes, defining the themes and finally completing the write up (Braun and Clarke, 2006). Thereafter, conclusions were drawn from the research findings and recommendations for implementation are presented.

7. FINDINGS AND DISCUSSION

Professionally registered CPMs were presented with questions through semi structured interviews to identify whether their awareness of the SIPDM, challenges hindering its implementation and the tools and techniques they can utilise towards improving service delivery. The responses were grouped according to themes and presented below.

7.1 **SIPDM Awareness, Importance and Use**

It was noted that all respondents agreed that they are aware of the SIPDM and are familiar with its design and intended use. One interviewee highlighted that *“the SIPDM it a key system that needs to be adhered to when implementing public sector projects”* which was further supported by another interviewee who noted that *“its systematic approach, if followed will allow public sector projects to be driven with guidance and purpose”*. This reinforced the importance of the SIPDM and its implementation on public sector projects.

7.2 Poor Implementation of the SIPDM and Impacts on Service Delivery

All respondents confirmed that poor adherence and lack of implementation of the SIPDM is currently impacting infrastructure service delivery in public sector projects. One interviewee noted that, *“It is clear that approvals to proceed to the next work stage are serious delay points on public sector projects”.* While another interviewee highlighted that, “*many public sector projects become stagnant well before going out to tender let alone proceeding into construction”,* supporting that service delivery is being impacted.

7.3 Service Delivery Challenges

It was clear that all respondents highlighted that service delivery challenges are still evident in the construction industry. Some of the key challenges identified through the interviewees were, *“cost overruns and time delays resulting from design errors scope change, inappropriate and inadequate procurement, and complexity of the project”.* While other challenges related directly to the public sector were listed as, *“poor scope brief and definition, lack of project background and knowledge, incompetent* *resource deployment and delays in sign offs and approvals.* This indicated that despite government efforts through policy implementation to improve service delivery, service delivery challenges are still present.

7.4 Client Financial Difficulties and Impacts on Service Delivery

Consensus was drawn by 13 respondents that financial difficulties and payment delays directly impact service delivery. Through the promotion of ensuring that potentially emerging contractors are given the opportunity to participate in the construction industry while contributing to public sector initiatives to drive service delivery, payment delays negatively impact the progress of the project, delaying its completion. Eight interviewees further noted that "*while the payment cycle procedures implemented through public sector are adhered to, once payment is issued for processing, they are not processed timeously"*. While two interviewees highlighted that they did not incur any financial challenges working on public sector projects indicating that not all public sector projects incur challenges which impact service delivery.

7.5 Incompetent Project Teams and Impacts on Public Sector Services

It was agreed by 12 interviewees that incompetent projects teams from both consultant and public sector directly impacts service delivery negatively. One interviewee noted that, *"the project team selection and resource deployment is critical towards running public sector projects successfully".* While 3 interviewees agreed with the importance of competent project teams, indicated that they did not experience incompetent project teams on public sector projects.

7.6 Improving Service Delivery through CPM Tools and Techniques

All respondents felt that project management tools and techniques under the ten areas of expertise could be utilised towards successful service delivery. One interviewee noted that, *"public sector needs to adopt and incorporate sound project management practices to assist in the effective facilitation of the SIPDM".* While another interviewee noted that, *"project managers are in a key role on construction projects and have the knowledge, skills and techniques to drive successful service delivery objectives in the public sector".* This was supported by nine interviewees who collectively agreed that, "*the public sector must consider deploying experienced project managers to monitor and control the implementation of the SIPDM as they have the expertise to drive construction processes from inception to completion".*

8. CONCLUSIONS AND RECOMMENDATIONS

This study reviewed the South African built environment and the public sector, service delivery and its challenges, the concept of the SIPDM and the construction management profession and taking the outcomes of the semi structured interviews into account, draws the following conclusions: it is evident that CPM's are aware of the SIPDM and are familiar with its design and intended use. Poor adherence and lack of implementation of the SIPDM negatively impacts infrastructure service delivery. Despite government efforts to improve service delivery through policy implementation (SIPDM), challenges are still present. Client financial difficulties, payment delays and incompetent project teams also contributed to poor service delivery. In addition, CPM's tools and techniques can be utilised towards successful service delivery. Finally, while it was identified that not all CPM's encountered service delivery challenges on public sector projects, its suggested that there are public sector entities and resources that are adhering to government policies and are implementing projects successfully towards improving service delivery.

A key players in construction projects, CPMs were identified to be in a pivotal position to drive the implementation of project management tools and techniques on public sector projects. It is suggested that the public sector may consider acquiring the services of professional CPM's to assist in eliminating and minimising challenges with implementing the SIPDM on public sector projects towards improving service delivery.

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Constraints in development of Grade 1CE contractors in Nelson Mandela Bay Metropole

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ABSTRACT AND KEYWORDS

Purpose of this paper
The Nelson Mandela Metropolitan Municipality (NMBM) has been providing work packages to Grade 1CE Contractors for more than four years, yet the number of Contractors moving up into Grade 2CE or higher is far fewer than the number that have received work packages. The study investigated the constraints facing the development of Grade 1CE contractors in the NMBM.

Design/methodology/approach
The objective of the study was achieved by employing qualitative methods. Since it is almost impossible to collect data from every contractor who participated in the NMBM Contractor Development Programme, a non-probability sampling technique was employed. Out of 30 contractors that were telephonically and respectfully requested to be interviewed, semi-structured interviews were conducted with the nine contractors who agreed to be interviewed.

Findings
The study found that these contractors could not meet the financial capacity component of the Construction Industry Development Board (CIDB) Register of Contractors (RoC) requirements necessary for upgrading owing to huge sums of money that were deducted for plant and material which were supplied by the main contractors.

Research limitations
The limitation of the study is that the researcher did not see any proof to support claims that the Grade 1CE contractors received less than R130 000 which is a financial capacity threshold requirement for upgrading. The study does not include any feedback from the main contractors who subcontracted the Grade 1CE contractors.

What is original/value of paper
This research study provides up-to-date information that can be used as a baseline by the NMBM policymakers and politicians to ensure the CDP gives entrepreneurs every opportunity to succeed. Other municipalities and government entities stand to gain from the results of this study since their challenges are similar to the challenges that forced the NMBM to adopt the policy that earmarks a minimum of 30% of the total contract value on all large contracts for the development of small, medium and micro enterprises (SMMEs).

Keywords: CIDB; Constraints; SMMEs; Grade 1CE contractors

1. INTRODUCTION

Amid the hijacking of construction sites by the so-called ‘construction mafia’ who demand access to economic opportunities, there is a need to determine the constraints facing the Grade 1CE contractors who have been given work packages as part of their development. The NMBM has been dealing with challenges of contractors who have demanded to be subcontracted in all major projects since as far back as 2014. In response, the NMBM adopted an Emerging Enterprise Development Support

Programme and Policy (EEDSPP) which mandated that 25% of the total contract value on all large projects be earmarked for the support and development of SMMEs. This threshold has increased to 30% since the introduction of the new Preferential Procurement Regulation in 2017 (National Treasury, 2017). To execute the 30% in accordance with the issued drawings and specification, the Municipality permits the Grade 1CE contractors to work under the direct supervision of the main contractors. This approach makes it easier for Grade 1CE contractors to acquire the necessary experience required for development.

The CIDB, a board that regulates construction, amongst others, has nine categories in which a contractor can register. Grade 1 categorises less capable contractors while Grade 9 represents the most capable. Although there are no work-related requirements needed to register a Grade 1 contractor, these contractors need to execute work to the value of not less than R130,000 in order to move into Grade 2CE (CIDB, 2016a). In fact, the CIDB requires all registered contractors to demonstrate their development from their previous projects in terms of financial capacity and work capabilities before a new grading designation can be determined.

To demonstrate the aforementioned capabilities and to determine a new grading designation, contractors need access to the civil engineering class of construction works. Civil engineering works are concerned with materials such as steel, concrete, earth and rock and other applications in the development, extension, installation, maintenance, removal, renovation, alteration, or dismantling of building and engineering infrastructure (CIDB, 2017b). However, the majority of small contractors struggle to obtain work opportunities while currently 96% of contracts are awarded to contractors between Grades 5 to 9 (CIDB, 2018a; CIDB, 2017a). Although it is not clear what percentage of the 4% was received by Grade 1CE contractor, reports confirm that upgrading of Grade 1CE contractors over the past three years has been very slow and has fluctuated between 6% and 10% (CIDB, 2017a; CIDB, 2018a). Alternatively, between 94% and 90% of Grade 1CE contractors have remained in the entry-level category over the past four years because they cannot satisfy the requirements set by the CIDB RoC for upgrading. The common reasons given by the CIDB (2016a) which prevent the development of Grade 1CE contractors include limited work opportunities, lack of job continuity and the fact that contractors do not carry out sufficient work that enables them to move upwards. Windapo and Catell (2011) reported that most of the available work in the construction industry cannot be sub-divided to cater for the contractors at the lower grades owing to its requirement of high levels of expertise and financial solvency.

Since the contractors cannot grow into established enterprises on their own owing to challenges such as lack of work opportunities and capital (Katua, 2014; Abor and Quartey, 2010; CIDB, 2016a), the National Contractor Development Programme (NCDP) framework provide clear guidelines for the establishment of contractor development programmes (CDPs) targeting at removing the constraints that affect the majority of contractors in the RoC. Subsequently, a number of CDPs have been set up throughout South Africa including in the NMBM, to assist with the development of small contractors. Although the study by the CIDB (2011a) reviewed the performance of CDPs in general and provided feedback on their success. No study has been conducted to determine why the majority of NMBM Grade 1CE contractors have not upgraded into Grade 2CE or higher, despite having been given work opportunities suitable to meet the CIDB RoC requirements for upgrading. This has been shown by the fewer number of these contractors that have upgraded since the establishment of the programme. The benefit of this research study is to provide the NMBM with up-to-date information about the real key constraints that prevent the Grade 1CE contractors from upgrading into Grade 2CE or higher in order to improve the CDP.

This study seeks to understand the constraints that continue to limit the development of Grade 1CE contractors in the NMBM since they have been provided with work opportunities to develop into established enterprises. The objectives of the research are the following:

- To understand why Grade 1CE contractors fail to prove they can upgrade to Grade 2 or higher despite executing suitable work packages;
- To identify the causes of failure of Grade 1CE contractors to meet the necessary financial capabilities after undertaking suitable work packages; and
- To identify the causes of failure of Grade 1CE contractors to demonstrate the necessary works capabilities after undertaking suitable work packages.

The intervention by the NMBM has been ongoing for more than four years, yet the contractors moving up the grade are far fewer than the number who received the work packages. That has prompted this study which seeks to determine the constraints the Grade 1CE contractors continue to face with a view to improving the contractor development programme.

The next section critically reviews the literature regarding the development of small contractors. Interpretivism, as utilised in this study, was chosen because it was most suitable to produce acceptable knowledge about the constraints that continue to prevent the Grade 1CE contractors from developing into established businesses. Consequently, the inductive approach was employed which is concerned with collecting data and developing theory by means of content data analysis (Saunders *et al.,* 2009). A cross-sectional method was undertaken with qualitative data developed from semi-structured interview questionnaires. Ultimately, conclusions are drawn and recommendations are made for the Municipality to implement as well as for students for further research.

2. LITERATURE REVIEW

The majority of Grade 1CE contractors are trapped in one category for longer than is the case in other categories of the RoC. For example, the total number of Grade 1CE contractors registered as at July 2015 was reported to be approximately 24,774 out of 30,293 of the total registrations in the ROC (CIDB, 2016a). In 2017 this number amounted to 37,754 out of 46,838 (CIDB Annual Report, 2016/2017). The reports by the CIDB (2017a) and CIDB (2018a) showed that upgrades of Grade 1CE contractors over the same period have been very slow and have fluctuated between 6% and 10% of the registered contractors. At the same time, reports indicated that 82% of public sector awards by value have been shared between 1,030 Grades 7 and 9 contractors in the recent years (CIDB, 2018b; CIDB Annual Report, 2017/2018). According to Windapo and Catell (2011), the reason has been that most of the available work in the construction industry cannot be sub-divided to cater for the contractors at the lower grades owing to its requirements of high levels of expertise and financial solvency. The study further reported that Grade 1CE contractors still find it difficult to meet the requirements of the financial institutions necessary for the approval of loans since they do not have collateral. According to the CIDB requirements for upgrading, the small contractors are required to execute work that will develop them until they are able to demonstrate the financial capacity and works capabilities demanded by most of the available work.

2.1 Access to work opportunities

In South Africa, there are a number of ways through which small contractors can gain access to work opportunities if there is no suitable work that they can bid on. These include firstly, forming joint ventures (JV) with experienced contractors; secondly, working as a subcontractor under established contractors; and thirdly, through contractor development programmes. For a JV to be formed, both parties must have something that can be of mutual benefit towards their respective goals. This becomes very difficult for Grade 1CE contractors to take advantage of since they have neither expertise nor resources to offer in such an agreement (CIDB, 2016a; Marx, 2014). Furthermore, the number of JVs is limited because there are more Grade 1CE contractors than contractors who can provide such opportunities. Lee and Baldwin (2008) reported that the formation of JVs in the United Kingdom is used "…as an effective measure in limiting their exposure to risks, as well as to acquire expertise and capital to outbid their rivals".

On the other hand, subcontracting is said to be an integral component of the construction industry (CIDB, 2013). The study further estimated that between 25% and 30% of the total project value of civil engineering work is subcontracted out to small contractors (CIDB, 2013). Although it is not clear what percentage goes to Grade 1CE contractors, it has become very difficult for newcomers to enter the market because the main contractors have their own preferred subcontractors. Their preference is influenced by the lower prices subcontractors are paid as well as by the performance they have demonstrated in previous projects (CIDB, 2013). Furthermore, the report noted that price remains the key determinant for subcontractor selection (CIDB, 2013).

Consequently, the formation of JVs and subcontracting work without implementing the NCDP framework becomes a trap and not a mechanism to develop small contractors. To this end, several CDPs were established to assist with the development of small contractors in a facilitated environment to improve their grading status, performance and quality (CIDB, 2018a). These CDPs are established through a "…partnership between CIDB, National and Provincial Public Works and other willing stakeholders and partners" (CIDB, 2011b). The number of small contractors moving up the grade as a result of these CDPs remains unknown, despite their having been operational for many years. The common reasons the CIDB (2011a & 2016a) provides for the Grade 1CE contractors' experiencing constraints to upgrading into Grade 2 or higher include limited work opportunities, lack of job continuity and the fact that contractors do not carry out sufficient work to enable them to move upwards. For contractors to upgrade, the CIDB requires them to execute work which results in the fulfilment of the necessary financial capacity and works capabilities (CIDB, 2017b).

2.2 Financial capacity

The RoC serves as a risk management tool in terms of the work that contractors are capable of doing. For example, the Grade 1 CE contractors are less capable than contractors at the higher categories of the RoC. As such, the Grade 1CE contractor is restricted to executing work that does not exceed R200,000, including value-added tax (VAT). Contractors with Potentially Emerging (PE) status are eligible "…to tender for work at one (1) grade higher than the contractor's registered grading designation" (CIDB, 2017b). For example, Grade 1CE PEs can undertake work to the value of R650,000, including VAT, only when the necessary support is provided. For the Grade 1CE contractors to upgrade to Grade 2CE, the contractors are required to execute work to the value of not less than R130,000. The financial capacity is determined by using the best annual financial history (turnover) from the two financial years immediately preceding the application and the working capital amount that one can muster to sustain a contract, i.e. available capital (CIDB, 2017b). Bank statements normally suffice for Grade 1 contractors. According to the World Bank Group (2018), financial capabilities include "…a combination of behaviours, skills, and attitude that enable effective and responsible financial decision making". The term "financial capability" (Johnson and Sherraden, 2007) does not only involve financial knowledge but it also includes access to financial institutions and services.

2.3 Works capabilities

There are no specific technical requirements that have to be achieved before this requirement is complied with except having experience in a civil engineering class of works. The works capabilities assess the competency standard of contractors before they are awarded a project in order to identify risks as well as understanding their potential to deliver in accordance with the requirements of a contract (CIDB, 2016a). This is demonstrated by a contractor's track record in the form of an appointment letter, a certificate of completion as well as the final payment certificate (CIDB, 2017b).

3. METHODOLOGY

3.1 RESEARCH DESIGN AND METHODOLOGY

The study favoured an epistemological philosophy which is concerned "…with what constitutes acceptable knowledge in a field of study" (Saunders *et al*., 2009). Interpretivism, as utilised in this study, was adopted for its scientific approach that makes it possible to understand differences between the Grade 1CE contractors who are the social actors (Saunders *et al.,* 2009). The theory was developed inductively from themes that emerged during the analysis of the collected data. According to Saunders *et al.* (2009), the inductive approach is concerned with collecting data and developing theory by means of content data analysis. The research strategy that was found to be most suitable is the case study because of its ability to provide answers to the posed research question (Saunders *et al*., 2009). A mono-method was used to solicit data from Grade 1CE contractors through semi-structured interviews over a cross-sectional time horizon.

3.2 Data collection

Semi-structured interviews were conducted with Grade 1CE contractors who participated in the NMBM development programme. The main targets were the contractors with at least three (3) years since the completion of their work packages.

3.3 Population, sample size and sampling technique

The population for the study included Grade 1CE contractors who had received work package contracts from the NMBM EEDSP in the past three (3) years. A database of these contractors was established with information that was solicited from the social facilitators. The social facilitators represented the Grade 1CE contractors to the main contractors during the execution of the work packages. Of the companies that were contacted telephonically and were respectfully requested to be interviewed, nine (9) agreed to be interviewed. The sampling technique followed in this study is the non-probability type. Non-probability sampling was selected because it provides alternative techniques that can be employed to answer the posed research question (Saunders *et al.,* 2009). Consequently, purposive sampling was more suitable and was adopted as a result.

3.4 Questionnaire design and administration

An interview schedule was developed using a set of questions to elicit answers to the posed research question. According to De Vaus (2002), an interview schedule is used to ask people to respond to the same set of questions in a predetermined order. Consequently, the researcher used a prepared schedule to solicit data pertaining to the posed question.

3.5 Data analysis

The transcripts were prepared by the researcher within 24 hours after the interviews. Atlas.ti services were employed to manage the analytical process. The researcher analysed the interview responses from which themes were identified. These themes were then interpreted to produce more detailed descriptions. Content analysis was employed to analyse and interpret these themes and compare them to the literature in order to provide findings of the study that answer the posed question. Data saturation was reached by the ninth contractor and there was no need for further interviews.

3.6 Reliability of data

The procedures that were followed to produce the findings of the study are explained in the relevant sections above. During the semi-structured interviews, the researcher asked the participants the same questions in the same way to achieve reliability. The collected data was carefully analysed until comprehensive themes emerged. According to Saunders *et al.* (2009), reliability refers "…to the extent to which your data collection techniques or analysis procedures will yield consistent findings". This study is the non-probability type which means that the findings of the study cannot be generalised to the whole population (Saunders *et al*., 2009).

4. FINDINGS

The study focused on Grade 1CE contractors who have been given work packages valued at R650,000 each, including VAT, through a CDP in the NMBM. Although this was a suitable opportunity for the Grade 1CE contractors to execute work and prove that they can upgrade in the RoC, the overwhelming majority of contractors who were interviewed noted unfavourable challenges that hampered their development. The themes that emerged from the data pertaining to the first objective were: (1) 'Exploitation' and (2) 'Predetermined profits'.

About the 'Exploitation' theme, the most significant extracts from the interviewees are indicated below:

> "I was exploited by the main contractor. I worked in waterlogged areas and I had to pump water out before I could lay the sewer pipes. I did not claim additional payment for pumping out the water since this work was not scheduled in the bill of quantities that was given to me. I only realise now that I should have submitted a claim for this work. The main contractor kept quiet even though he knew I was doing extra work" **Contractor 1**.

> "The main contractor charged me hours that did not check out with the hours I recorded for the work activities. He could not show me his records when I asked for a proof and he deducted the amount anyway" **Contractor 5.**

> "Material and plant were supplied by the main contractor. I was never given a chance to organise my own plant nor negotiate a fair rate with the main contractor. The main contractor wanted everything to happen so fast [sic]. For example, there was a guy locally that would have given me a better rate but the situation forced me to rely on his plant" **Contractor 4**.

Regarding the ‘Predetermined profits’ theme, the most significant extracts from the interviewees are indicated below:

> “I don’t know how the main contractor measured my work. It did not balance with my own work measurements. I requested a breakdown from the main contractor to no avail. Also, I was amongst the very first subcontractors to be on site and we spent a lot of time than [sic] most of the subcontractors but I received less payment” **Contractor 5**.

> “I did not understand how the main contractor was doing things. How can we all receive the same payment? For example, the main contractor’s surveyor delayed the setting out of the sewer levels for some time and I had to wait. I received no additional payment for the standing time. Also, some of my work was rejected and I redid it. The point I’m making is that I received equal payment as [sic] the other subcontractors” **Contractor 9.**

It is not clear what the objectives of the CDP were. However, the experiences of the contractors indicate that the programme was not properly structured as required by the CIDB (2011b) to provide the Grade 1CE contractors with every chance of success. As a result, the CDP failed to remove the constraints that contractors face under the traditional formation of JVs and subcontracting that is arranged by themselves.

With regard to objective two, although the Grade 1CE contractors were given work packages valued at R650,000 each, the study found that more than half of the contractors failed to upgrade into higher grades owing to their receiving a payment of less than R130,000. The theme that emerged from the data was ‘Lack of finance’. In the extract below contractors are identifying their challenges pertaining to the financial capacity component requirement by RoC for upgrading:

> “My work package required plant and material for execution and that was provided by the main contractor since I did not have a capital for the project. I had no choice but to accept the help I was getting from the main contractor because financial institution don’t [sic] want to finance subcontractors. After the main contractor deducted his money for plant and material, the total payment that was paid to me was less than the R 130,000 threshold required for upgrading” **Contractor 1.**

> “My work package was R 650,000, VAT inclusive. From that contract value, I received a total payment that was less than
> R 130,000. The majority [sic] of the money went to the main contractor for the plant and material he provided” **Contractor 4**.

> “I was subcontracted for construction of gabions. The main contractor provided all material including the plant to dig trenches. He also paid wages for my workers. This is the reason why I did not receive the money equivalent to [the] contract value” **Contractor 7.**

The findings of the study echoed what was reported by Maholwana (2015: 42), namely that small contractors relied on bigger contractors for financial support in some of the Coega Development Corporation projects in order to buy material and to hire plant. In addition, these contractors reported that the work packages relied on resources such as material and plant which forced them to depend on the main contractors for the execution of the work. In return, the main contractors would deduct their dues for the services provided from the contract value and pay the subcontractors the balance. Furthermore, the study established that the contractors who managed to accumulate the R130,000 threshold required by the RoC for the financial capacity component of the requirements are contractors who have completed at least two projects.

About objective three, demonstration of proof of track records such as appointment letters and completion certificates was not identified as a challenge by the overwhelming majority of Grade 1CE contractors. Only one contractor did not receive his completion certificate owing to disagreements he had with the main contractor. The following are the most significant quotes from the contractors:

> “The documents that I have received include the appointment letter and completion certificates” **Contractor 1**.

> “I only received the appointment letter. I did not get the completion certificate. I think the disagreement that I had with the main contractor during the construction stage has to do with this” **Contractor 4**.

The study has found that the overwhelming majority of Grade 1CE contractors are able to demonstrate the works capability component which forms part of the requirements for upgrading in the RoC.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The CIDB requires the Grade 1CE contractors to execute work which results in the fulfilment of the necessary financial capacity and works capabilities (CIDB, 2017b). It is notable that although the work opportunity assisted the Grade 1CE contractors to gain work experience and exposure to the construction industry, the overwhelming majority of contractors mentioned frequently during the interviews that the work packages largely relied heavily on plant and material. That consequently forced them to depend on the main contractors for the execution of the work. In return, the main contractors would deduct their dues for the services provided from the contract value and pay the subcontractors the balance. As a result, the majority of the Grade 1CE contractors failed to accumulate the R130,000 threshold which is a financial capacity component of the RoC requirements for upgrading.

5.2 Recommendations

The CDPs are used as a mechanism to develop previously disadvantaged contractors such as Grade 1CE to improve their CIDB grading status, performance equity and quality, skills development, safety, and health and environment, amongst others (2011c). To achieve this, the NMBM needs to set clear predetermined objectives, goals and targets for the CDP which are established at the outset as suggested by the CIDB (2011a). Further recommendations for the NMBM include the following:

- Play an oversight role in ensuring that work packages provided to small contractors are simple, non-complex and require labour-intensive methods for their execution to make it easier for the contractors to meet the predetermined developmental objectives;
- Employ qualified independent construction managers whose focus would be to develop the small contractors by providing technical support for the execution of the work packages that meet project specifications; and
- Facilitate access to finance for small contractors such as Grade 1CE so that they do not have to rely on the main contractor for capital.

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Employer-Related Causes of Schedule Overruns on Public Sector Construction Projects: The Case of the Eastern Cape, South Africa

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ABSTRACT AND KEYWORDS

Purpose of the paper
The primary objective of the study was to identify the main employer-related causes that lead to schedule overruns on public sector construction projects in the Eastern Cape Province of South Africa. This will enable construction professionals to focus on the most critical employer-related causes in respect of time management on public sector projects, as these projects are funded by taxpayers' money.

Design/methodology/approach
The study is based on a literature review and survey. Existing literature was reviewed to identify the main employer-related causes that contribute to schedule overruns on construction projects. The survey consisted of a questionnaire, which was issued to construction professionals to further investigate the primary employer-related causes that contribute to schedule overruns in the public sector. The data received from the questionnaires were subsequently analysed using descriptive statistics protocols and compared against the existing literature.

Findings
The results indicated that 86% of the respondents were experiencing schedule overruns on their projects, with a delay in interim (progress) payments to contractors being ranked as the primary employer-related cause of schedule overruns on public sector construction projects.

Research Limitations
The study is limited to the Eastern Cape province of South Africa in terms of primary data. Further research is recommended to include other provinces for a larger sample.

Practical Implications
The study highlighted the leading employer-related causes of schedule overruns on public sector construction projects, and further contributes to the body of knowledge on the subject of schedule overrun in construction.

Value of the paper
The paper identifies the major employer-related causes that contribute to schedule overruns on public sector construction projects. These causes should furthermore be addressed as early as the concept and design development stages of a project. The result will be a major decrease in the occurrence of schedule overruns, thereby also improving the overall cost performance on public sector construction projects and subsequently providing more value for taxpayers' money.

Keywords
Construction project, employer, public sector, schedule overrun

1. INTRODUCTION

The South African construction industry operates in a complex project-oriented environment that integrates different investors, employers, consulting professionals and contracting strategies. It directly affects the South African public at large, and its improved effectiveness and efficiency will enhance productivity, quality, monetary value, health, safety and environmental outcomes (Marx, 2014, p. 2). Furthermore, the industry contributes significantly to the national economy of South Africa, as it creates employment and opportunities for enterprises, plays a role in the development of technology, and contributes directly to improving the living standards of the users of its products (Windapo & Cattell, 2013, p. 65).

Aziz & Abdel-Hakam (2016, p. 1516) accurately rationalised the negative effect of time overruns on construction projects by stating that time is money; meaning that a delay in time affects money, which is the lifeblood of an economy. The late completion of construction projects therefore has undesirable consequences on project success in terms of cost, quality and safety (Adugna, 2015, p. 2). This makes it imperative to identify the primary employer-related causes that contribute to schedule overrun, as the mitigation or avoidance of these events or actions will save many valuable public sector projects from turning into losing ventures, if employers and consultants are aware of the implications of their actions and can, therefore, take proactive measures in a timely manner.

2. LITERATURE REVIEW

2.1 The Measurement of Project Performance in Africa

The world has a negative view towards the performance of construction projects in Africa, known as the “African Project Failure Syndrome” (Rwelamila & Ssegawa, 2014, p. 212). The “iron triangle”, which is time, cost and quality, has been the traditional measurement criterion of project success in developing countries (Atkinson, 1999, p. 338; Luu, et al., 2008, p. 759; Nguyen & Chovichien, 2014, p. 22) , with projects that are delivered on time and completed within budget and to technical specifications, being critiqued a success.

Baloyi & Bekker (2011, p. 52) stated that the performance of public sector projects in South Africa is closely monitored in terms of time and cost, as they are objective measurement units that provide numerical results due to project schedules and approved budgets. Quality, on the other hand, is a subjective measurement unit, as it mostly relates to project stakeholders’ needs and expectations of the deliverables (Steyn, et al., 2017, p. 227).

However, this paper will only further focus on the time aspect of project performance.

2.2 The Public Sector as an Employer in the South African Construction Industry

Employers (clients) are the parties that initiate projects and are either public sector employers or private sector employers. The public sector spends funds obtained from taxation, while the private sector uses risk capital, consisting of loan capital and its own capital. With this in mind, Hauptfleisch & Siglé (2018, p. 32) argued that the source of project funding directly influences the conduct of employers.

The various classified types of public sector employers are as follows: central government (first tier), provincial government (second tier), local authorities, municipalities and district councils (third tier), universities and universities of technology, which are self-governed but government subsidised, and public corporations, public companies belonging to the state or under state control, and semi-government institutions (Hauptfleisch & Siglé, 2018, pp. 32-33).

The public sector usually invests in capital projects to provide “services” and strives to make justifiable investments by rigorously applying their own normative guidelines. Furthermore, public corporations in South Africa have recently developed a profit motive for capital project investments, which is due to partial privatisation in certain instances. This tendency should grow stronger in the future, as it is a stated government policy (Hauptfleisch & Siglé, 2018, pp. 33-34).

However, Mbande (2010, p. 218) remarked that there is a skills shortage within South Africa’s state-owned enterprises. The Construction Industry Development Board (CIDB, 2018, p. 26) further regards the capacity of the South African public sector as a major constraint on infrastructure delivery and sustainable growth in the construction industry. This assertion is supported by Ofori (cited in

Windapo & Cattell, 2013, p. 67), who stated that the range and complexity of projects that can be undertaken by a client depends on the expertise and experience of the available personnel within the employer's organisation.

2.3 Schedule Overrun on Construction Projects

The definition of schedule overrun

Schedule overrun, or alternatively time overrun, occurs when project completion happens after the original date contractually agreed upon by the parties (Mukuka, et al., 2015a, p. 1691). Gamil & Rahman (2017, p. 240) expanded this definition by stating that schedule overrun is the additional time required to complete a project after the original or extended date for contract completion. This assertion corresponds to the view of Fugar & Agyakwah-Baah (2010, p. 104), who stated that time overrun should be measured from the original or extended date for contract completion up to the definite date of project completion. Schedule overrun, therefore, occurs when the delivery of a project to the employer occurs after the original or extended contract completion date.

The scale of schedule overrun in developing countries

Endut, et al. (2005) studied schedule overruns on 308 public sector projects in Malaysia. They surveyed professional quantity surveyors who were involved on the projects, with their findings indicating that 79% of the projects were completed late.

Assaf & Al-Hejji (2006) studied the effect of delays on the time performance of projects in Saudi Arabia. They surveyed 15 employers (clients), 19 consultants, and 23 contractors. Their findings indicated that 56% of the consultants and 73% of the contractors experienced an average of 20% schedule overrun on their projects. Furthermore, 25% of the consultants experienced an average of 40% schedule overrun on their projects.

Rahman, et al. (2012) investigated the time performance of projects in South and Central Malaya, otherwise known as Peninsular Malaysia, by surveying 140 industry role-players. Their findings indicated that 92% of the respondents' projects were completed late. However, the average time overrun was reported to be within a 10% deviation of the original contract duration.

The causes of time overrun in Uganda's public sector projects were researched by Alinaitwe, et al. (2013), who surveyed 21 quantity surveyors, 85 architects and 141 engineers. They concluded that the average schedule overrun on the parties' projects was 47%.

Battaineh (cited in Shah, 2016, p. 45) studied schedule overruns on public sector projects in Jordan between 1996 and 1999. The study focussed on 28 road construction projects and 164 building projects, concluding that the projects respectively experienced average schedule overruns of 60% and 20%.

Sweis (2013) also investigated schedule overruns on public sector projects in Jordan. The study focussed on 57 projects by surveying 30 engineers, who indicated that 65% of the projects experienced time overrun.

Okafor (2016) studied the causes of schedule overrun on construction projects in Nigeria. A survey was conducted, with 95 construction professionals responding that consisted of project managers, architects, civil engineers and contractors. The findings indicated that 89% of the parties' construction projects were experiencing schedule overrun.

Employer-related causes of schedule overrun

The existing literature further revealed several employer-related causes that lead to schedule overrun on construction projects. The causes listed in Table 1 (below) were recurring throughout the current research findings, and can therefore be seen as the main employer-related causes of time overrun. Take note that Table 1 lists these causes generally and not in any ranking order.

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Table 1: Employer-related causes of time overrun on construction projects

Nr.	Issues	Description
1	Delay in approving design documents	The employer provides unclear or late information to consultants, which results in the late delivery of design documents for approval. Otherwise, the employer engages inexperienced consultants that deliver the design documents late, or produce design documents with mistakes and discrepancies that needs to be corrected.
2	Delay in approving shop drawings and sample material	The employer provides unclear or late information to suppliers and manufacturers, which results in the late delivery of shop drawings and sample material for approval. Otherwise, the employer engages inexperienced suppliers and manufacturers that deliver the shop drawings and sample material late.
3	Delay in delivering the site to the contractor	The employer hands the site over to the contractor later than the date originally agreed upon.
4	Delay in interim (progress) payments to the contractor	The employer misses milestone payments during the execution of a project. This leads to contractors having inadequate cash flow, which delays the purchase and delivery to site of equipment and materials. Contractors can also not pay their workers' salaries and wages.
5	Design and work change orders during execution	The employer changes the original scope of work by adding work that alters the original completion date of the project.
6	Slowness in decision-making	The employer slows down project activities when he/she does not make decisions on time regarding specific project matters. This could be due to organizational bureaucracy or the use of wrong communication channels.
7	Poor coordination and communication to the project team	The employer has inadequate manpower to properly manage and coordinate a project. This could be due to the the employer not properly assessing whether he/she has the required resources to complete such project. Also, the employer uses the wrong communication channels.
8	Suspension of the works	The employer instructs the contractor to temporarily stop work on all or a portion of a project. This could be due to insufficient funding.

Sources: Assaf & Al-Hejji, 2006; Fugar & Agyakwah-Baah, 2010; Aziz, 2013; Kamanga & Steyn, 2013; Sunjka & Jacob, 2013; Aigbavboa, et al., 2014; Adugna, 2015; Mukuka, et al., 2015b; Aziz & Abdel-Hakam, 2016; Islam & Trigunarsyah, 2017.

3. RESEARCH OBJECTIVE

The primary objective of the study was to identify the main employer-related causes of schedule overrun on public sector construction projects in the Eastern Cape, then ranking these causes in order of importance to raise the awareness level of South African government departments and state-owned enterprises, including their consultants. These role players, as owners and managers of public sector projects, should subsequently be conscious to eliminate or minimize the probability of the identified events or actions in future, as taxpayers' money is used to fund their projects.

4. RESEARCH METHODOLOGY, POPULATION, SAMPLING AND ETHICAL CONSIDERATIONS

The utilization of a self-administered survey achieved the objectives of the study. The purpose of the questionnaire survey was to establish the main reasons for schedule overrun because of the actions, or non-actions, of public sector employers.

However, a literature review identified the employer-related causes that lead to schedule overrun, followed by the forming of the questionnaire based on the compiled list of causes. The questionnaire mostly consisted of closed-type questions, as they are easier to answer and requires less time and little skill from respondents (Zikmund, 2002, p. 333). The questionnaire was setup in Survey Monkey, which is an electronic web-based program, for data collection.

Websites of various departments, organizations and regulatory bodies, which operate in the public sector of the Eastern Cape Province in South Africa, provided the contact information of potential respondents. The identification of respondents was by means of random sampling for professional consultants and contractors, and purposive sampling for employers. Thereafter 110 construction role-players were e-mailed, with the e-mail stating the aim of the research, requesting their voluntary participation in the study, and providing the survey link. The sample size was considered necessary in order to have an accurate reflection of the causes of construction project schedule overruns in the region (Taherdoost, 2017, p. 238). Furthermore, the benefits of an e-mail survey are that it only requires an e-mail address to distribute, and usually provides a high response rate because it requires little effort to answer (Kierczak, n.d.).

The survey response rate was 65%, with 71 construction role-players responding to the survey. This was considered adequate for analysis based on the assertion by Richardson (2005, p. 409) that an overall response rate of 60% or more is both desirable and achievable. The data received from the questionnaires were subsequently analysed using descriptive statistics protocols and compared against the existing literature.

4.1 Characteristics of the Respondents

Construction sector of respondents

The purpose of the first question was to establish the sectors of the construction industry from which the respondents operate. The respondents indicated that 37% were contractors, 31% were representatives from government departments and state-owned enterprises, 26% were professional consultants, and 6% selected 'other', specifying themselves as building inspectors and health & safety agents.

Profession of respondents

The second question aimed to establish the professions, or roles, of the respondents within the industry. The respondents indicated that 34% were quantity surveyors, 27% were project managers, 17% were contract managers, 4% were engineers (i.e. civil, structural, electrical and mechanical), and 18% selected 'other', specifying themselves as building inspectors, health & safety agents, construction managers and project schedulers.

Project involvement of respondents

The third question aimed to establish how involved the respondents were with projects during the current time period. Figure 1 (below) indicates that 36% of the respondents were involved with 1 to 2 projects, 20% were involved with 3 to 4 projects, 9% were involved with 5 to 6 projects, 4% were involved with 7 to 8 projects, and 31% were involved with more than 8 projects.

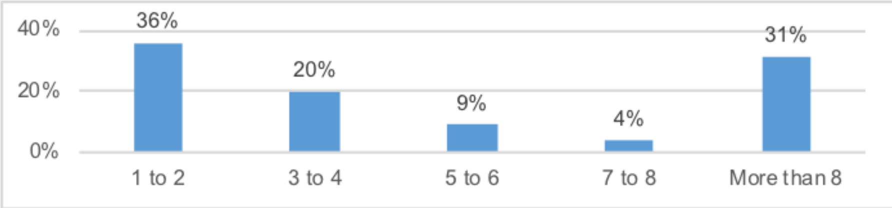

Figure 1: Project Involvement of Respondents

5. DISCUSSION OF THE RESULTS

5.1 Percentage of Respondents Experiencing Schedule Overrun and the Average Percentage of Schedule Overrun

The fourth question aimed to establish how many of the respondents were experiencing schedule overrun on their projects, along with the average percentage of schedule overrun in relation to the original contract durations of their projects. Figure 2 (below) firstly indicates that 86% of the respondents were experiencing schedule overrun on their projects, with only 14% reporting that they did not experience any schedule overrun.

Secondly, 61% of the respondents were experiencing 1-10% overrun, 11% were experiencing 11-20% overrun, 4% were experiencing 21-40% overrun, 3% were experiencing 41-50% overrun, and 7% were experiencing more than 50% overrun. Therefore, 72% of the respondents reported an average overrun of 1-20% on their projects.

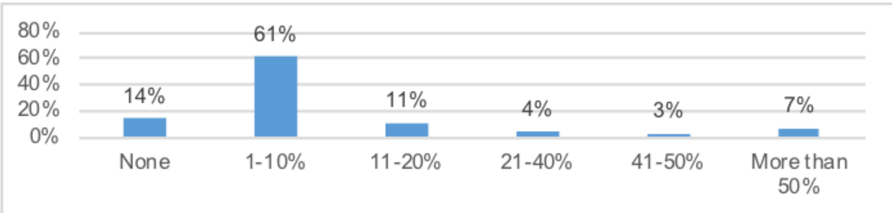

Figure 2: Percentage of Respondents Experiencing Schedule Overrun and the Average Percentage of Schedule Overrun

The findings of this study that 86% of the respondents' experience schedule overrun correlates with the findings of Rahman, et al. (2012) and Okafor (2016), who respectively reported that 92% and 89% of their respondents experienced schedule overrun on their projects.

Further, the findings that the majority of the respondents' experience an average schedule overrun of 1-20% relates with the findings of Rahman, et al. (2012), whose majority of respondents reported an average overrun of 10% on their projects. The findings also generally agrees with the findings of Battaineh (1999) and Assaf & Al-Hejji (2006), whose majority of respondents reported an average overrun of 20% on their projects.

5.2 Ranking of Schedule Overrun Causes

The fifth question aimed to establish the main employer-related causes that contribute to overall schedule overrun in the Eastern Cape Province. The question was based on a typical five-point Likert scale where the respondents had to rate the literature-identified causes as the reasons for schedule overrun on their projects. The scales were as follows: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree, with the causes ranked according to their respective average weightings. A mean score of 3.5 was chosen as the cut-off point for significant causes, as it is equal to 70%, which implies strong support for the cause (factor).

Therefore, figure 3 (below) indicates that the major causes are: (i) delay in interim payments to contractors (4.43), (ii) slowness in decision-making (3.99), (iii) design and work change orders during execution (3.86), (iv) poor coordination and communication to the project team (3.80), and (v) delay in approving design documents (3.61).

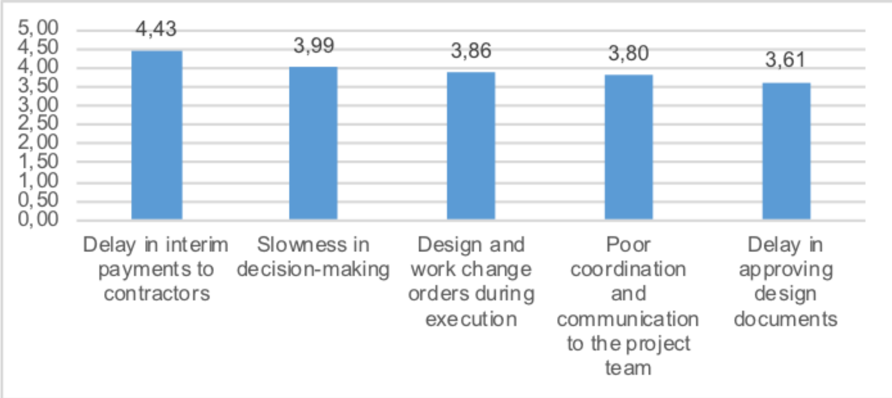

Figure 3: Ranking of Schedule Overrun Causes

These findings agree with the findings of Fugar & Agyakwah-Baah (2010), Aziz (2013), Kamanga & Steyn (2013), Aigbavboa, et al. (2014), and Islam & Trigunarsyah (2017), where delays in progress (interim) payments to contractors was also ranked as their primary employer-related cause of schedule overruns. The findings are also in general agreement with Mukuka, et al. (2015b), except that their primary cause was slowness in decision-making.

6. CONCLUSION AND RECOMMENDATIONS

The study confirmed the findings of Fugar & Agyakwah-Baah (2010), Aziz (2013), Kamanga & Steyn (2013), Aigbavboa, et al. (2014), and Islam & Trigunarsyah (2017), with delay in progress (interim) payments to contractors being the primary employer-related cause of schedule overrun on public sector construction projects.

The results firstly indicated that 86% of the respondents were experiencing schedule overrun on their projects, with 72% reporting an average overrun within 1-20% of their projects' original contract durations. It can therefore be concluded that schedule overruns are extremely common on public sector construction projects in the Eastern Cape, but most of the overruns would not be deemed as severe. Proactive project management that involves contingency planning should be able to avoid these minor overruns in the future.

The results, thereafter, indicated the rank of the schedule overrun causes, with delay in interim (progress) payments to contractors ranking as the primary employer-related cause of schedule overrun on public sector construction projects. It is therefore critical for public sector employers to recognise the extent of their influence on the usefulness of cost planning and cost control. The value of these exercises is rendered useless if funds are misused within their organizations, and the fundamental principle remains that cash flow is the lifeblood of small and medium-sized contractors.

The other predominant causes influencing schedule overrun were slowness in decision-making, design and work change orders during execution, poor coordination and communication to the project team, and delay in approving design documents. It can be concluded that the identified causes of schedule overrun emanates from the projects' inception stages and cannot only be controlled during the construction stages.

In closure, the following recommendations might help public sector employers (government departments and state-owned enterprises) to avoid or reduce time overrun on their projects:

- Ensure that the required funding is available for a project, allow enough time for the consultants to compile a comprehensive cash flow forecast, and work in co-operation with the financing department (or institution) to guarantee that contractors are paid according to scheduled times and agreements;
- Make swift decisions to finalize a project's objectives and details during the concept and final design stages, or to resolve any challenges that may are arise during the construction stage;
- Do proper project planning from the inception stage of a project, with major consideration given to the concept and final design stages. Consultants cannot account for ideas that clients (employers) are undecided on during the concept and final design stages of a project, only for items to be added during the construction stage;

- Apply good project management processes, referring specifically to effective coordination and communication, throughout a project.

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Evaluating the challenges of maintenance of public schools infrastructure in Capricorn district municipality in Limpopo Province

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Sub-theme: Sustainable Construction and environment

ABSTRACT

Purpose of this paper
The study was stimulated by the observation of the condition of the infrastructure of public schools, particularly the ones located in the townships, villages and farms. The physical condition of the public school infrastructure did not appear to be adequate in comparison with the independent schools.

Methodology
A set of questionnaires were distributed to 20 public schools in the Capricorn District Municipality, Limpopo Province. The schools were randomly selected from the database of the Limpopo Department of Education (LDoE) and the National Education Infrastructure Management System (NEIMS). The study reviewed and obtained the experience of the users with regard to the current condition of their buildings and how it affected their planning for maintenance as well as understanding the processes in place for daily maintenance, if available. The questionnaires were dispersed to the school principals, teachers and members of the school governing body. Random sampling was employed and both qualitative and quantitative research approaches were adopted.

Findings
The findings of this study have furnished the current condition of the public school infrastructure and the factors that impede the government planning for maintenance. The implementation of the recommendations possibly will ensure that the life span of the school buildings is prolonged and the learners are educated in a conducive environment similar to that of their peers in privately owned schools. The analysis of the results revealed some of the factors that hinder the planning for maintenance by government pertaining to the Limpopo Department of Education. The factors, which were deemed to contribute the most to the aforesaid, were ranked. The discussion was based on the factors that received the three highest rankings by the schools, namely; that there were insufficient funds to maintain the buildings, non-response to maintenance request and a lack of preventative maintenance methods and standard procedures. Financial resource appeared to be one of the major impeding factor that, if supported by effective planning, could be addressed through the vigilant reprioritisation of funds.

Value
The recommended strategies would address factors impeding the planning for maintenance in the public sector based on the findings of the study. The study validates customs that are effective in realising a sustainable school infrastructure through an effective maintenance management system Effective maintenance systems have been demonstrated to exert a positive effect on the condition and sustainability of infrastructure. This would in turn reduce the backlog of dilapidated school structures and costly refurbishment and rehabilitation.

Keywords: Maintenance, School infrastructure, Sustainability.

1. INTRODUCTION

As suggested by The Department of Basic Education (2011), The primary purpose of the infrastructure programme was mainly developed in order to back the Presidential outcome 1: which deliberated on the schooling 2025 objective of better quality of basic education with the goal that, by 2025, the schools and their teaching and learning surroundings will be set at the new and relevant international best practice level of provision and functionality. The school setting ought to be in a condition to pull in and hold great educators and have the capacity to make a domain that is helpful for education (The Department of Basic Education, 2011).

The state of the buildings does not meet the required standards. Regardless of the processes and policies in place, public school buildings are still in an average condition, some have deteriorated and have a backlog of maintenance work. The research also focuses on sustainable infrastructure which includes a construction built environment at all levels and building maintenance, including immovable asset management until disposal of the structure. Sustainability could be characterized as a capacity or limit of something to be kept up or to continue itself. It is about captivating what one needs to live presently, without risking the potential for one to meet their needs in the future. On the off chance that an action is said to be sustainable, it ought to almost certainly proceed until the end of time (LandLearn NSW, 2015). Sustainability in this context refers to the prolongation of the life span of a building.

Under the Basic Education system, the schools are categorized into 5 groups called quintiles, based on the relative wealth of their surrounding communities. Schools in the poorest communities are classified as quintile 1 and schools serving the wealthiest communities are classified as quintile 5.Quintile 1, 2 and 3 were designed as no fee paying schools and are fully funded by the Government.

The Limpopo Department of Education (LDoE) has in excess of 4 200 school facilities in its infrastructure resource portfolio that should be maintained. The present backlog, as far as Education standards and benchmarks, should be recognized and, in this manner, programs must be created and executed to address this backlog. In addition, these projects must line up with the venture needs of the LDoE and spending plans for each budgetary year (Limpopo Department of Education, 2014). This research project furnishes an overview of infrastructure maintenance constraint analysis and the realization of the prominence of a sustainable school infrastructure. In addition, it proposes a theoretical framework for handling impending factors.

2. LITERATURE REVIEW

According to The South African Institution of Civil Engineering (2011), there are around 24 460 state funded schools in South Africa that would require infrastructure maintenance. However the government concentrated on capital works in zones with next to zero access to education and the upgrading of schools lacking fundamental infrastructural facilities in order to address politically-sanctioned racial segregation inheritances. In this manner, the quantity of overcrowded schools were reduced by half, schools with power access got increased (11 174 to 20 713), water was given to just about 6 000 schools and the quantity of on location toilets expanded to right around 2 000. However, noteworthy infrastructural backlogs remain, particularly with respect to learning facilities (specifically, libraries and laboratories), power and water access. These backlogs exist notwithstanding the requirement for new schools, and the maintenance needs of the present school infrastructure.

The South African Institution of Civil Engineering (2011) also indicated that it has been recommended that the key issues with maintenance and repairs backlogs can be tended to in a couple of ways. Firstly, an organized framework to survey infrastructure and organize required maintenance; secondly, unique models of upkeep, for instance, assigning basic maintenance errands to school staff as opposed to raising them to the level of the district and province; lastly, enhancing aptitudes and capacity at all dimensions.

The literature review herein comprises a study of theories relating to the maintenance of public buildings, infrastructure sustainability, and government asset management policies which results in a conceptual model used to evaluate the maintenance management systems utilized in sustaining the infrastructure of public schools as well as the evaluation of all those factors that contribute to the lack of maintenance. Inadequate and non-existent repairs and maintenance of current infrastructure are a reflection of limited budgets as well as staff and skills shortages, which clearly exert a negative impact on the condition of the infrastructure. The long term consequences include asset stripping and lower service levels that in all likelihood also negatively affect sustainability and economic investment while they raise the likelihood of social unrest (Development Bank of South Africa, 2013).

Adnan, Fauzi, Rahmat, and Supardi (2012) pointed out that legitimate and auspicious maintenance and refurbishments of facilities is fundamental for safe operations and the general economy. Choices with respect to what, where, when, and how maintenance and restoration ought to be performed should be made. While these choices address the conditions, spending limitations and other substantial and elusive issues likewise influence the basic leadership process. Adnan et al. (2012) further highlighted that factors, for example, a deficient spending plan being allotted, inadequate staff, absence of equipped contractual workers, inexperienced maintenance staff, and confused procedures for planning documentation would hinder legitimate maintenance of the infrastructure. In 2011, the Infrastructure Grant to Provinces (IGP) was reorganized in 2011 to enhance the arrangement of provincial infrastructure transfers with part needs, and the Education Infrastructure Grant (EIG) was one of three new contingent grants made simultaneously. The EIG is advantageous financing to provinces to help quicken development, maintenance, overhauling and recovery of new and existing infrastructure in Education. In spite of the fact that the EIG can be utilized for both maintenance and new infrastructure, the manner in which the EIG formula is as of now organized implies that regions with bigger school infrastructure backlogs get more capital (Abdoll & Barberton, 2014).

It was prescribed that to turn around the long haul disregard of school property, structures and grounds, schools should ring-fence 10% of the norms and standards allotment to cover fixes and maintenance of buildings. For a "normal" school of 400 students in a poor zone (Quintile 1), the suggested yearly allotment for 2012 was R384, 000 (400*R960). While 10% of this financial plan is just R38, 400, it was considered adequate to do fundamental repairs in the year according to Government notice number 1017, Gazette 33723 of 5 November 2010 (Department of Basic Education, 2011).

A study conducted by Xaba (2012) showed that maintenance subsidizing was observed to be the premise of facilities upkeep challenges at most schools. Despite the fact that the Department of Education apportions funding to schools, the respondents demonstrated that the allotment is inadequate. Each respondent indicated that the money assigned to schools, the Department apportioned 12% for maintenance, which was "ring-fenced", inferring that regardless of whether maintenance needs surpassed the 12%, schools couldn't utilize reserves allotted for different capacities. The vast majority of the respondents, particularly experienced principals, demonstrated that their maintenance spending plans were higher than the assigned 12% and they needed to raise assets to enlarge the allotted sums.

Xaba (2012) further featured that financing is additionally founded on standards that decide the quintile characterization of a school. As far as these standards, rural schools for the most part get less financing than the alleged quintile 1 schools, paying little respect to the idea of facilities at these schools and the accompanying maintenance necessities. This is the reason most rural schools, while having air conditioning systems, can't make utilization of them. As one respondent expressed, it would be too costly to even consider repairing the systems, not to mention sustain their usefulness.

While detailed costing has not been performed for all the provinces, analysis of the maintenance budgets needed compared to the norms and standards funding for a typical rural province (Limpopo) shows that the funds allocation for quintile 1, 2 and 3 schools is adequate only if each school spends at least half of the funds on repairs and maintenance of facilities. However, schools face competing demands for these funds, for example, to pay for municipal services, extracurricular activities and text books over and above those provided by the Provincial department. However, a multi-year approach will eventually bring all the schools to an acceptable condition. Thus, it is recommended that every school should allocate at least 10 percent of their funding to building maintenance and repairs. To obtain the best value for money, these funds should be used to buy materials where possible while the public works artisans should do the work. Alternatively, the school may use volunteers or service providers to carry out the repairs and maintenance (Department of Basic Education, 2011).

3. PROBLEM STATEMENT

The importance of maintenance is well acknowledged by the built environment at large; however, government departments are still allocating a notable proportion of the annual budget to capital projects. The problem addressed by this study is that regardless of the systems and policies in place, it is not understood why maintenance is not happening in the public schools. In this study, the maintenance systems for sustaining the public school infrastructure are analyzed and evaluated and the various factors that contribute to the lack of planning for maintenance in the public sector are investigated. Therefore, the following specific research questions are addressed:

- What are the various factors that contribute to poor maintenance practice in the public schools?
- How does the public schools perform their infrastructure maintenance function within the existing maintenance system?

Specific research objectives are:

- To recommend strategies to address factors impeding the planning for maintenance in the public sector based on the findings of the study.
- To validate customs that are effective in realizing a sustainable school infrastructure through an effective maintenance management system.

4. RESEARCH METHOD

A set of questionnaires were distributed to 20 public schools in the Capricorn District Municipality, Limpopo Province. The schools were randomly selected from the database of the Limpopo Department of Education (LDoE) and the National Education Infrastructure Management System (NEIMS). The study reviewed and obtained the experience of the users with regard to the current condition of their buildings and how it affected their planning for maintenance as well as understanding the processes in place for daily maintenance, if available.

The questionnaires were dispersed to the school principals, teachers and members of the school governing body. Random sampling was employed as both qualitative and quantitative research approaches were adopted.

Interviews were conducted with six officials within the planning and maintenance units in the Limpopo Department of Education and the Limpopo Department of Public Works, Roads and Infrastructure. The methodology aided in understanding the factors and challenges linked to the lack of planning for maintenance and their approach to planning to attain a sustainable school infrastructure. These have in turn been appraised for detecting strategies to improve maintenance practices. The following sources were consulted: accredited journals, theses and books. The information that was analyzed was mainly historical data. Some Internet web addresses were also visited during the study in order to obtain information from relevant organizations in the construction industry such as the Infrastructure Delivery Management System (IDMS) and the Construction Industry Development Board (CIDB). Previous studies from other countries were also consulted in this study in order to obtain a broader understanding of the importance of maintenance and the challenges experienced in the public sector in view of the fact that challenges faced by the government in other developing or developed countries could be more related to the challenges that are encountered by the government in South Africa. The data for this study were mainly statistically analysed.

The interview results established the crucial contributing factors regarding difficulties in practising effective maintenance management and possible strategies for improvement. Conclusions were drawn after analysing the results of the questionnaire. Ethical issues were censoriously considered and taken into consideration, particularly due to the political underlying forces of the research area. An explanatory method was used where the questionnaires and interviews were conducted on a voluntary basis and the respondents were not asked to provide their names.

5. RESULTS AND DISCUSSIONS

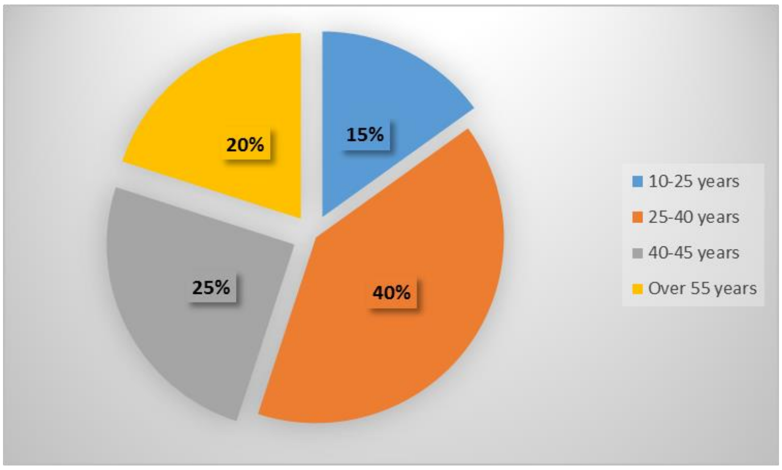

Figure 5.1: The number of years the school have been operational

Figure 5.1 indicates the number of years that the schools had been operational. The majority (40%) of the schools had existed between 25-40 years.

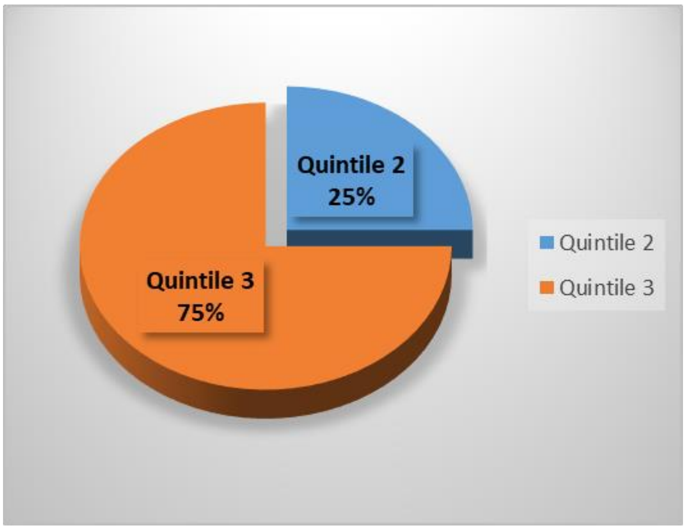

Figure 5.2: Quintile types.

The majority (75%) of the nominated schools were the quintile 3 type schools with 25% being quintile 2 schools.

Figure 5.3: Fee or no fee paying

The schools visited were all non-fee paying

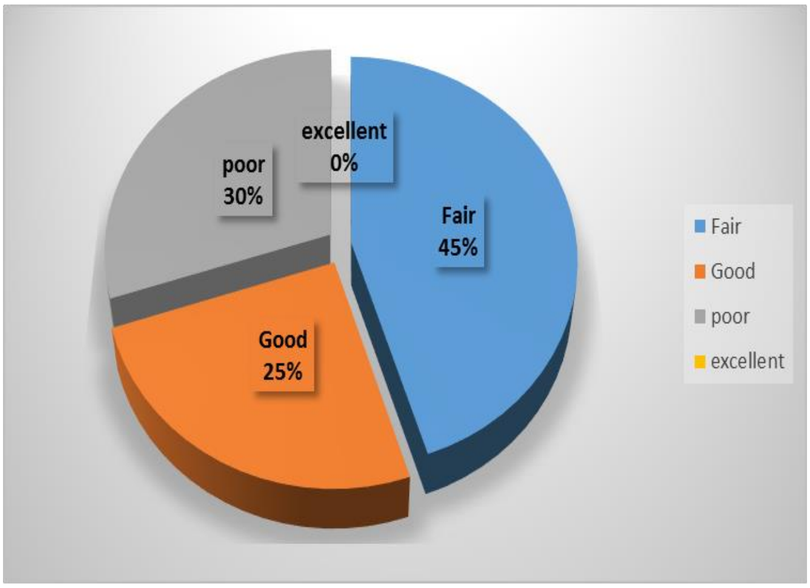

Figure 5.4: Rating of the infrastructure condition of the school

The majority (45%) of the respondents rated their school infrastructure to be in a fair condition.

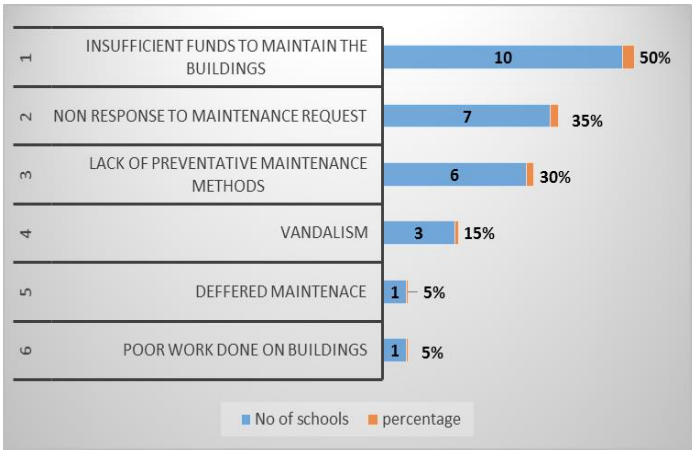

Figure 5.5: Potential elements affecting the infrastructure condition

The respondents were given a list of elements from which to select the likely causes for the current condition of the school infrastructure. The results were ranked in order of the highest potential cause to the lowest according to the number of respondents who selected the specified element. Insufficient funds to maintain the buildings ranked first as the potential cause by 10 out of 20 (50%) of the respondents

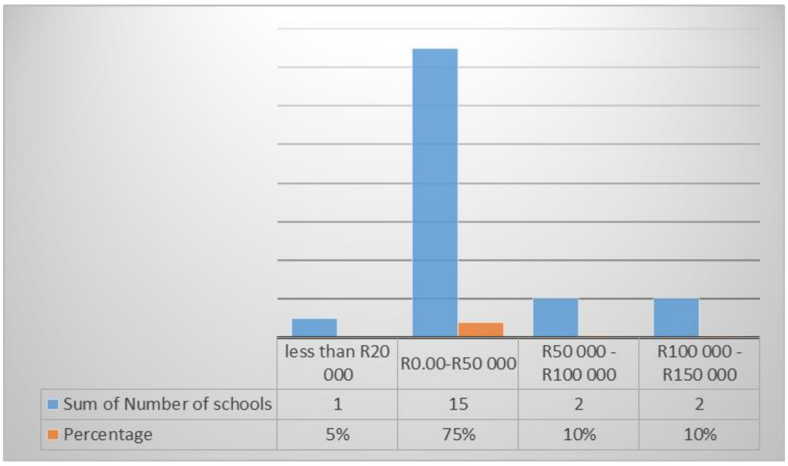

Figure 5.6: Amount of money spent by the school for maintenance of the buildings

The results of the analysis indicate the average amount spent annually by the schools in maintenance of their buildings (Figure5.6). A significant number of respondents (75%) indicated that they spent between R0.00 and R50 000.00 annually for maintenance.

“Absence of adequate funds will compromise the advancement of maintenance works. Maintenance works can't be completed and it will upset all the effort given in the entire procedures of doing preservation” (Adnan et al., 2012).

6. CONCLUSIONS AND RECOMMENDATIONS

The analysis of the results revealed some of the factors that hinder the planning for maintenance by government pertaining to the Limpopo Department of Education. The factors, which were deemed to contribute the most to the aforesaid, were ranked. The discussion is based on the factors that received the three highest rankings by the schools, namely that there were insufficient funds to maintain the buildings, non-response to maintenance request and a lack of preventative maintenance methods and standard procedures.

The current condition of the majority of the infrastructure of the schools, according to the findings of the survey, were in a fair to poor condition. The lifespan of a normal brick structure was indicated to be from 25 – 50 years; however the estimated life span in comparison with the years that the schools have been operational, given the context that maintenance was not executed as required, clearly gives an indication of the degree of dilapidation of the structures.

Considering the current economic conditions of South Africa, the National Treasury has elaborated on numerous occasions that there will not be any increased budget allocations and the provinces should reprioritise their allocations in order to deliver the most essential services to be public. We would therefore recommend to the Department of Basic Education to appropriate the Education Infrastructure Grant (EIG) and ring-fence 50% of the allocations for maintenance purposes. This would allow the provinces to focus on the rehabilitation of seriously dilapidated schools of which the repairs would certainly not be covered by the norms and standards funding.

Secondly, it is recommended that the available financial resources be effectively used by utilising the disaster fund instead of the grant, for schools that are declared to be have been struck by disaster as a result of thunderstorms.

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Examining management structure of public sector organisations for public-private partnership projects delivery in Southwestern Nigeria

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ABSTRACT AND KEYWORDS

Purpose of this paper
The study aims to provide insights into how to develop enabling structural arrangements which are critical to the successful delivery of Public-Private Partnership (PPP) projects by investigating the institutional and legal frameworks, human capital, technical management tools and human resource in Public Sector Organisations (PSOs).

Design/methodology/approach
The study was based on a questionnaire survey of professionals in PSOs in the Southwestern Nigeria, who were sampled through drawing of referral chain by the adoption of Respondent-Driven Sampling (RDS) method. Data collected were analysed using descriptive percentage and mean.

Findings
Key findings reveal that PPP team and project implementation units are the main institutional framework set up for project delivery in the study area. Memorandum of Understanding (MoU) and concession agreement were also identified as the main legal backing for PPP contracts. The alliance of consultant and in-house public sector employees was found to be the dominant human capital for PPP projects delivery. Feasibility studies and public finance analysis were the major management tools adopted for decision making on PPP projects.

Research limitations
The generalization of the findings would be limited both by the relatively small sample and the respondent driven sampling approach adopted.

Originality/ value of paper
The study provides relevant information for enhancing PSOs' management structure which could assist in improving PPP projects delivery.

Keywords: public sector organisation, management structure, public-private partnership projects.

1. INTRODUCTION

A robust management structure constitutes a critical success factor for delivery of PPP projects. This is crucial because of the complexity of PPP project arrangements, network of multiple interdependent actors driven by competitive interests, inflexibility of PPP project by its long-term concession period, complicated and lengthy procurement processes of the projects (Ukwayi et al., 2012; Liu and Wilkinson, 2011). The Planning Commission Government of India (2012) emphasizes the imperativeness of the existence of a well-defined management structure to oversee effective PPP contract performance. Authors such as Scott (1995) built on institutional theory to authenticate that institutional management structures enable PSOs to regulate the activities of the private sector for PPP projects, impose regulations and pursue the achievement of public interests within the context of defined procedures, rules, norms and routines as guiding principles.

World Bank (2016) identified lack of enabling management structure as one of the key impediments to PPP infrastructure development in Africa. For example, the failure of the 20-year concession of the Zambian Railway System was attributed to poor legislative and institutional structure (World Bank, 2016). Existing studies conclude that the causes of poor and non-satisfactory outcome of PPP projects with respect to cost overrun, time overrun and unmet projected demands and benefits lie within the remit of weak management structure of PSOs rather than the private sector (Adukpo and Leiringer, 2016). The poor management structure of PSOs in Nigeria has significantly contributed to unmet expectations of PPP projects delivery, characterised by controversies, court injunctions, revocation of concession agreements, alteration of procurement option and/process, political conflicts of interests, time overrun and partial completion (Opawole and Jagboro, 2016).

The contributions of previous studies on PPP project success lay emphasis on critical success factors, risk management, institutional capacity and governance and framework for infrastructure delivery (Osei-Kyei and Chan, 2017; Jooste et al. 2015). Attention to the management structure of PSOs in PPP project delivery in Africa is limited, particularly in Nigeria. The aim of this study is therefore to examine the management structures in the PSOs in Southwestern Nigeria, with a view to providing information to improve public sector structure for enhanced PPP project delivery.

2. LITERATURE REVIEW

Farrugia et al. (2008) argue that the peculiarity of the management structure that governs the delivery of PPP projects is country-specific and project-type specific. They highlight that slight similarities and contrasts of structures exist in countries which operate PPP agencies and/or PPP units by PSOs. Farrugia et al. (2008) and PPIAF (2007) stress that PPP units form part of the institutionally enabling environment that assist the PSOs in the United States and France in establishing PPP policy; assessing the feasibility of PPP project procurement option; developing PPP market and providing technical assistance for project approval, procurement and contractual matters. Delhi and Mahalingam (2012) postulate that management structures for PPP projects are institutionally established through the creation of *ad hoc* PPP teams work within a single ministry and PPP cells in appointed ministries and departments.

Sajko (2009) asserts that technical resources are important management tools required in the preparation and valuation of PPP projects prior to execution. The technical expertise are; feasibility studies, cost-benefit analysis, users' satisfaction analysis, valuation of the public market demands for public services, public finance analysis and public sector comparator (PSC). PSC, otherwise known as profitability calculation, as a technique commonly used in countries with established PPP institutional structure (Australia, UK, Canada, Netherlands) to quantify the value for money (VfM) in PPP projects (Ismail et al., 2012). EIU (2015) and Harris (2012) indicate that human resources are significant management arrangements in PSOs for PPP project success. EIU (2015) stress that African countries face human capital challenges for PPP projects, which vary according to the country's broader development level. Harris (2012) observe that human capital challenges seem to be changing with the development of dedicated PPP units specific to developing economies. PPIAF (2007) assert that PPP units in the UK and South Africa mostly engage the hands of public sector organisation's in-house employees and only outsource short-term work that requires specific technical expertise and/or hire long-term consultants to work with full-time staff. The PPP unit in India is staffed by independent engineers, finance officers and consultants under the government (Planning Commission Government of India, 2012).

McCann et al. (2014), Mistarihi et al. (2013) and PPIAF (2007) stress that PSOs need human resource with financial, legal, technical, and transaction advisory background for PPP projects to be successful. ADB (2012) opines that the public sector team for PPP project should include engineers, public budgeting officials, procurement specialists, legal specialists, consumer experts, who make decisions on project contract design, construction costs, local counsel, environmental impacts, and accounting and tax implications. The public sector officials in charge of PPP in line ministries and departments as PPP team include director, senior manager, contract manager, executive director, general manager, commercial manager, and contract administrator (McCann et al., 2014). Mistarihi et al. (2013) state that PSOs can boost their human resource strength by employing engineers, consultants and advisor to develop monitoring mechanism and database system. This also requires the practice of encouraging in-house PPP team to work closely with private party throughout the entire phase of PPP development and projects delivery.

Jooste, Levitt, and Scott (2015), Delhi and Mahalingam (2012) and Mahalingam and Kapur (2009) examined the institutional issues related to project governance of PPP projects in the Netherlandish and Indian public sectors. They found that the factors entrenched in the PPP governance framework for successful PPP project delivery in the countries were; clear rationale, legitimacy, trust, balancing interest, political willingness, advocacy, predictability and commitment in decision making and capacity to develop and monitor projects. These institutional factors form the basis for the robustness of management structure in PSOs in the delivery of PPP projects.

3. RESEARCH METHODOLOGY

The study employed a questionnaire survey to capture professionals in PSOs who have handled and/or are handling PPP projects at decision making levels, as such was established to have adequate knowledge on PPP (McCann et al., 2014). This enhanced the credibility of the information supplied. The professionals were architects, builders, quantity surveyors, engineers, lawyers, accountants, and public administrators. The respondents were sampled using Respondent Driven Sampling (RDS) method because the database of the professionals that have handled PPP projects in the Nigerian construction industry is not readily available (Opawole et al., 2019). RDS is an advanced snowballing method adopted in a hidden population known for the difficulty in obtaining information (Salganik and Heckathom, 2004). PSOs constitute a hidden population because information on capital projects is tagged confidential, thus difficult to access for fear of public scrutiny and criticism. A total of 104 questionnaires from the building up of referral chain of professionals were administered in Osun, Ondo, and Lagos State. These states were established to witness increased adoption of public-private partnership procurement system for infrastructure delivery in Southwestern Nigeria (Opawole and Jagboro, 2016). Seventy-seven (77) copies of questionnaire were retrieved, which represented 74.0% response rate and were considered suitable for the analysis. Data collected were analysed using percentage and mean.

4. RESULTS AND ANALYSIS

4.1 Profile of the respondents

The distribution of the questionnaire retrieved were; 18 copies (23.38%) in Osun State, 15 copies (19.48%) in Ondo State and 44 copies (57.14%) in Lagos State. Up to 6 directors (33.33%) who occupied top management positions and take management decisions on PPP projects in PSOs were captured in Osun State, 3 directors (20.00%) were captured in PSOs in Ondo State, and 9 directors (20.45%) were captured in Lagos State. This also included the other categories of top decision makers on PPP projects who were captured by the study in PSOs in the three States. The professionals in charge of PPP projects delivery in the PSOs were accountants who represented 27.78% of the total respondents in Osun State, 33.33% of the total respondents in Ondo State, and 11.36% of the total respondents in Lagos State. Engineers have the percentage representations of 16.67% of the total respondents in Osun state, 13.33% in Ondo State, and 31.82% in Lagos State.

The professionals with Bachelor's degree constituted 50.00% of the total respondents in PSOs in Osun State, 46.67% of the total respondents in PSOs in Ondo State were Master's degree holder, and 45.45% of the total respondents in PSOs in Lagos State were Master's degree holders. None of the respondents in PSOs in charge of PPP projects delivery in Osun State had a PhD degree, but 6.67% and 2.27% of the total respondents in PSOs in Ondo State and Lagos State had PhD degrees respectively. More than half of the professionals (62.4%) had a mean of 18 years of work experience in civil services in the three States. Also, more than half of the professionals (79.2%) in the PSOs in the States had an average of 8 years of work experience in the delivery of PPP projects. Up to 38.89% of the professionals in PSOs in Osun State were involved in education infrastructure, 46.67% of the professionals in PSOs in Ondo State were involved in commercial/market project, while 43.18% of the professionals in PSOs in Lagos State had been involved in road projects.

4.2 Evaluation of Management Structure for PPP Projects Delivery

The findings on the existing management structure in PSOs for PPP projects delivery in Osun, Ondo and Lagos States are tabulated in Table 2 and Figures 1 and 2. The management structure was classified under PPP institutional framework, PPP legal framework, human capital, technical management tools and human resource. The study established that the institutional framework put in place for delivery of PPP projects by the PSOs are PPP units, PPP team and PPP project implementation unit. The PSOs in Osun State operate mostly as PPP team and PPP project implementation unit to deliver PPP projects. The frequency of operation of these institutional frameworks by PSOs in Osun State shows that PPP team (14, 77.80%) is mostly instituted for PPP projects delivery. The PPP project implementation unit (4, 22.20%) was found to operate as both Joint Contract Committee (JCC) and Project Monitoring Unit (PMU) in the delivery of PPP projects in Osun State.

Table 2 indicates that the delivery of PPP projects is institutionalised under PPP unit (1, 6.70%), PPP team (13, 86.60%) and PPP project implementation unit (1, 6.70%) in Ondo State. PPP projects delivery by PSOs in Lagos State is institutionalised under PPP units, PPP team and PPP project implementation unit. PPP team (23, 52.27%) constitutes the most frequently operated PPP institutional framework in Lagos State, then PPP unit (12, 27.27%). The existence of the PPP institutional framework in the PSOs in Osun, Ondo and Lagos State support Delhi and Mahalingam (2012) that PPP projects are institutionally launched via the creation of PPP units and PPP team, which form part of the institutional enabling environment for PPP project delivery as asserted by Farrugia et al. (2008).

Table 2: Management Structure for Delivery of PPP Projects in PSOs

PPP Management Structure	Osun State		Ondo State		Lagos State	
	Frequency	(%)	Frequency	(%)	Frequency	(%)
PPP Institutional Framework						
PPP Units	-	-	1	6.70	12	27.27
PPP Team	14	77.80	13	86.60	23	52.27
PPP Project Implementation Unit	4	22.20	1	6.70	9	20.45
PPP Legal Framework						
Memorandum of Understanding (MoU)	13	72.2	11	73.3	21	47.7
PPP Law	-	-	-	-	8	18.2
PPP Rules	-	-	-	-	3	6.8
Concession Agreement	5	27.8	4	26.7	12	27.3
Human Capital/PPP Team						
In-House Public Sector Employee	4	22.2	1	6.667	18	40.91
Contract Staff (short termed)	-	-	2	13.33	-	-
Consultants (long termed)	-	-	-	-	1	2.27
Consultant and In-house Public Sector Employee	14	77.8	12	80	25	56.82
Total	18	100.00	15	100.00	44	100.00

The PPP legal framework adopted for delivery of PPP projects in all the states are Memorandum of Understanding (MoU), PPP law, PPP rules and concession agreement (Table 2). MoU) (13, 72.20%) and concession agreement (5, 27.8%) were established by the study to be adopted for the delivery of education infrastructure, market and airport in Osun State. The legal framework for the delivery of PPP projects in Ondo State was found to be instituted on the preparation of MoU and concession agreement. MoU (11, 73.30%) was established to be frequently prepared and employed for monitoring and enforcement of standards in PPP projects delivery in Ondo State. MoU, PPP law, PPP rules and concession agreement were the legally established framework for the delivery of PPP projects in Lagos State. While MoUs (21, 47.7%) were mostly prepared and adopted for PPP projects, concession agreements (12, 27.3%) were also frequently employed for delivery of road projects in Lagos State. PPP law (8, 18.20%) and PPP rules (3, 6.8%) were adopted for the delivery of PPP projects in Lagos State as well. The existence of these PPP legal frameworks in the PSOs for PPP projects delivery concurs with the establishment by institutional theory that such frameworks are the guiding principles that control and regulate activities of actors within the context of established policy (Scott 1995).

The public sector organisations' human capital constituted for the delivery of PPP projects in the three states were in-house public sector employees, contract staff (short termed), consultants (long termed), and consultants and in-house public sector employee (Table 2). The study established that the synergy of consultant and in-house public sector employee (14, 77.8%) is often engaged in the delivery of PPP projects in Osun State. In-house public sector employees (4, 22.20%) were also engaged independently to constitute PPP team for the delivery of PPP projects in Osun State. The PSOs in Ondo State was found to partner with their private sector counterpart in the delivery of PPP projects via in-house public sector employees, contract staff (short termed), and consultant and in-house public sector employees.

The collaboration of consultants and in-house public sector employees (12, 80%) was established by the study to dominate the human capital in partnership with private sector for delivery of PPP projects in Ondo State. The alliance of consultants and in-house public sector employees (25, 56.82%) majorly constituted the human capital representation of the PSOs in Lagos State in the delivery of PPP projects. In-house public sector employees (18, 40.91%) and consultants (long termed) (1, 2.27) constituted the human capital for PPP projects delivery in Lagos State as well. The study established that the alliance of consultants and in-house public sector employees were the main PSO representatives in the delivery of PPP projects in the study area. Although, these findings support the assertion by Mistarihi et al. (2013) that PSOs can boost their human resource strength by employing consultants to develop monitoring mechanism and database system and by encouraging in-house public sector employee to work closely with the consultants for delivery of PPP projects, they, however, corroborate EIU (2015) that African countries face shortage of public-sector skills for the delivery of PPP projects.

The technical management tools adopted by PSOs in the study area for the delivery of PPP projects are displayed in Figure 1. These were; public sector comparator, feasibility studies, cost-benefit analysis, users' satisfaction analysis, public market valuation, and public finance analysis skill. The percentage distribution of the various technical management tools indicates that more than one of the technical tools is applied at a time for PPP projects delivery. The feasibility study (16.43.2%) has the highest percentage representation in Osun State. In addition to the adoption of feasibility studies are the use of cost-benefit analysis (9, 24.3%), public market valuation (3, 8.11%) and public finance analysis (9, 24.3%) to make decisions that justify the adoption of PPP procurement option for the delivery of projects in Osun State.

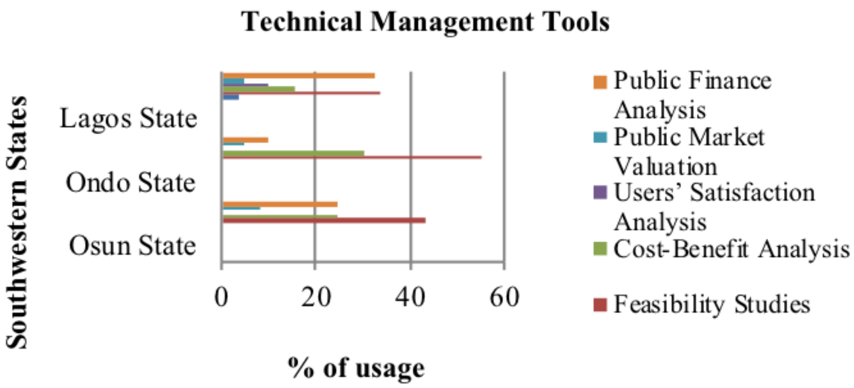

Figure 1: PPP Technical Management Tools

Feasibility studies (11, 55%), cost-benefit analysis (6, 30%), public market valuation (1, 5%) and public finance analysis (2, 0%) were found to be the technical management tools adopted by PSOs in Ondo State for delivery of PPP projects. All the identified technical management tools presented in Figure 1 were established to have been adopted by PSOs in Lagos State for the decision making in the delivery of PPP projects, which is in contrast to what applies in Osun State and Ondo State. The study established that of all the technical management tools adopted for PPP projects delivery in the study area, public sector comparator (PSC) is rarely adopted. This is unlike the case in Australia, the United Kingdom and the Netherlands where PSC is commonly adopted as a technical tool to determine value for money in PPP projects (Sajko, 2009).

The representation of human resource that characterises the management structure for PPP projects is indicated in Figure 2. Results show that different combinations of the human resource characterise the various PSOs as revealed by the responses. The human resource includes professionals in engineering/works department, public budget officials, procurement official/specialist, legal expert, and consumer expert. The study established that public budget officials (13, 27.70%) and legal experts

(13, 27.70%) constituted the highest representation of human resource in PSOs in Osun State in the delivery of PPP projects. The professionals in works department (11, 23.40%), particularly engineers, and procurement specialist (10, 21.30%) represent the human resources that constituted the management structure for PPP project delivery in Osun State. The structure of human resource in PSOs in Ondo State in the delivery of PPP projects is similar to that of Osun State. These are professionals in works department (10, 38.46%), public budget official and procurement specialists (4, 15.38% respectively), and legal expert (8, 30.77%). The study established that engineers in PSOs in Lagos State (23, 29.49%) are well represented in the management structure for PPP projects. Public budget officials (23, 29.49%), particularly the chartered accountants, procurement officers/specialists (16, 20.51%), legal experts (12, 15.38%), and consumer experts (4, 5.13%) were established to characterise the management structure for PPP projects delivery in Lagos State. The low percentage representation of consumer experts indicates that they rarely constitute the human resource in PPP project management structure in the States (Figure 2).

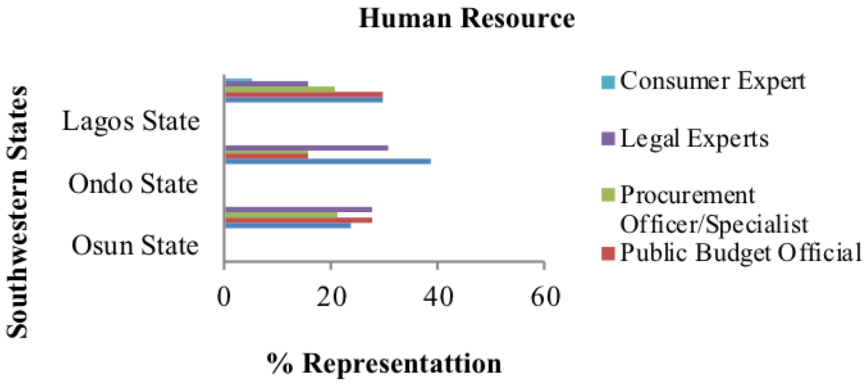

Figure 2: PPP Human Resources in PSOs in Southwestern Nigeria

The representation of the human resource in the PSOs in the study area for PPP projects delivery concurs with the views of McCann et al. (2014) and Mistahiri et al., (2013) on public sector human resource composition for PPP projects delivery, except that consumer experts are scarce supply in the PSOs.

5. CONCLUSION AND RECOMMENDATIONS

The findings of this study established that PPP team and PPP project implementation units which were temporarily created for the delivery of PPP projects are the main institutional frameworks in existence in PSOs in the study area. PPP unit which operates on permanent basis for PPP projects delivery are infrequently established, rather MoU and concession agreement were the frequently adopted legal framework by PSOs. The study revealed that four (4) technical management tools; feasibility studies, cost-benefit analysis, public market valuation and public finance analysis, are used by the PSOs for the preparation and valuation of PPP project. However, the use of PSC which quantifies the value for money in PPP projects is uncommon. Consultants and in-house public sector employees are found to often form a coalition for the delivery of PPP projects and are mostly characterised by public budget officials, legal experts, professionals in public works departments and procurement specialists.

With the identification of PPP units and PPP team in this study as institutional structures that have largely enhanced PPP project delivery, creation of such units and structure in states where they are not presently available is strongly recommended. There is also the need for PSOs to create opportunity for a close working relationship of their employees with the private party counterparts and independent consultants in every PPP projects as a means of developing in-house capacity. However, this learning process must be carefully implemented so as to eliminate any form of opportunistic tendency by the private investors. This study is limited by adopting only a quantitative approach and the relatively small sample and respondent driven sampling method. Further research involving a mixed method is recommended to provide more robust results.

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Strategic Crisis Management in Egypt: An investigation on the role of resilient design in mitigating the impacts of coastal floods

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ABSTRACT

Purpose of this paper
This paper seeks to investigate the fundamental role of strategic crisis management implemented within the Architectural design process to enhance the building resiliency. Adopting this approach will further act as a catalyst towards mitigating the consequences of the rising sea levels. That are triggered on the coastal areas of Egypt by climate change.

Design/methodology/approach
To attain the aforementioned aim, a research methodology comprising of a literature review and a comparative case-study analysis. This research methodology targets the following three main objectives, throughout the paper:

- The construction of a thorough background research by reviewing literature on the main pillars of the research topic: (a) Strategic Crisis management, (b) the architectural design process and the method of integrating resiliency within it, in addition to (c) climate change and its impact on coastal areas in Egypt.
- The comparative analysis of two different case-studies tackling similar incidents. The assessment of outcomes via a summary of the research conclusions with the aim of constructing a list of recommendations. These recommendations would be those which are deemed applicable to the context of the Egyptian coastal areas under threat of flooding.

Findings
A general lack of awareness towards the implementation of crisis management within the architectural design, which is considered a cornerstone towards achieving sustainability. Nonetheless, the accompaniment of resiliency with crisis management has been shown to be a driving factor towards achieving sustainability - especially in areas under threat of impacts induced by climate change. The case-studies assessed show simple design solutions that may be implemented. These solutions would add more precautions by recreating a crisis management strategy with an architectural design in an integrative manner that could be easily implemented onto hazard-prone coastal areas in Egypt.

Research limitations
The scope of the research was solely based on the perceptions on CM and resiliency in Egypt.

Practical Implications
Properly implementing strategic crisis management within ADFs in Egypt would introduce strict resilient design standards fabricated for hazard-prone coastal areas.

Originality / Value
This research investigates strategic crisis management implemented within ADFs in Egypt, a country striving towards sustainable development by introducing resilient design as a fundamental consideration during the design process. In addition to shedding light on the need for interdisciplinary collaboration - between design and management - this paper also promotes the significance of preventative measures against climate change inflicted disasters, focusing on coastal areas and means by which to mitigate disasters through integrative work.

Keywords: Strategic Crisis Management, Architectural Design Process, Coastal Areas, Resiliency.

1. Introduction

The effects of climate change are hazardous today, due to negligence and human error: water levels are rising, and the relative global temperature is increasing (NASA, 2016). In 2011, Egypt published a national strategy, which aims at adapting the country against unforeseen hazards, through the reduction of climate change-induced disaster risks. In accordance with the World Bank, Egypt comes in third place as a highly impacted region by climate change and its side-effects. This being attributable to the Delta basin, a third of which is prone to disaster. For the past decade, the Egyptian government has been directing its attention towards developing frameworks to combat the issue of climate change in the country (The Advisory Committee for Crisis/ Disaster Management and Disaster Risk Reduction, 2010). The importance of this call-to-arms has been expounded on in Egypt's vision for 2030 - a celebrated, and often publicized target year for major environmental as well as economic improvement. Highlighted in this manifesto is the importance of innovative and sustainable structures, however, negligence to mention the integration of disaster consideration and early preparedness is one major blind spot (El-Megharbel, 2015).

In most developing countries today, disaster seldom recognized after disaster strikes, with no on-duty crisis manager responsible for pre-planning and very few responsive organizations to prevent the calamity. In Japan, the number of architectural agencies that consider resilience within their practice have led to an increase in the preparedness and overall mitigation (Minnery, 2013).

On the other hand, contemporaneous and preventable disasters hit Egypt due to the lack of proper site allocation in hazard-prone areas and little attention to resiliency. In order to improve Egypt's resiliency towards rising sea levels that may flood its coastal areas, such prospects should be known and studied at the very beginning of the design process. Herein, this paper aims to investigate the role of strategic crisis management implementation as a catalyst towards resiliency - within the architectural design process. The specific area of interest is in mitigating the impact of floods, triggered by rising sea levels on the built environment in Egypt.

2. Research Methodology

The research methodology comprising of the literature review and the comparative case-studies aspire to attain the objectives sequentially by the succeeding means:

- First and foremost, developing a comprehensive background of the research topic through the investigation of the literature reviews that argues the impacts on climate change on the coastal areas in Egypt. Moreover, the role of resiliency within design through the implementation of strategic crisis management.
- Secondly, the collection of data concluded from case-studies and their analysis that evaluated the different resilient design approaches implemented internationally as well as nationally.
- Ultimately, defining the outcomes of the research and the possible recommendations beneficial for the successful implementation of strategic crisis management in Egypt.

3. Literature Review

3.1 Climate change and its impact on coastal areas

3.1.1 Defining climate change

Consistent with the philological denotation of climate change as stated by Oxford (2019), it is considered an alternation in the planet's weather, predominately due to the surge of harmful greenhouse gases in the atmosphere which incarnates in the form of rapid temperature alterations, deviating wind patterns and precipitation. Meanwhile, the scientific definitions of climate change claimed by the UN's Framework Convention on Climate Change (UNFCCC, 2017) states that it could be recognized for having an unequivocal or an indirect association with human commotion, such activity may modify the conformation of the global environment, witnessed over analogous periods.

3.1.2 Drivers of Climate Change

According to the categorization of the Intergovernmental Panel on Climate change (2014), there are main classes that climate change may instigate from; (a) natural, "anthropogenic" causes, (b) atmospheric intensities of certain emissions and finally (c) global warming which is predominately inflicted by the negligence of human actions.

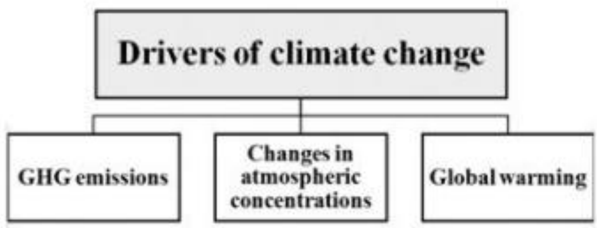


Figure 3.1 Main Drivers of Climate change (IPCC, 2014).

Table 3.1 The 3 main drivers for climate change and their causes. Developed by author.

Driver	Causes
1. Greenhouse gas emissions	These gases form a protective layer from the radiation reaching the atmosphere, yet with the excessive emission of GHG from appliances and other activities humans utilize that produce such emissions, the layer then thickens and cannot avert the radiation back (IPCC, 2014).
2. Changes in atmospheric concentrations	This process occurs subsequently to the driver before it, as the layer thickens, these gases increase, and the balance of the atmospheric gases is Ofsted.
3. Global Warming	The increase in temperature of the atmosphere, transcends into a warming of the oceans. For the past half a century has led to staggering implications on the sea levels, as the icecaps start to melt, which leads to the overall rising of the sea (IPCC, 2014).

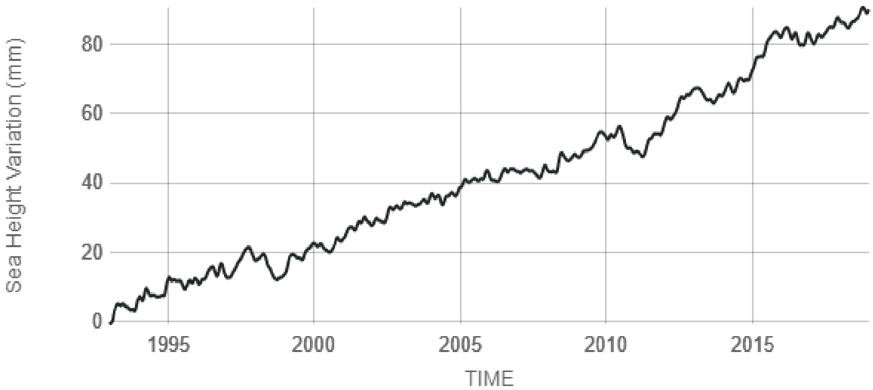


Figure 3.2 Rising sea level in accordance to the latest recording by NASA (2019).

As shown in Fig (2), there has been an appalling incline the sea-height variation since it started to be recorded during the early 20th century. According to NASA (2019), there is an average rate of change of 3.3 mm annually.

3.1.3 Impact of Climate change [Globally vs. Nationally]

According to IPCC-WGII (2007) following figure which demonstrates the areas with extreme vulnerability to the rise in sea levels, the Nile Delta is under extreme threat.

Figure 3.3 Highly hazard prone areas and the vulnerability estimate by 2050 (IPCC-WGII, 2007).

Meanwhile as mentioned by Moufaddal (2013) the figure below shows the most areas that will endure the majority of the rise in sea levels are highlighted where lakes Burullus and Manzala are allocated, deeming them the ones at most risk.

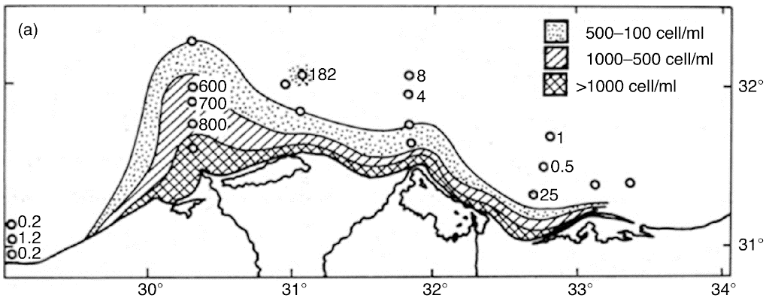


Figure 3.4 Expected SLR by 2050 in the Northern coasts of Egypt (Moufaddal, W., 2013).

3.2 The Architectural design process

The seven phases of transforming an idea into reality begins with the demand or need for a certain type of Building which is usually between the architect or the architectural firm and the client, whatever they may be (The American Institute of Architects, 2019). Usually, this is considered:

Table 3.2 Architectural Design Processes. Adapted from: (AIA, 2019).

Conceptual design	where the contracts and needs of the clients are discussed and then followed by the other six stages which need the constant approval of the client to move forward.
Schematic design	The very beginning of the conceptual phase, where requirements met the creative thought process of the architect and is reincarnated in the form of sketches. Identifying the needed spaces and establishing a proper connection between them, to create plans from the function and later develop the form.
Design development	After all necessary drawings are finalized, they are represented with the appropriate scale and specifications which specify the required budget for finishing (materials, finishes, extra utilities). This is also the final design process and all final amendments are stated here till the final approval and the progression towards construction.
Construction documents	Subsequently to the final agreement, the architect arranges the detailed shop drawings and bills of specifications for the contractor to use as guidance as well as reference for the construction process and its needs. An estimated budget is also fabricated in this stage.
Construction bidding	The stage where the appropriate contractor is selected to carry out the construction process of the project, this is usually the owner’s qualification. However, the architect might suggest. Nevertheless, usually multiple contractors propose their bids and the selection process commences.
Construction administrative stage	The contractor has been agreed upon and selected, and the project commences into the construction phase. it is a duty of the architect to ensure the construction is following the plans precisely.
Project Close out	Usually the schedule indicated by the contractor determines when the project should terminate. Nevertheless, the architect should ensure its legitimacy.

3.2.1 The Concept of Resiliency

According the Resilient Design Institute (2013), Resilience is the aptitude to respond and adjust to altering circumstances, preserve or reclaim regularity in times of disorder. Nevertheless, the role of the architect is overshadowed at certain times. Knowledgeable and qualified architects can pioneer the pathway towards more attentiveness on the study of resiliency within structures, in addition to planning for future hazards by integrating such concepts within the practice, striving for more sustainable shelters. This ideology is further confirmed by FEMA by stating that the main initiative for the design process for an architect should be influenced by the level awareness of the proposed site and whether it can sustain safe structures or not (FEMA, 2006). Subsequently, such investigations could determine several factors that may deem problematic if proper site analysis is ignored, such as: the mass and form of the building.

3.2.2 Resilient Design Approaches

Whilst the design process is a 7-phase procedure, most of the resilient design standards are only applicable for integrating during the first few stages of design. Where the conceptual stage can be influenced by the environment in which it is situated and adapts to it through the resiliency standards and hence giving it its form. In addition to the Schematic and Design Development processes which rely heavily on the final outcome. Nevertheless, it is important to note that the administrative construction stage requires the architect to maintain monitorization of the proposed design.

Table 3.3 Some resiliency design standards according to EM-DAT (2014).

1. Layout & Site Analysis
- Utilize setbacks wisely - Entrances and access to the structure must be apparent and has an alternative entrance for emergency services (police, ambulance, fire department) - Easy access to critical infrastructure to ensure safe accessibility to and from [post-event operability] - Ensuring all hazardous utilises are securely tucked and sheltered - Evacuation areas with appropriated standoff dimensions.

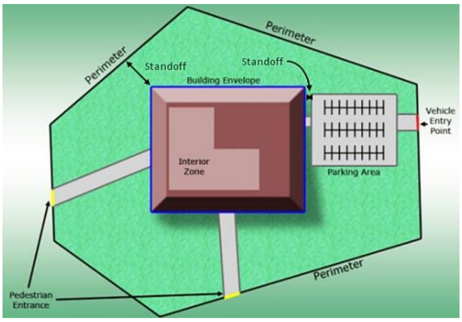
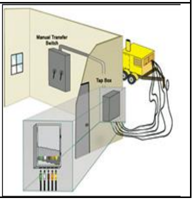


Figure 3.5 Layout regulations for flood resiliency EM-DAT (2014).

2. Passive Design
By ensuring the surrounding safety to the site location, which could be heightened by the use of sustainable elements: •Fixed bollards on the pavements •Fencing or secured Barriers •Street furniture •Retaining walls •Trees and Xeriscaping •Water management elements and landscape as well
3. Active Design
•Street surveillance systems •Electronic automatically controlled systems and notification systems •Pedestrian and vehicle access infrastructure •Standby emergency power •Wireless backup for telephone services •Sump pumps for flooded areas containing critical functions
4. Operational Infrastructure
• Assessed to signify which infrastructure require continuous processes and which do not • Life safety related infrastructure systems should be capable of combating the incidents for a period
5. Building Services
By the addressing the need for resiliency management, recognizing where the main HVAC equipment lies and establishing a relationship matrix to speed the decision-making process.
6. Rippling effects
Integrated Resilient Design Process flowchart shown in the figure below where all possibilities of the Cascading events (CE) are recognized
7. Multi-hazard needs
Specifically, for infrastructure, to ensure that if the crisis escalates, the main urban community can still access any retreat areas,
8. Recovery and Response
• Make sure there is a method of access to the site • Equipment set-up locations must be available for water, power and fire-emergency indicating systems • Backup methods that are securely stowed such as generators 

3.3 Strategic Crisis Management

Crisis management is a process comprised of two main focal actions, the first to grasp and assess any preliminary warning signs and the second is to execute the necessary actions needed to oppress the consequences of the crisis at hand (Sahin, 2015). This denotation is usually specified within the construction industries, where the process is more of a linear sequence.

Figure 3.6 Five fundamental steps towards crisis management. Developed by Author.

Whereas the steps include:
(i) Expectation: the estimation of a hazard due to early warning signals or the predictions grounded from preceding incidents.
(ii) Prevention or Preparedness: planning and development organized by interdisciplinary crisis management teams.
(iii) Control
(iv) Recovery: regarded as a transition back to the norms.
(v) Assessing/ Evaluating: Lastly, this phase tries to facilitate the elimination of ineffective precautions for future relevance.

On the other hand, Crisis management may seem to be a linear prospect; however, it could also be a cycle which is set beneath 3 main stages (pre-disaster, warning phase, post-disaster phase). The 3 main stages include a set of different procedures (Abulnour, 2014).

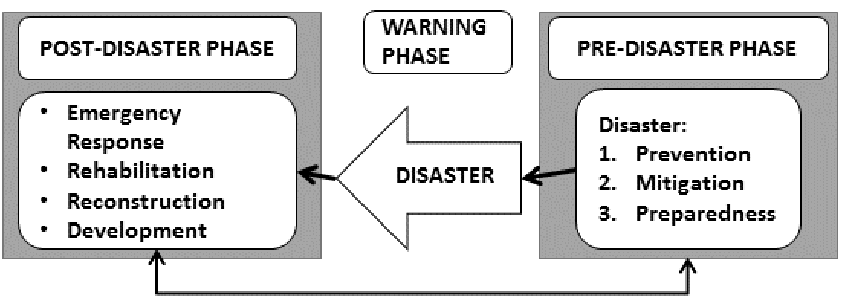


Figure 3.7 Disaster Management diagram (Abulnour, 2014).

3.3.1. Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Reduction & Egypt SDS Vision 2030

Egypt has been on the pathway towards more sustainable development, a series of frameworks have been fabricated throughout the past decade for a better future of the country. The Egypt SDS vision comprises of 3 main pillars; Social, Environmental and Economical. The 3 main pillars expand into 10 main elements distributed upon them. However, the pillar which is the most familiar to this research topic would be the environmental pillar, where there is a priority for the urban development as one of the important factors that ensures the provision of a composed management system for the expansion of communities (Baubion, 2013).

On the other hand, the framework proposed by Egypt's National strategy for Adaptation to Climate Change and Disaster Risk reduction focuses mainly on enhancing the agility of the community to responding to disasters; however, it highlights only the disasters established due to climate change. Moreover, it emphasizes the need to reinforce the needed resources to eliminate such disasters. The strategy is focused mainly on two pillars: accommodation and protection to hazard-prone areas; however, deserts the ideology of resilience (UNISDR, 2015). The vital interventions introduced by the strategy prompt the idea of protection by barriers and erecting other defensible structures. Nonetheless, also neglect to promote more resilient standards within design and renovations (UNISDR, 2015).

3.3.2 Limitations of the existing strategies

The strategy's two main objectives documented to achieve preparedness and response towards disasters are "protection and accommodation". The first limitation is underlying within the main elements in which the strategy chooses to implement disaster management and risk reduction upon. Which vary from water resources, agriculture, coastal zones, tourism, housing, health, roads & fisheries (UNISDR, 2015). The main elements put to inspection are highly profound critical points within any community and are also considered during the processes of crisis management. Nevertheless, the pillar of housing overlooks the concepts of resiliency as an approach, it simply states the improvement of natural elements within existing structures such as daylighting and ventilation.

Alternatively, it does promote the improvement of building codes and regulations in order not to overwhelm the built environment by pilling up structures in a densely constituted region and yet betrays the ideologies of implementing codes and regulations to promote the careful assessment of land for any hazard-prone characteristics prior to the formalization of construction.

Meanwhile, the objectives of protection and accommodation lack the sense of a proactive approach, the methodology for resolving any future hazards are simply reactive procedures taken for temporary resolving of the issues, for instance, accommodation could be considered by re-settling within safe grounds and relocating further away from any coastal line. In addition to protection proposed through the erection of gigantic barriers to absorb the shocks of the disasters. While the anticipated resolutions within the strategy cover obstructions that may hinder disaster prevention, the strategy lacks clear assessment of the core issues through temporary instead of prolonged resolutions (UNISDR, 2015).

3.4 Relationship between the literature pillars

Connecting all research pillars together, it becomes apparent that the role of the architect exists before or after an impact which in this case would be coastal flooding due to climate change. The Design process integrated with resiliency is shown in the form of the blue arrows, and hence, highlighting the position of architecture within the context of disaster.

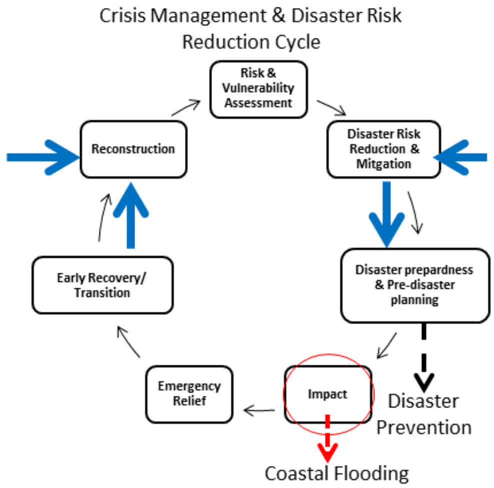


Figure 3.7 Relationship between the pillars of research. Developed by Author.

4. Case-studies

4.1 Overview of the case studies

The case-studies investigate the two out of ten types of mitigation approaches that usually adopted to lessen the potential impacts on coastal areas. The first type of case-study is internationally based and reviews the adoption of flood-resilient design through the accommodation for the estimated SLR as well as the multiple functionalities that the structure is flexible to lodge. Meanwhile, the second case-study analyses the region within the Nile Delta with the most expected amount of hazard: Abu-Qir Bay and suggests an innovative approach through very large floating structures (VLFS). Findings from both case-studies constructed a comparative study which outlines the plausible and most feasible adaptations illustrated in the table below.

4.2 Comparative analysis of case-studies

The case studies were analyzed accordingly to a set of attributes which detain the degree of effectiveness, in addition to representing the responsible bodies necessary for adequate implementation:

Table 4.1 Comparative analysis between two case-studies. Developed by Author.

Case-Studies	
International	**National**
Coastal- front of New York City, US (NYC Department of City Planning, 2019)	Abu Qir Bay, Egypt (A.A. El-Shihy, J.M. Ezquiaga, 2019)
Proposed Solution	
Elevated Structures	Very Large Floating Structures (VLFS)
Description	

Adapt to the different expected SLR through erecting the building and utilizing the space underneath in a flexible manner to maintain feasible after an impact		Architectural Design Concept & Guidelines for Floating Structures as a solution for the Sea-Level Rise (SLR) impacts
Anticipated Impact		
Environmental	0.2-1 % increase in floodplains within 30 years (0.6 m SLR)	0.5 – 2 m SLR
Social	• 4-15% expected Land loss • 45 – 81 k dwellings • 350-435 k residents	• Whereas the Nile Valley composes only 6% of the total area of Egypt (6.1 million inhabitants at risk in the occurrence of a 1 m SLR) • The remaining land is 94% uninhabitable desert • An increase in the Delta region erosion
Economic	Essential infrastructure & commercial buildings at risk & halts main transport routes (e.g. underground)	In & offshore strategic economic activities declination
Hazard-Triggering characteristics		
Climate change that increase the SLR and increases coastal flooding		
The recorded history of the activity of: + the neighboring masses of water + any possibility of erosion, alteration, topography or bathymetry of the floodplain susceptible to tropical Hurricanes (previously Irene in 2011 & Sandy in 2012)		• Land subsidence issues while there is a rise in sea-levels which is expected to lead to a submerged Nile Delta Coastline • The continuation of usage of traditional mitigation solutions which are not sustainable nor designed for long-term • Considered the most vulnerable and susceptible region to SLR within the Nile Delta region • (a) It suffers from “eutrophication” and pollution, due to the existence of Abu Qir Fertilizers and Chemicals Industries Company which produces nitrogen fertilizers situated on that bay.
Main Priorities		
Ensuring liveability & maintaining good Quality of life		proposing a more sustainable. Long-term & cost-effective alternative to land reclamation

Process	
1. Considerable measures towards flood risk within hazard-prone areas. **2. Building codes and regulations** must consider the degree of elevation required, also known as the “Freeboard”. **3. Urban design** must be taken into consideration based on the individual work of architects and designers to provide proper pedestrian areas.	1. Examining the existing coastal management solutions proposed by the 2. Site Analysis of Abu-Qir region concluded it to be the most vulnerable area within the Nile Delta 3. Selecting the most appropriate mitigation solution to the area with regards to
Application	
Zones divided according to the expected SLR (Table.) Land usage divided into 5 main categories where small dwellings are considered category I, escalating to category IV which defines the essential infrastructure Base Flood Elevation (BFE) = Design Flood Elevation (DFE) (BFE) increase by 1-2 m according to building occupancy	1. Coastal areas 2. Low-lying areas 3. small islands Applying all the research into adapting a "floating self-sufficient" community utilizing the technology inspired by oil mils
Advantages	
Elevated structures allow for parking, access to building & could be utilized for storage due to the permitted utility below (DFE) enhance the innovation of streetscapes that are functional and aesthetical provides flexibility with mechanical equipment through sheltering it in upper storeys Dry proofing of the DFE allows for the building to be utilized for non-residential purposes	findings conclude it to be the best solution for Abu Qir which would be costly to fill with sand (land reclamation) Site-suitability & flexibility due to the modular system of prefabricated elements which facilitate the construction, assembling and reassembly conserves fragile eco-systems as well as safeguards borders along with their habitats Protects in & offshore strategic economic activities by having flexible ports
Limitations	
Residential buildings are not allowed usage below DFE for safety	lacks long term national analytical SLR scenario & proper assessment

5. Recommendations

For the purpose of implementing proper resiliency standards, there are a set of recommendations that might come in handy while considering the possibility of mitigating floods.

Zoning

Utilized for the purpose of moulding buildings, in addition to fostering better design towards flood defence.

Elevation heights

I. Levels should take into consideration the freeboard and the equivalent protective measures.
II. Implement the architectural aspects and streetscape to act as an optical illusion between the elevated floor and the street.
III. Show access elements as much as possible on the exterior and the interior
IV. Provide enough flexibility with the mechanical equipment to be placed on upper levels so that in the case of a flood, everyday life activities could be maintained and resumed.

Table 5.1 Further General Recommendations

For Architects/ ADFs in Egypt: - Adopting resiliency within the design process and establishing its basic needs for the construction and maintenance stage. - Enhancing the urban resilience as well as the community resilience through the interdisciplinary participation to increase the awareness on the matter. **Local Authorities and governments:** -Establish conversion and adaptation policies -Strictly implement policies regarding hazard-prone areas -Promote the resilient design standards as part of the building codes and regulations -Monitor the coastal structures at regular intervals -Implement strategies for coastal zone management

6. Conclusion

All things considered; the comparative case-study analysis serves as a sound practice for practical solutions to the future hazards that may instigate due to the climate change. The need for adaptation instead of re-construction is a solution considered by the coastal area of NYC. However, damage may have brought the region to chaos, it also led to the focus on the prominence of the flood-resistant construction regulations and standards in areas like so. The preposition of elevating the structure away from the expected levels that occur due to the floods is undoubtedly a solution that will immensely reduce both the socio-economic impacts on the built environment as well as lead to less environmental damage as less structures collapse and demolish. Nevertheless, it is feasible to consider the negative impacts that may lead to undesirable visual patterns of the streetscape or the urban environment and find adequate solutions to add aesthetical value to them. Meanwhile, although Egypt is not of geographical coordinates that lead it to being an area prone to the natural disasters as New York, it is edged on the North by the Mediterranean Sea and centrally lined with the Nile River, both bodies of water that could become an instant threat to residents of the surrounding areas. Nevertheless, the solution proposed does not highlight the type of storm, yet solely focuses on how to alter its impact by adapting the frontline structures towards resiliency and moulding them to working with the disaster, not against it. With the strategies that the Government and international organizations are collaborating for towards a paved road of resiliency, it seems useful to introduce some tangible solutions that pivot around the role of the architect within a community that depends on their visions for safety.

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Validating a Framework of Transportation Infrastructure Project Sustainability Measures

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Abstract and Keywords

Purpose of this paper
Transportation infrastructure contributes significantly to any economy. However, the long-lasting nature of such projects is threatened if sustainability elements are not taken cognizance of during the planning and operation stages of the projects. The objective of the current study is to validate a structure of transportation project sustainability measures to evaluate projects and ensure continual delivery of intended benefits in the long run.

Design
Empirical data were collected using a field questionnaire survey developed from literature review and a preliminary qualitative inquiry. A total of 132 built environment professionals were included based on purposeful and snowball sampling techniques. A model-generating confirmatory factor analysis was undertaken to validate underlying structures of sustainability measures.

Findings
The findings validated that a four-factor structure, with eleven variables, could adequately measure transportation infrastructure project sustainability (PS). The CFA structure achieved construct, convergent and discriminant validity, with fewer variables than theorised and established in the exploratory factor analysis.

Value
The validated four-factor structure is envisaged to be beneficial to transportation infrastructure project stakeholders in better decision-making with regard to selecting worthwhile projects as well as monitor operational projects with the aim of delivering long-term benefits to generations of users.

Keywords: Confirmatory factor analysis, infrastructure, South Africa, sustainability, transportation

1. INTRODUCTION

Transportation plays an essential role in countries' competitiveness, through employment and income creation, balanced and livable spatial development, access to water and energy, and food security, and is critical for social inclusion and improved quality of life, enhances economic development and growth (Friedrich and Timol, 2011; Chen and Cruz, 2012; Vilana, 2014; United Nations, 2015). However, such projects are fraught with uncertainties, which if not considered during the planning of the projects and/or continuous monitoring to sustain intended performance, is detrimental to the immediate community and society. Sustainability performance across the life cycle of an infrastructure project is a crucial aspect in achieving the goal of sustainable development (Amiril, Nawawi, Takim and Latif, 2014). Sustainability enables sound economic development, job creation and productivity; enhances quality of life; and promotes a more efficient and effective use of financial resources (investors' margins) (Montgomery, 2015). However, sustainability of infrastructure is hampered by lack of finance, governance and policy problems, planning inefficiencies and technical capacity (Bueno, Vassallo and Chueng, 2015). This then behooves transportation planners, policymakers and indeed researchers to find ways to maintain sustainability of such projects. Therefore, research on transportation infrastructure project sustainability is paramount in order to ensure that projects continue to deliver intended benefits to generations of users.

Although previous studies have explored key sustainability and performance elements, the focus has been singularly on one aspect. For instance, Amiril et al. (2014) developed a framework for railway infrastructure in Malaysia while Gamalath, Perera and Bandara (2014) and Park, Mount, Liu and Xiao (2019) focused on environmental and social sustainability aspects, respectively. Yu, Zhu, Yang, Wang and Sun (2018) conducted a simulation analysis using system dynamics, but focused on effectiveness of transport policies. Further, Amiril et al. (2014) employed a literature review for their study and although Wai, Yusof and Ismail (2012) applied factor analytical techniques to determine important project success criteria, sustainability was regarded as a secondary factor. This is inadequate since failure to address sustainability risks on projects is likely to result in long-lasting and potentially irreversible impacts on wellbeing, health and the economy (Bhattacharya, Oppenheim, and Stern, 2015). Thus, for projects to be sustainable, there are key elements or conditions, which must be extant.

Therefore, with limited studies, which holistically cover sustainability elements, the objective of the study was to validate critical project sustainability (PS) indicators for transportation infrastructure. The study employs confirmatory factor analysis to validate the underlying structure of sustainability indicators (Okoro, Musonda and Agumba, 2019). The study provides a reliable tool for ex-ante and ex-post evaluation of transportation infrastructure projects in order to ensure that lasting benefits are obtainable for generations of users.

2. TRANSPORTATION INFRASTRUCTURE PROJECT SUSTAINABILITY MEASURES

A plethora of infrastructure sustainability indicators exists in different contexts and sectors. Rating systems and assessment tools (LEED, CEEQUAL, INVEST, GreenLITES, etc.) have been used. However, they focus on singular elements, either environmental, or economic assessments and therefore fail to fully address all components of sustainability holistically (Bueno *et al.*, 2015). They are also usually based on historical trends and relationships and thus could be biased (Lyons and Davidson, 2016). Essentially, sustainability assessment measures should possess representativeness to cater for the complexity of factors that must be considered in infrastructure sustainability (Cottrill and Derrible, 2015).

Sustainability integrates the useful operational life, technical or structural quality, project leadership, and natural resource management (Jeon, Amekudzi, and Guensler, 2010; Friedrich and Timol, 2011; Kaare and Koppel, 2012). A cornucopia of factors was therefore identified from extant literature as indicative of sustainability. These were used to develop variables (twenty-eight, grouped into six factors) (Table 2.1), comprising:

- socio-economic environment (SE1 – SE8) (including *there are no complaints about travel times; there are no complaints about user discomfort during travel; there are no complaints about* *inconvenience during travel; there is no competition between different modes of transport; property values have increased after the infrastructure was built; new business ventures have developed after the infrastructure was built; infrastructure is accessible by all including the disabled and elderly; demand for the infrastructure services is as expected);*

- financial factors (FI1 – FI3) (including *capital invested has been recovered; there are no complaints about maintenance resources; there are no complaints from investors about revenue*);
- condition of physical infrastructure (CI1 – CI4) (including *the infrastructure is in good condition; there are no complaints about the cleanliness of the infrastructure; there is no traffic overload; the infrastructure, in its present condition, is able to withstand common adverse weather*);
- safety and security (SS1 - SS5) (including *signage for safety is adequate; fencing (median) is in place for safety; security officers are visible; security cameras are in place; formalised sidewalks are in place for pedestrians*);
- stakeholder satisfaction (ST1 – ST5) (including *the needs of the stakeholders are satisfied; users are satisfied with pricing/charges; there are no operational problems; the actors are able to work in collaboration with other stakeholders; there is clarity of responsibilities among partners*, and
- service quality (SQ1 – SQ3) (including *management responds quickly to user complaints about infrastructure services; management responds quickly to user complaints about safety incidents; the infrastructure services (rides) are predictable*).

(Jeon *et al.*, 2010; Dhingra, 2011; Quium, 2014; Cottrill and Derrible, 2015; Pavlina, 2015; Litman, 2016).

3. METHODS

The study presents quantitative results from a sequential exploratory research approach, whereby the results from a qualitative multi-case study phase was used to develop, test and validate a framework of transportation infrastructure sustainability measures in the quantitative phase (Darke, Shanks and Broadbent, 1998). Data were amassed from 132 respondents selected through purposive and snowball sampling techniques, comprising Built environment professionals in the nine provinces of South Africa, involved in transportation projects, at the feasibility and/or operational stages. The respondents comprised 69% public and 31% private entity professionals. These were directors, deputy director and heads of departments (25%), project managers (15%), engineers (12%) and safety officers (10%), executive/deputy managers (8%), development managers/ agents (6%), feasibility study consultants (4%), quantity surveyors (4%), planners (4%), academics (3%), and technical assistants on projects (2%) on road, bridge, rail, airport and tunnel projects. Prior to data collection, ethical clearance from the university authorities and consent from the respondents' superiors, were obtained. The questionnaire, distributed by hand and online (email and google forms), sought information on a five-point Likert scale, with responses ranging from 1=strongly disagree to 5=strongly agree.

Data was analysed using AMOS software version 25, because it was able to read SPSS data as an input and accommodate plugins for automatic programming and building of a series of paths (Nokelainen, 2007). The maximum likelihood method (Carter, 2006). Preliminary considerations in terms of missing data (treated using mean imputation), sample size, univariate and multivariate normality and outliers (using univariate skewness and multivariate kurtosis (*Mardia's* coefficient), as well as Mahalanobis d-squared distance tests, which should be ≤ 1.0 and < 1.96, respectively, definability of the model (degrees of freedom, *df*, which should be positive (greater than 1), theoretical specifications, method of estimation (maximum likelihood), model fit criteria and modifications were undertaken (Byrne, 2001; Awang, 2012). A sample size of 132 was considered sufficient, with a ratio of 5 to 1 (Kenny, 2015). Seven outliers were deleted

The model-generating CFA was thereafter undertaken to determine the model of factors that best fit or represented the data underlying the theory. Hu and Bentler's (1999) two-index presentation strategy was adopted, using both absolute and comparative fit indices, including Comparative fit index (CFI) (close to 0.95 or $\geq$ 0.90), Relative chi-square (CMIN/df) (χ^2 *to df* ≤ 2 or 3). Standardised root mean square residual (SRMR) (> 0.05 to 0.08; the lower the better), and Root mean square error of approximation (RMSEA) (Close to 0.06; 0.08 – reasonable fit; > 0.10 – poor fit) (Hu and Bentler, 1999; Schreiber, Stage, King, Nora and Barlow, 2006; Iacobucci, 2010).

Other assessments for model suitability included examination of the standardised residual matrix (items with high correlations above 1.0), factor loadings or variance explained in the model ((squared multiple correlations below 0.5 were problematic items), and the modification indices (items that may be redundant in the model). Items were deleted iteratively and the model rerun, bearing in mind that item deletion may not exceed 20% of the total number of items and latent constructs should have at least two or three items. Statistical significance of the parameter estimates (squared multiple correlation and factor loadings less than 1.0, and the critical ratio values, akin to *Z* statistic greater than 1.96 at the 0.05 significance level) was also assessed (Byrne, 2006). Reliability and validity were also checked using Cronbach alpha, composite reliability (CR) and average variance extracted (AVE) and the results are presented in a later section.

4. RESULTS AND ANALYSIS

The CFA analysed the relationships between the latent constructs and their variables as presented in the input diagram in Figure 4.1, using the 125 cases remaining (data set with outliers deleted). The rectangles are the observed variables or indicators of each latent construct. The ovals represent the latent constructs. The error terms for each observed variable are represented as circles. These are residual or error variances, which uniquely cause response variations in the observed variables. The results of the model-generating CFA are presented hereunder.

4.1 Initial Project Sustainability Model Fit Analysis

The initial evaluation of the PS input model showed that there were no high correlations (exceeding 0.80) between the latent constructs. This indicated that there was discriminant validity for the PS input model. The model fit indices for the first run (Table 4.1) showed that the chi-square was significant (χ^2 =203.084; p=0.000), indicating that the postulated model was significantly different from the sample data. Other indices revealed that CMIN/*df*=2.860 (cut-off value= ≤ 2 or 3), CFI=0.888 (cut-off value= $\geq$ 0.90), SRMR = 0.0687 (cut-off value = > 0.05 to 0.08), and RMSEA=0.122 (cut-off value = 0.09). The CFI and RMSEA values indicated that the hypothesised model did not match the data. However, the SRMR, which informs on the degree of discrepancy between the hypothesised model and the sample data, was acceptable, indicating that the PS input model matched the data. Nevertheless, an examination of other output from this first run was undertaken to determine if the model fit could be improved.

4.2 Diagnostic Fit Analysis and Model Modification

An examination of the standardised residuals covariance matrix revealed that there were no high residual covariances (above 2.58). However, SE6 and SS1 covaried with four and three other items in the model, respectively, with values more than 1.0 and they were deleted successively. The model fit indices (Table 4.2) showed the results after the deletion. It was notable that the model fit improved significantly after the third run with CMIN/df = 1.986, falling below the recommended 2.0, CFI = 0.949, close to 0.95 (cut-off value > 0.90), RMSEA = 0.089 (cut-off value = < 0.09), and SRMR = 0.0586 (cut-off value > 0.05 to 0.08). Based on the two-index presentation strategy advocated by Hu and Bentler (1999), the model after the third run was observed to be an excellent fit to the sample data.

However, the item ST2 was found to have a low contribution of 34%, indicating that the item was contributing more error variance than explained variance in the model and it was removed and the test rerun. The final model (Figure 4.1), displayed acceptable fit (Table 4.1), with values within the recommended ranges: CMIN/df = 2.087 (cut-off value < 2 or 3), CFI= 0.95 (cut-off value > 0.90), RMSEA = 0.094 (cut-off value 0.09), and SRMR = 0.0570 (cut-off value > 0.05 to 0.08). These results indicated that the hypothesised PS model matched the sample data by 95% and with a residual value of 5.7%, the model can be deemed to be an excellent fit to the data. It was notable that approximately 20% of the number of items (three out of 14) were deleted, and this was observed to be permissible in a model-generating CFA (Byrne, 2001; Awang, 2012).

Table 4.1: Model fit indices for first and final PS model

Fit indices	Cut off value	Estimate (input model)	Estimate (final model)	Comment
Chi-square χ^2		203.084	85.579	
Degrees of freedom *df*	> 0 ; positive	71	41	Acceptable
Relative chi-square (CMIN/*df*)	≤ 2 or 3	2.860	2.087	Acceptable
Comparative fit index (CFI)	≥ 0.90	0.888	0.950	Acceptable
Standardised root mean square residual (SRMR)	> 0.05 to 0.08	0.0687	0.0570	Acceptable
Root mean square error of approximation (RMSEA)	< 0.09 – good fit < 1.0 – reasonable fit	0.122	0.094	Acceptable

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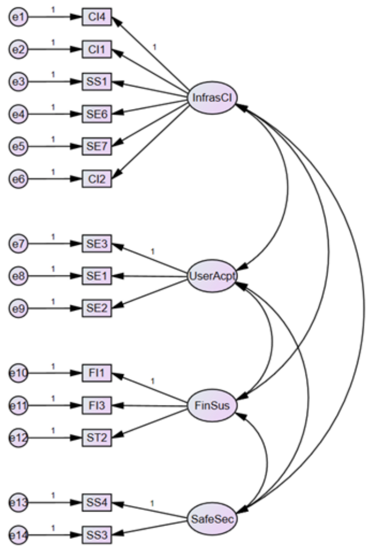

Figure 4.1: CFA input model

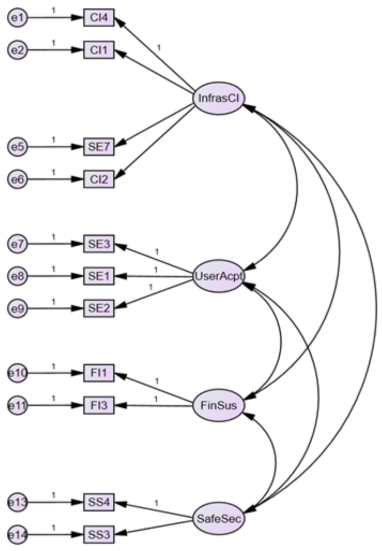

Figure 4.2: Validated model

4.4 Statistical Significance of Parameter Estimates

An examination of the factor loadings (regression weights), standard errors and critical ratio estimates was undertaken to determine if the model parameters were statistically significant (Byrne, 2006). The PS final measurement model parameters exhibited statistical significance with the squared multiple correlations values all less than or equal to 1.0 and therefore reasonable. The parameter estimates had high correlation values (above 0.4). The correlation values suggested a high degree of linear association between the indicator variables and their latent constructs, and therefore reasonable.

In addition, the critical ratio test statistic, analogous to *Z* scores, was used to test the significance of the parameters. The critical ratio, which is the parameter estimate divided by its standard error, had to be greater than 1.96 at the 0.05 significance level for it to be said to be statistically different from zero and considered significant. Table 4.2, containing the parameter estimates, showed that the critical ratio values were all above 1.96 and therefore statistically significant.

Table 4.2: Parameter estimates of the selected PS measurement model

Latent construct	Variable	Squared multiple correlations R^2	Factor loading (unstandardised λ)	Factor loading (standardised λ)	Critical ratio	Significant at 0.05 level?
Infrastructure condition and impacts	CI4	.559	1.000	.748	…	Yes
	CI1	.633	.972	.795	8.645	Yes
	SE7	.442	.822	.665	7.174	Yes
	CI2	.705	1.150	.839	9.100	Yes
User Acceptability	SE3	1.000	1.000	1.000	…	Yes
	SE1	.773	1.000	.879	…	Yes
	SE2	.808	1.000	.899	…	Yes
Financial sustainability	FI1	.548	1.000	.740	…	Yes
	FI3	.622	1.000	.789	…	Yes
Safety and security	SS4	.689	1.000	.830	…	Yes
	SS3	.717	.871	.847	7.454	Yes

… Values not determined due to unstandardised regression weight of 1.0

4.5 Reliability and Validity of the Project Sustainability Model

The piloting and reviews of the questionnaire by the researcher's supervisors and statistician refined the tool and increased face or content validity of the questionnaire. Including a variety of professionals and transport projects increased generalisability and reliability of the results. Statistically, internal consistency reliability of the measures before and after EFA was assessed using Cronbach's alpha test and values ranged from 0.76 to 0.84 (before) and 0.92 (N=14) (after), indicating good reliability. Discriminant validity was also achieved by the modification indices being below 15 and the inter-construct correlations were lower than 0.85 (Musonda, 2012; Ahmad, 2016). Discriminant validity was also achieved by the inter-construct correlation values being below the square root of the AVEs, as shown in Table 4.3. Unidimensionality of the CFA model was good with all factor loadings positive and above 0.5 (Awang, 2012). Composite Reliability (CR) and average variance extracted (AVE) tests for reliability and validity indicated that the confidence level of the CFA latent variables was good, with values greater than 0.6 and 0.5, respectively (Table 4.4) (Awang, 2012; Xue *et al.*, 2018). Convergent validity was achieved by the AVE values all being above 0.5. Construct validity was achieved by the model being of good fit, with all the fit indices within the recommended cut-off ranges.

Table 4.3: Discriminant validity for PS measurement models

Construct	Infrastructure condition and impacts	User acceptability	Financial sustainability	Safety and security
Infrastructure condition and impacts	**0.76**			
User acceptability	0.57	**0.93**		
Financial sustainability	0.73	0.44	**0.77**	
Safety and security	0.63	0.46	0.46	**0.84**

Table 4.4: Reliability results for selected PS measurement model

Latent construct	Item	Factor loading λ	CR (> 0.6)	AVE (> 0.5)	Comment
Infrastructure condition and impacts (n = 4)	CI4 CI1 SE7 CI2	.748 .795 .665 .839	0.762	0.585	Required level was achieved
User acceptability (n = 3)	SE3 SE1 SE2	1.000 .879 .899	0.926	0.860	Required level was achieved
Financial sustainability (n = 2)	FI1 FI3	.740 .789	0.765	0.586	Required level was achieved
Safety and security (n = 2)	SS4 SS3	.830 .847	0.839	0.703	Required level was achieved

5. DISCUSSION

The validated CFA four-factor solution revealed that critical transportation infrastructure project sustainability measures include:

- condition and impacts - including *ability to withstand common adverse weather*, *infrastructure is in good condition, accessibility to all including the disable and elderly*, and *no complaints about cleanliness*;
- user acceptability - including *no complaints about inconvenience during travel, no complaints about travel times,* and *no complaints about user discomfort during travel*;
- financial management factors - including *capital invested has been recovered* and *no complaints from investors about revenue;* and
- safety and security – including *security cameras are in place* and *security officers are visible.*

The above findings slightly align with Amiril et al. (2014) study, which found that in addition to the traditional iron-triangle consideration of social, economic and environmental sustainability aspects, the quality and functionality as well as project financing are critical sustainability elements. The criticality of the wide-range of factors, which emerged from the analysis, has also been emphasised. The condition of transportation infrastructure with regard to its ability to withstand poor weather conditions or natural disasters and being in good condition (generally) were identified as important performance measures for road infrastructure in South Africa (Friedrich and Timol, 2011). These views were also shared by Jeon et al. (2010) and Stapledon (2012) who emphasised the importance of technical and structural conditions and network capacity in sustainability assessments. Likewise, user acceptability was defined in line with the satisfaction of travel needs of the stakeholders including the end-users (Amiril et al., 2014; Yu et al, 2018). Safety and security were classified under social factors in Amiril et al. (2014) and Litman (2019). Nonetheless, given the range of objectives, impacts and options considered in transportation developments, which invariably affect different people in many ways, a variety of factors need to be considered in order to ensure that decisions are consistent with strategic long-term goals of sustainable transportation development (Litman, 2019).

6. CONCLUSION

Project sustainability was initially theorised to be measured by a six-factor structure comprising socio-economic factors, financial factors, condition of physical infrastructure, safety and security, stakeholder satisfaction and service quality, with twenty-eight items. However, the EFA indicated a four-factor solution including infrastructure condition and impacts, user acceptability, financial sustainability as well as safety and security, with fourteen items. Using a model generating approach to CFA, the primary focus was to generate a measurement model that best described the sample data, and as such, modifications were necessary based on the sources of misfit identified. Findings from the CFA, it was revealed that the four-factor structure established during the EFA could adequately measure project sustainability, albeit with fewer variables (eleven). This model achieved construct, convergent and discriminant validity and is therefore deemed reliable and generalisable in sustainability assessments of transportation infrastructure projects in South Africa. It is argued that some of the problems and challenges encountered in the operational stage of transport infrastructure projects could be mitigated by according considerable attention to sustainability factors before and after implementation or development of such infrastructure. The performance of transportation infrastructure projects can be sustained if attention is given to developing robust strategies to overcome or mitigate the impact of sustainability risks associated with the identified factors. It is notable that the relative importance of the factors was not presented in the current study. Future studies could be dedicated to establishing the relative importance of the measures as well as the relations among the variables.

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A review of durability modelling of reinforced concrete structures towards carbonation induced corrosion

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ABSTRACT & KEYWORDS

Purpose of this paper
In this paper, a brief description of the carbonation process and the durability design approach has been provided and the concrete durability models, more specifically models predicting carbonation of concrete has been reviewed.

Design/methodology/approach
The reinforcing steel in reinforced concrete structures are generally protected from corrosion by the alkaline environment of concrete through passivation (formation of a protective oxide layer on the steel surface). However, the protection provided by the concrete can be overcome by the environmental agents (e.g., carbon dioxide), which penetrate the cover concrete, react with the cement hydration product and de-passivate the reinforcement steel, making it vulnerable to corrosion. Various carbonation models have been developed inorder to predict the rate of carbonation. The mechanism of carbonation was discused and the carbonation models were reviewed in this paper.

What is original/value of paper.
Is is important, both from an industry and research point of view to study and model the carbonation process, in order to determine the time for corrosion initiation of reinforced concrete structures. Different carbonation models were reviewed and proposal for future development towards carbonation modelling has been made.

Keywords: Carbonation, Carbonation model, Concrete, Durability.

1. INTRODUCTION

The durability performance of concrete has been a major concern for engineers. The durability of concrete can be defined as the ability of the material or structure to withstand the service conditions for which it was designed over a prolonged period without significant deterioration (Alexander, Mackechnie and Ballim, 1999). While all concretes are made with the core constituents; water, cement, coarse aggregate and fine aggregate. The variability in these core constituents and exposure environments can lead to one of many forms of deterioration which affect the durability of the concrete.

Controlling the durability of concrete structures will be a fundamental challenge for the engineers. Past decades have shown us that the classical procedures for design, construction and use of concrete structures have failed to provide reliable long-term performance (Siemes and Edvardsen, 1999). To improve the long-term reliability of structures, new and verifiable methods of durability design is critical. Many researchers have investigated the various deterioration mechanisms and developed various models to address the durability issues experienced. The durability and serviceability models associated with the carbonation of concrete will be reviewed in this paper.

2. CONCRETE CARBONATION

Carbonation is a reaction-diffusion process, where carbon dioxide (CO_2) present in the atmosphere reacts with the products of cement hydration such as calcium hydroxide (CH) and calcium silicate hydrate (CSH) resulting in the formation of calcium carbonate ($CaCO_3$) as shown below (see Equations 2.1-2.3)

Reaction with CH

$$H_2O + CO_2 \rightleftharpoons 2H^+ + CO_3^{2-} \qquad (2.1)$$
$$CH + 2H^+ + CO_3^{2-} \rightarrow CaCO_3 + 2H_2O \qquad (2.2)$$

Reaction with CSH

$$CSH + 3CO_2 \rightarrow (3CaCO_3 \,.2SiO_2 \,.3H_2O) \qquad (2.3)$$

However, (Castellote, Andrade, Turrillas, Campo and Cuello, 2008) observed the following with respect to CH and CSH carbonation

- CSH carbonation is restricted to the surface layer of the concrete.
- The CH carbonation front proceeds more rapidly than the CSH carbonation front.
- The CH carbonation and the associated lowering of the pH is the mechanism important to steel corrosion.
- Moreover, it has not been confirmed whether the carbonation of CSH lowers the carbon dioxide concentration, especially as the CSH carbonation front is so close to the concrete surface.

Furthermore, carbonation is a gradual process and the carbonation of the concrete can be idealised as ‘front’, which progresses from the outer surface of the concrete inward as shown in Figure 2.1.

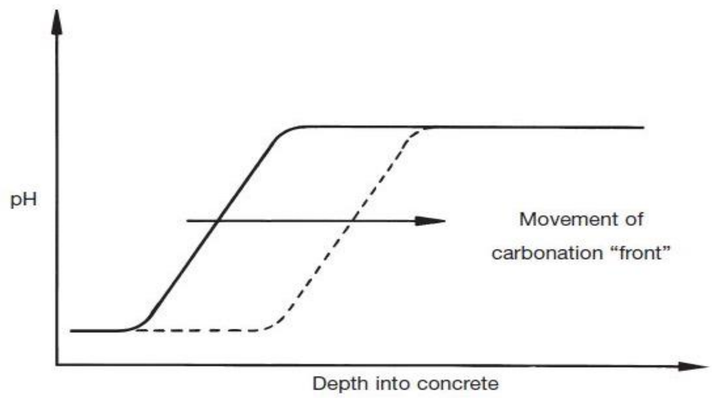

Figure 2.1 pH reduction due to carbonation moving as a “front” from the concrete surface(Owens, 2009).

Several factors influence the process of carbonation. Some of the factors which have a marked influence on the carbonation rate are (Owens, 2009):

- Relative humidity (RH) in the pore structure of the concrete: Carbonation progresses most rapidly in concrete with RH varying between 40% and 70%. No carbonation takes place in completely dry or completely saturated pores; as CO_2 is not readily soluble in water and moisture is required in the reaction to take place in dry condition(Beushausen, Otieno and Alexander, 2012).
- Water binder ratio (w/b), which influences the permeability of concrete. Carbonation rate reduces by approximately 50% when the w/b ratio is reduced from 0.6 to 0.4(Parrot, 1987).
- Binder composition of concrete, which is responsible for the amount of CH available for the carbonation reaction.
- Curing, which influences the pore structure of the concrete cover layer.
- CO_2 concentration: Carbonation rates increase with an increase in the CO_2 concentration of the exposure environment

Carbonation depth is measured by spraying 1% phenolphthalein solution on a freshly cut or broken concrete surface. The indicator (phenolphthalein) solution turns pink where the pH of concrete is above about 9 and becomes colourless where the pH of concrete is lower than about 8. The colourless section of the concrete indicates that concrete is carbonated, since carbonation is a neutralising reaction in the cement paste whereby the pH reduces from above 12 to less than 9(Parrot, 1995). When the carbonation front reaches the level of reinforcing steel in concrete, the protective oxide layer developed on the reinforcing steel due to the alkalinity of the concrete becomes unstable. This makes the reinforcing steel susceptible to corrosion in the presence of sufficient moisture and oxygen.

3. DURABILITY INDEX APPROACH

South Africa has a set of durability parameters based on limiting values specified in codes, and standards. For examples the limiting values for w/b, cement content, concrete cover etc. This provides a tick box approach and does not necessarily ensure that a good quality concrete structure is achieved. Durability indexes aim to control durability problems by describing the physical, chemical and electrochemical parameters of cover concrete by using standardised tests. The South African concrete durability design method adopts a performance-based approach (details in section 4.2) using durability indexes (DI’s). DI’s have been adopted as engineering measures of the potential resistance of concrete cover to the transport mechanisms of gaseous permeability, water absorption and chloride diffusion.

A concerted effort has been ongoing in South Africa to develop the durability index approach to ensure that durability is better understood and planned for during the design stage by providing a physical test which can be used to measure the parameters and compare them to standardised norms. Alexander *et al.* (1999) Monograph 2 is seen as the start of this process, which has led to the release of SANS 3001-CO3 series, which standardised the durability index tests.

South African durability index testing consists of three tests, oxygen permeability for permeation, water sorptivity for absorption and chloride conductivity for diffusion. The test which is important with respect to concrete carbonation is the oxygen permeability test, which measures the ability of concrete to transfer fluids by permeation. The oxygen permeability test is conducted with a falling-head gas permeameter, the outcome of the test will provide the D’Arcy coefficient of permeability (details of the permeability cell, test and calculations: Alexander *et al.* (1999) and (SANS3001-CO3-1, 2015; SANS3001-CO3-2, 2015). The D’Arcy coefficient of permeability was then calculated for each specimen; and from the data obtained, the Oxygen Permeability Index(OPI) (one of the DI) is expressed as the negative log of the average of the coefficients of permeability. Since the permeability coefficient from the oxygen permeability test characterize the pore structure of concrete; the permeability coefficient was used as a key variable in modelling carbonation of concrete (Salvoldi, 2010).

4. PERFORMANCE BASED VS PRESCRIPTIVE APPROACH

4.1 Prescriptive approach

Most of the current codes make use of prescriptive requirements in an effort to ensure acceptable durability of reinforced concrete structures. Prescriptive approaches allow quick comparison of different options and incorporation of durability into structural design. Historically the compressive strength of concrete has been a key parameter used to predicate durability, stating that high compressive strength would lead to increased durability. Using the compressive strength to describe durability ignores the fact that strength and durability are not necessarily directly related (Alexander, 2018). The detached nature of compressive strength and durability is shown in Figure 4.1, which compares OPI values (based on oxygen permeability test) of concrete specimens taken from structures in service with their corresponding compressive strength.

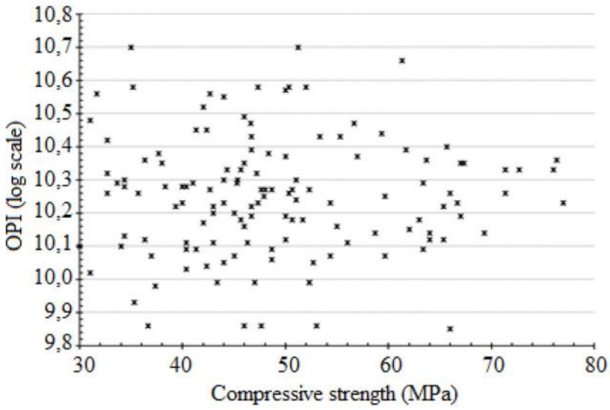

Figure 4.1 Lack of correlation between standard cube compressive strength, and oxygen permeability (log scale) measured on actual structures (Nganga, Alexander and Beushausen, 2013).

The OPI is a durability parameter used in South Africa Durability Index testing. It can be seen from Figure 4.1 that the results are scattered all over the graph, and therefore, shows that there is no direct correlation between compressive strength and the durability parameter. This further demonstrates the inadequacy of using compressive strength to represent concrete durability. There are cases where concrete with high compressive strength will have good durability characteristics. On the other hand for concrete mixes with same compressive strength, their pore structure varies and hence their permeability properties changes. As a result the resistance of concrete towards deterioration mechanisms varies, and hence the durability of concrete mixes with same compressive strength may be different.

It was observed by (Bamforth, 2002) that in general, industry continues to use the relatively crude, deemed to satisfy, prescriptive approach to durability design; instead a rigorous approach is needed. However, in the past few years, performance based approaches (details see section 4.2) have been gaining industry acceptance and are making inroads into codes and guidelines.

4.2 Performance based approach

The performance based approach involves giving a set of outcomes which are required from the finished structure. These outcomes should be well defined in a specification document and should be quantifiable to enable measurement thereof, once the structure is complete. Performance based design relies on the engineer having a thorough understanding of the deterioration mechanisms and

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modelling. These performance specifications should clearly specify the testing required for pre-qualification and site acceptance.

Alexander (2018) stated that prescriptive approach might suppress innovation in the manufacture and use of concrete. The lack of flexibility for the contractor and producer to develop unique mixes which meet the performance requirements ultimately results in little to no benefits for industry. On the other hand performance based specifications are free of limitations on the material quantities and proportions etc. Given that not all designers are familiar with the best ways to achieve a given end result, a performance based specification will allow designers to focus on what is needed. The end product needs to comply with the given specification by means of testing and measuring, which ensures the durability of the structure.

Performance based design concept is benificial not only within the design phase but also during construction and in service (Schiessl, 2005). The advantages of a performance based approach can be seen in the South African Durability Index approach, which takes into account the state of compaction and the degree of interconnectivity of concrete pore structure of the cover concrete. Moreover, it incorporates the material properties such as binder type, water binding ratio, curing condition etc. in the indexes. Alexander (2018) concluded that a shift from prescriptive to performance specifications is one of the important steps necessary to address the shortcomings that are often apparent in current reinforced concrete construction.

5. OVERVIEW OF CARBONATION MODELS

Carbonation models have been developed to predict carbonation depth using different approaches and methods. An overview of some of these models is presented below.

5.1 Square root of time model

The simplest concrete carbonation model is based on the square root of time equation as given in equation (5.1).

$$x = k.\sqrt{t} \tag{5.1}$$

x is the penetration depth (mm), k is the carbonation rate (mm/√year), characteristic of the exposure environment and the type of concrete and t is the time (year). This means the carbonation depth progresses by an exponential decrease in time.

The model is relatively simple in the formula being used, but historical data of the penetration depth is needed to form a baseline of the carbonation rate in order to predict future carbonation depths. The model lacks robustness in that it does not account for many variables without expanding the carbonation rate variable.

5.2 Papadakis model

The Papadakis model is a mathematical model based on reaction engineering principles for the physiochemical processes involved carbonation. The model uses a carbonation front for which an analytical expression calculating the evolution of this front with time. The equation is a modified square

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root of time which take CSH, dicalcium silicate (C_2S) and tricalcium silicate (C_3S) quantities into account with the CO_2 concentration (Papadakis, Vayenas and Fardis, 1989). $D_{e,CO2}$ is the carbon dioxide diffusion coefficient as shown in equation (5.2).

$$x_c = \sqrt{\frac{2D_{e,CO_2} \cdot [CO_2]}{[CH] + 3[CSH] + 3[C_3S] + 2[C_2S]} \cdot t} \tag{5.2}$$

When the concrete is completely hydrated C_3S and C_2S is equal to zero. The Papadakis model was develoed based on accelerated carbonation test results and hence it does not account for the wetting and drying cycles which is experienced by concrete structures in real-world conditions. It is also worth noting that the experiments were based on portland cement (PC) concretes. The addition of cement extenders and the advances in the production of cement in recent times may present challenges to the accuracy of this model.

5.3 Salvoldi model

Salvoldi (2010) developed a carbonation model (see equation (5.3))with permeability coefficient from the oxygen permeability test as the key variable. The model was developed based on accelerated carbonation test data for varying input parameters such as cement content, binder type and cement replacement percentages, water/binder ratios, ambient relative humidity, ambient carbon dioxide concentration and duration of wetting periods.

$$x = \sqrt{\frac{2D_{dry} c\beta}{a}} \times \sqrt{t_e} \tag{5.3}$$

Where, x is the depth of carbonation, D_{dry} is the effective diffusion coefficient and is calculated from the permeability coefficient from the oxygen permeability test, ‘c’ and ‘a’ are the ambient CO_2 concentration and the amount of carbonatable material (mol/m^3) respectively, β is the relative humidity factor and t_e is the effective time of carbonation over the service life of the concrete. The model has an advantage that it uses accelerated carbonation testing for the development of the model which reduced the time required to verify the model. But accelerated testing is not always a true representation of real-world conditions and the permeability of the concrete used for the model development were on the lower side which indicates good quality concrete. Therefore, further verification of the model is necessary in order to assess the suitability of the model to use for concrete with high permeability. Another drawback of the model is that the model development was based on the accelerated carbonation data and hence the model prediction for natural carbonation may vary. Furthermore, the model developed provides a deterministic output which contrasts with the variable concrete properties.

5.4 Ta model

Ta, Bonnet, Senga Kiesse and Ventura (2016) developed a meta-model to predict concrete carbonation. A Meta-model is an amalgamation of some of the different types of models described previously. The data sets of empirical, semi-empirical and numerical models can be used as the basis of a meta-model. A new generic model was built based several already available specific models (Ta *et al.*, 2016).

The model makes simplifications in the development thereof. The carbonation is modelled as a sharp carbonation front moving inwards, CO_2 diffusion under steady state is the controlling factor meaning that the reaction of CO_2 is much faster than the CO_2 diffusion process and the amount of CO_2

absorbed is for completely carbonated concrete which only accommodates natural carbonation and not accelerated carbonation.

Although the model shows good correlation with a number of carbonation results found in the literature, the first data set that it correlates well with are data from (Balayssac, Detriche and Grandet, 1995) and data it does not correlate well with are those from (FIB, 2006) and (Papadakis *et al.*, 1989). The results from the meta-model is further compared to a variety of results from different studies in different regions which all use varying parameters, assumptions and simplifications and shows good correlation. It cannot reasonably be expected that this one amalgamated model is accounting properly for these variances in a verifiable and reproducible manner as the amount of variance to be expected between the studies should be quite high for the same parameters, assumptions and simplifications.

5.5 FIB(Fédération internationale du béton) model

FIB (2006) sets out a carbonation model for concrete carbonation based on the Duracrete research project as slightly revised in the DARTS project. The carbonation model developed is as shown below in equation (5.4).

$$X_c(t) = \sqrt{2.k_e.k_c.R_{NAC,0}^{-1}.C_s}\ .W(t).\sqrt{t} \qquad (5.4)$$

Where, $X_c(t)$ is the carbonation depth at time t (mm), t is time (years), k_e is the environmental function, k_c is the execution transfer parameter, k_t is the regression parameter, $R_{NAC,0}^{-1}$ is the inverse effective carbonation resistance of concrete [(mm^2/years)/(kg/m^3)], C_S is the CO_2 concentration (kg/m^3) and W(t) is a weather function. The equation has the advantage that numerous variables are accounted for and as such the equation has the potential to yield quite accurate predictions. The equation uses Fick's 1st law of diffusion as the primary transport mechanism in concrete.

The equation does not consider the variability of the CO_2 diffusion into the concrete structure. Instead, a constant diffusion coefficient is used without accounting for the variable conditions the structure may be exposed to during its service life.

6. PROBABILISTIC MODELLING

Probabilistic models are models in which the failure probability is quantified to enable a comparison with specified reliability targets. The "probability" is not necessarily considered as a "relative frequency that can be observed in reality" but rather probabilistic modelling expresses a degree of belief with a given set of variables and at best it can be expressed as a "best estimate" of the relative frequencies (Joint Committee on Structural Safety, 2001). The accuracy of this "best estimate" is directly related to the amount of data available.

Probabilistic models require the use of variable inputs as distribution functions which provides an output of in the form of a service life distribution that can be assessed statistically to give an estimated service life within a given probability. In accordance with (FIB, 2006) the following requirement needs to be fulfilled in a probabilistic approach towards corrosion of reinforced concrete due to carbonation.

$$p\{\} = p_{dep.} = p\{a - x_c(t_{SL}) < 0\} < p_0 \quad (6.1)$$

$p\{\}$ probability that de-passivation occurs due to carbonation
a: concrete cover (mm)
$x_c t_{SL}$: carbonation depth at the time t_{SL} (mm)
t_{SL}: design service life (years)
p_0: target failure probability

The probability of failure has to be defined as a maximum target probability dependant on the safety philosophy based on the equation above.

When compared to other models, probabilistic modelling is able to account for the inherent uncertainty that is part of concrete durability design by giving a range of probabilities which can be assessed rationally. As such concrete carbonation is also dependant on a range of variables and parameters and can also benefit from a probabilistic approach tailored to South African conditions and standards.

7. CONCLUSION

The design of concrete durability in South Africa is still largely done by prescriptive methods which have shortcomings in the parameters they account for and are sometimes based on international standards which may not always apply to South African conditions.

Similar to the current procedures for structural design, design for durability should be performance based taking into account the probabilistic nature of the environmental aggressiveness, degradation processes and material properties. Therefore a probabilistic model for carbonation needs to be developed with the permeability coefficient from the oxygen permeability test as the key variable; based on the natural carbonation data instead of accelerated carbonation test data.

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An assessment of the adoption of innovative technologies in the South African construction industry

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ABSTRACT AND KEYWORDS

Purpose of this paper
The aim of the study is to assess the adoption and implementation of innovative technologies in the South African construction industry by examining availability, knowledge levels and barriers thereof.

Design/methodology/approach
A survey was undertaken using questionnaires that were distributed to a stratified randomly selected sample of 83 construction professionals in the fields of construction management, project management, quantity surveying and architecture in the South Africa. The data was captured on excel and analysed using descriptive statistics.

Findings
Key findings show that there are many innovative technologies available on the market such as Building Information Modelling, 3D Mapping, Drones, 3D Printing and Virtual Reality. The results also revealed limited adoption of innovative technologies within the industry and low levels of knowledge of innovative technologies among the respondents. The poor implementation of innovative technologies was found to be due to several barriers such as; high cost, limited knowledge, time consuming, fear of change, lack of interest, nature of construction processes and poor team dynamics.

Research limitations

The generalization of the findings would be limited by the relatively small sample.

Originality/ value of paper
The study provides relevant information for optimising the adoption of innovative technology among firms in the construction industry. There are many innovative technologies available which can be beneficial to construction firms. However, it appears there are several barriers which hinder implementation more than the drivers and benefits motivate implementation.

Keywords: barriers, construction, innovation, implementation, innovative technologies.

1. INTRODUCTION

Globally, the construction industry has an opportunity for growth from 2018 to 2023, at a possibly $10.5 trillion market value (Wood, 2018), and innovative technology is key to achieving that growth. The industry however, is slow in the adoption of innovative construction technologies (Babatunde, 2018; Solas & De Almeida, 2016). Firms view innovative technology as disruptive to the current familiar operations and the flow of business (Cebull, 2015). Globally, the construction sector has not fully embraced new digital technologies that need up-front investment even though digitalization has long-term advantages (McKinsey and Company, 2016). A global construction survey found that 8% of construction firms were categorized as “cutting edge technology visionaries” and 64% of the contractors and 73% of project owners as “industry followers” (KPMG, 2016). In agreement, McKinsey and Company (2016) indicate that construction is among the least-digitized industries, a shortcoming which contributes to the industry’s productivity gap.

Studies show that in order for the South African construction and engineering industries to compete at a global level, firms must be willing to adopt innovative construction technologies, as failure to do so can lead to a decrease in productivity and competitiveness (Fitzimons, 2014). However, despite potential advantages, there seems to be inadequate empirical evidence regarding firms’ reluctance to adopt innovative construction technologies and/or extent of usage of (Xue, Zhang, Yang and Dai 2014). Though innovation studies exist, there are limited studies conducted on South African construction firms, a gap which this study identifies.

Thus, the study aims to assess the adoption of innovative technologies in the South African construction industry with a view to optimizing the usage thereof. The objectives of the study include examining the availability, knowledge levels and barriers to the implementation of innovative technologies. The study is beneficial to construction firms as it highlights the available technologies, knowledge levels and the barriers, aimed at optimization with potential to improve productivity.

2. LITERATURE REVIEW

2.1 Innovative technologies in the construction industry

Innovation within an industry is synonymous with risk taking (Fleming, Osborne, Kinder, 2014). Adopting innovation is a time-consuming and difficult process to implement which requires a lot of attention and work. Akintoye, Goulding, Zawddie (2012: 4), quoting Slaughter (1998), define construction innovation as; “the actual use of a non-trivial change and improvement in a process, product, or system that is novel to the institution developing the change.” According to McKinsey and Company (2016: 2) “the construction industry is ripe for disruption”, but in order to implement innovative strategies, the industry has to disrupt the current way of thinking, working and building. Innovative technologies can transform the phases of the construction (Blanco, Mullin, Pandya and Sridhar, 2017). Adopting innovative technologies within the construction industry can optimize competitiveness of organisations (Thornton, 2017).

The construction industry is traditionally slow to respond and adapt to change including innovative technologies and methods (Babatunde, 2018; Solas & De Almeida, 2016). Yet, there is currently an increasing trend to automate whereby computers and robotic technologies would replace routine human manual work, as the 4th industrial revolution unfolds (Babatunde, 2018). According to Miller, (2016: 1), many firms do not have a clear technological strategy and those that have one either often adopt it in a piecemeal manner or not at all. Technology creates new opportunities and challenges for an organisation and some of the innovative technologies available in the literature are highlighted as follows below.

Three-dimensional (3D) printing is a key area for the digital future of the construction industry (McKinsey and Company, 2016). It is a manufacturing technique for building concrete items, such as walls, from a digital file uploaded to a three-dimensional printer (Cohen, Sargeant, and Somers, 2014). The Drone is an aircraft technology controlled by a remote or an on-board computer. Due to the Drone’s multiple abilities and applications, its usage has increased over the last few years within different industries (Castellano, 2016). Areas where this technology can be implemented and used by contractors include; construction site surveying, tracking project activities, obtaining maps of site and improving site productivity and health and safety (Ayemba, 2018). Virtual reality (VR) is a computerized technology that is used to experience a situation that does not exist (Woodford, 2018). This technology can transform a sector such as the construction industry (Comunale, 2017). Bot-link technology is a software that project managers can use for conducting site surveying with a drone and bot-link software (Taylor, 2017). “BusyBusy” is a tracking device that can be installed in any equipment used on site (Kyocera, 2017). This technology enables the site manager to track the equipment from a phone, computer or a tablet using a geographical positioning system (GPS). The construction work site zone camera technology enables construction firms to create a visual time frame of a project to monitor project progress (Khaled, 2018). The Rhumbix software aims to make running a project and site easier, digitally and paperless (Taylor, 2017).

2.2 Barriers of innovative technologies in construction

A study by Eckert, (2011) established the following as drivers of innovation; desire to lower costs and margins, new technologies, social factors and globalization. However, the construction industry is one of the least innovative industries (McKinsey and Company, 2016). According to Arthur-Aidoo, Aigbavboa, and Thwala (2015), there is a lack of innovation implementation in the construction industry due to the following barriers; industry related such as actions that hinder transformation; organisational related such as culture, communication, resources, team dynamics and legislation and regulation related.

For Aidoo *et al.,* (2015) barriers to the implementation of construction innovation include; firm barriers, culture, communication, resources, team dynamic and individual personality behaviours. Similarly, Benmansour and Hogg *(2002*) found that barriers which can lead to the failure of implementing innovation within the construction industry include; fear of risks, failure and bias, qualities of team members, different needs, cultures and perceptions. According to Dahan, (2017), the low uptake of innovative technologies within the industry is due to limited expenditure on research development.

3. RESEARCH METHODOLOGY

A survey approach was applied in the study. A stratified random sampling method was used to select 375 construction-related professionals in the fields of construction management, project management, quantity surveying and architecture in the South African construction industry. The member lists/registers of the various respective professional bodies were used as the sampling framework. A web-based questionnaire was electronically distributed using contact details from respective professional Councils' registers as well as the Construction Industry Development Board (CIDB) registers obtained online. The 83 completed useable questionnaires received back were analysed using an excel spreadsheet and then statistically analysed using basic descriptive statistics such as percentages, mean scores. Data collection only commenced after ethics approval was obtained from the University.

4. RESULTS AND ANALYSIS

4.1 Profile of the respondents

The majority (30.1%) of respondents identified themselves as Architects and the least at 12.0% were Construction Managers. Of the respondents, nearly half (48.2%) were not professionally registered, while 28.9% were registered with the South African Council for Architectural Professionals, 12.0% with the South African Council for Project and Construction Management Professions and 12.0% with the South African Council for Quantity Surveyors Profession. Majority (38.6%) worked for medium size firms, 20.5% for large firms, 16.9% for international firms, 15.7% for micro firms and 8.4% for small firms.

4.2 Available Innovative Technologies and their Implementation

The different innovative technologies available and the level of implementation are indicated in Table 4.1 on a 4-point scale ranging from 1 being poor to 4 being excellent.

Table 4.1 Implementation level of innovative technology in organisations

Type of Technology	Implementation of innovation N=87				Mean Score	Ranking
	1=Poor	**2=Limited**	**3=Good**	**4=Excellent**		
the (BIM)	23	15	29	16	2.46	1
Virtual Reality (VR)	28	22	25	8	2.16	2
3D Printing	40	18	19	6	1.89	5
3D Mapping	39	20	16	8	1.92	4
Drones	32	20	24	7	2.07	3
Rhumbix Software	64	13	6	0	1.3	9
Construction work site zone camera	42	22	16	3	1.76	6
Bot-link technology	61	17	4	1	1.34	8
Busy tracking device	59	16	4	4	1.43	7
Other	36	5	6	8	1.16	10

Source: Field Survey, (2018).

BIM was ranked 1st, Virtual Reality was 2nd and the Drone was 3rd. These three were the only ones with mean scores of above 2, which was the midpoint on the scale used. These scored the highest probably due to 30% of respondents being Architects who might be familiar with the particular technologies. The overall mean score (average of mean scores) was low at 1.73, which is below 2. The findings suggest that while there are many innovative construction technologies available, implementation is poor to limited. The findings resonate with authors such as McKinsey and Company (2016) who contend that the construction sector has not fully embraced digital technology. According to a study by PWC (2016), 54% of organisations struggle to align innovation and business strategies

4.2 Participants' knowledge levels of innovative technologies

Respondents rated their level of knowledge of various innovative technologies implemented on a scale of 1 to 4 as depicted in Table 4.2.

For Table 4.2, an overall mean score of 1.83 was obtained which suggests low knowledge levels of innovative technologies among the respondents. Only 4 of the innovative technologies scored means of above 2 namely; BIM (ranked 1st); Drone (ranked 2nd) and Virtual Reality and 3D (ranked 3rd). The findings are consistent with those obtained in table 4.1, which shows the types of innovative technologies implemented in construction firms. It can be seen that the most used technologies in firms are also the technologies which the respondents have relatively more knowledge of and vice versa. This is probably due to exposure. According to Staack and Cole (2017), lack of knowledge regarding innovative technologies is one of the reasons why the construction industry lags behind with implementation. It appears individuals are aware of various technologies available but are not fully knowledgeable about them.

Table 4.2 Level of knowledge on innovative construction technologies

4.3

Type of Technology	Level of knowledge N=87				Mean Score	Ranking
	1=Poor	2=Limited	3=Good	4=Excellent		
BIM	10	31	33	9	2.49	1
Virtual Reality (VR)	19	28	26	10	2.33	3
3D Printing	21	23	30	9	2.33	3
3D Mapping	31	27	21	1	1.98	4
Drones	17	25	30	11	2.42	2
Rhumbix Software	59	20	3	1	1.35	7
Construction work site zone camera	41	25	16	1	1.72	5
Bot-link technology	62	17	4	0	1.30	8
Busy tracking device	52	24	7	0	1.46	6
Other	34	9	8	1	0.96	9

Source: Field Survey (2018)

Barriers to implementation of innovation in construction

Respondents indicated the barriers to implementation of innovative technology in construction as shown in Figure 4.2

According to figure 4.2, the five top most barriers were found to be; high cost (70.9%), limited knowledge (58.2%), time consuming (34.2%), fear of change (30.4%), lack of interest (30.4%) and nature of construction processes (26.6%). However, although some barriers were ranked low, they all hinder the implementation and firms must be given due consideration. The results support previous studies such as Arthur-Aido et al., (2015) which highlight a number of barriers. Further, the results suggest that although innovative technologies are available to organisations within the industry, most organisations may not afford them due to the high cost.

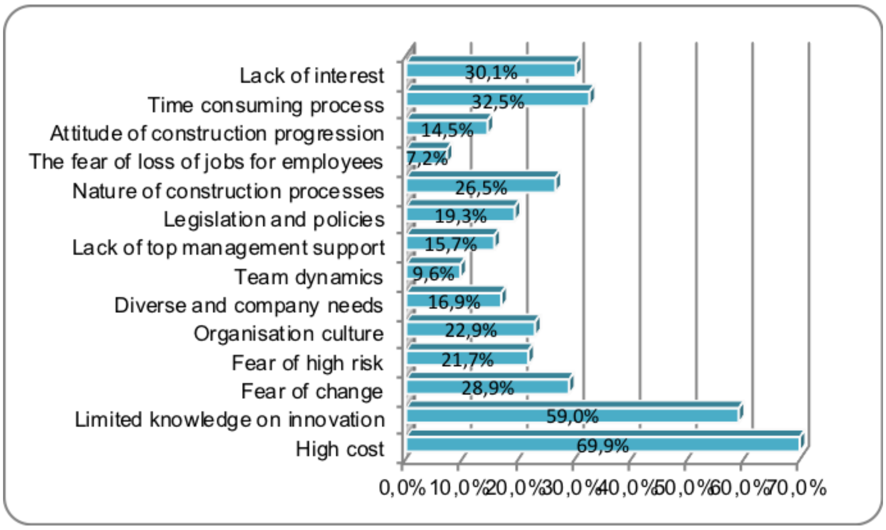

Figure 4.2: Barriers to implementing innovative technologies in construction

Source: Field Survey (2018).

4.4 Level of agreement on innovation statements

On a scale of 1 – 5 where 1 is strongly disagree, 2 is disagree, 3 is neutral, 4 is agree and 5 is strongly agree, respondents indicated their level of agreement or disagreement as summarised in Table 4.3.

Table 4.3 Extent of agreement or disagreement about innovative technology

Statements on Technology Innovation	Level of agreement N=87					Mean Score	Ranking
	1=SD	2=DA	3=N	4=A	5=SA		
Limited knowledge of innovative construction technology leads to poor adoption of technology.	0	2	9	39	33	4.24	1
High costs associated with innovative construction technology hinder the firms from adopting these technologies.	1	2	14	34	32	4.13	2
Nature of construction work hinders adoption of innovative technologies.	4	13	23	37	6	3.34	8
Risks associated with innovative construction technologies are too high.	5	27	32	14	5	2.84	10
Current innovative technologies available in South Africa are not practical.	10	22	32	15	4	2.77	11
Implementing	0	10	22	44	7	3.58	7

innovative technologies has both positive and negative effects.							
Innovative technologies do increase a firm's competitiveness.	2	3	9	41	28	4.08	3
Innovative technologies do improve product quality.	0	7	8	47	21	3.99	4
Innovative technologies do improve health and safety.	1	7	25	36	14	3.66	6
Innovative technologies do improve your employer – employee relationships.	2	13	37	27	4	3.22	9
Innovative technologies do lead to higher productivity.	1	6	11	40	25	3.99	4
There is no need for innovative technologies in construction for the organisation.	41	28	6	5	3	1.81	13
I prefer to carry on with familiar methods of operation.	21	29	21	10	2	2.31	12
Innovative technologies can reduce time for completing projects.	4	8	7	39	25	3.88	5

Source: Field Survey (2018)

A high overall mean score of 3.42 was obtained for the results shown in Table 4.3 whereby 68% of the data was found to be between >2.68 and <4.16, for all 14 statements. These results suggest a good level of agreement to the statements considering that all, except two scored above the midpoint of 2.5. The two top ranked statements reflected barriers. Statement 1 said "limited knowledge of innovative construction technology leads to poor adoption of technology", (ranked 1^{st} as the main barrier to innovation). Statement 2 said "high cost associated with innovative construction technology hinders the firms from adopting these technologies" (ranked 2^{nd} barrier). The statements ranked 3^{rd} and 4^{th} respectively recognised the benefits of innovative technology. Respondents do not seem to agree with the statements that 'there is no need for innovative technologies in construction for the organisation' (ranked last) and 'I prefer to carry on with familiar methods of operation' (ranked second last)**.** The results suggest that despite limited implementation and low knowledge levels, respondents acknowledge the need for innovative technologies in construction.

5. CONCLUSION AND RECOMMENDATIONS

The study set out to assess the adoption of innovative technologies in the South African construction industry with a view to optimizing the usage thereof. It highlighted that there are many innovative technologies available which can be beneficial to construction firms in many ways. However, there were a number of barriers found to be hindering implementation more than the drivers or benefits do motivate implementation. Most of the organisations and individuals in the study were aware of innovation, but lacked comprehensive knowledge of the concept. Barriers such as lack of knowledge, high cost and poor team dynamics were the reasons cited for firms' reluctance to implement innovative technologies vigorously. However, if individuals and firms do not make concerted efforts to be involved in trying out different innovate technologies, they do so at their own peril.

The study concludes that innovative technology is currently not optimised in the construction industry and this has implications for change and growth. It recommends that firms consider investing in research and development in order to better exploit the potential of innovation for organisations and the industry at large. There is also need for firms to undertake cost-benefit analyses of innovative technologies in order to make informed decisions regarding costs and utilisation. This would require firms to do assessments of their organisational culture and technological needs as well as raise the level of awareness among employees. Detailed plans should be drawn up before implementing innovative technologies. Research into technologies which can be applied to improve construction processes should be undertaken using relatively large samples.

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An overview of the influence of shrinkage reducing admixture on the properties of concrete

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ABSTRACT

Purpose of this paper
This paper presents a review of the research work on the influence of shrinkage reducing admixture on the properties of concrete such as reduction in shrinkage and weight loss. The paper also discuss the different type of shrinkage and the mechanism of shrinkage reducing admixture. Some of the practical applications of shrinkage reducing admixture is also highlighted in this paper.

Design/methodology/approach
The influence of shrinkage reducing admixture on the strength of concrete based on previous research work was reviewed in this paper. Furthermore, the effects of these admixtures on the plastic shrinkage, autogenous shrinkage, drying shrinkage as well as on weight loss were also reviewed.

Findings
Based on the literature, it can be concluded that incorporation of shrinkage reducing admixture reduces the compressive strength by 8-15%. On the other hand a drastic reduction in shrinkage of the order of 35% to 60% can be achieved by using these admixtures in concrete.

Practical implications
This study intended to review the existing research on the influence of shrinkage reducing admixture on the properties of concrete in terms of shrinkage reduction. Such knowledge is beneficial for South African construction industry in developing durable concrete structures interms of reduced shrinkage and associated shrinkage cracking using these admixtures.

Original/value of paper
The results from past literatures are reviewed and an insight on the effect of shrinkage reducing admixtures on the strength and shrinkage properties of concrete, incorporating these admixture has been extabilished.

KEYWORDS: Concrete, Shrinkage, Shrinkage reducing admixtures.

1. INTRODUCTION

Concrete structures are subjected to volumetric changes. Shrinkage is one of the phenomenon which induces volumetric changes in concrete, and can be defined as the time dependant decrease in concrete volume without the effect of any external load. Shrinkage usually occurs due to loss of moisture from the capillary pores from either fresh or hardened concrete. The paste in concrete is responsible for the phenomenon of shrinkage due to the physical and chemical changes that occur in the hydrating and hydrated cement paste. The environmental conditions, size of the member and the material characteristics, like the volume of aggregate, elastic modulus of the aggregate and water cement ratio of the paste, influence the shrinkage to a great extent. Any resistance to the volumetric changes caused due to shrinkage results in cracking of concrete, which in turn make the concrete vulnerable to various deterioration mechanisms, thereby reducing the durability of concrete structures.

A number of different approaches can be adopted in order to reduce or mitigate shrinkage in concrete; such as adopting mix design for reducing shrinkage, use of fibers, use of chemical admixtures etc. However, the use of shrinkage reducing admixtures (SRA) had gain acceptance in industry as a viable solution to shrinkage. SRAs are glycol based chemical admixtures, which reduces the surface tension of the pore water in concrete, thereby reducing the shrinkage of concrete (Folliard and Berke, 1997). In addition to reducing the shrinkage, SRAs also helps to improve the flow of concrete (Shah et al., 1992) and reduces the air content in concrete (Cope and Ramey, 2001). Therefore in this paper, a detailed, review on the types of shrinkage and the influence of SRA towards them has been reviewed and presented, along with some examples of industrial application of SRA.

2. SHRINKAGE MECHANISMS AND AFFECTING FACTORS

Based on the mechanisms, shrinkage can be classified as plastic shrinkage, autogenous shrinkage and drying shrinkage.

Plastic shrinkage is associated with drying when the concrete is in the plastic stage, i.e., between placement and the time of final set. The duration of plastic shrinkage is usually short, approximately one to twelve hours. Plastic shrinkage is generally attributed to four driving forces: rapid evaporation of water that creates menisci and high tensile stresses in the capillary water near the surface; differential settlement, since plastic shrinkage cracks are frequently observed above reinforcing steel or at locations where there is a sudden change in cross-sectional thickness; differential thermal dilation due to temperature gradients and temperature development within the fresh concrete; and autogenous shrinkage that occurs during the plastic phase (Lura et al., 2006). Plastic shrinkage is further increased by the lack of bleed water to replace the evaporating surface water. Once the layer of bleed water at the surface is consumed by evaporation, air-liquid menisci are formed between the solid particles on the surface. Experimental studies show that the requisite for plastic shrinkage is a build-up of capillary tension in the menisci after the surfaces become dry (Cohen et al., 1990). The tensile capillary pressure rises at an increasing rate until it reaches a maximum called the break-through pressure. Shrinkage strain rises at an increasing rate, similar to the capillary pressure and continues to rise until the time the break-through pressure is reached when cracking occurs (Concrete in Practice, 2009).

Autogenous shrinkage is a phenomenon that varies from negligible to very high values from normal to high strength concrete. The Japanese committee on autogenous shrinkage (Aitcin, 1999) defined autogenous shrinkage as: “the macroscopic volume reduction of cementitious materials when cement hydrates after initial setting”. Autogenous shrinkage is mainly the result of chemical shrinkage affiliated with the hydration of cement particles. Chemical shrinkage is one in which the volume change is associated with the chemical reactions of unhydrated cement particles with the pore water. Here the volume of the product of hydration is smaller than the individual compounds (i.e., cement and water). Autogenous shrinkage is also caused by the removal of water from the capillary and the gel pores for the hydration of cement paste. This internal drying resulting from the lowering of the internal relative humidity is termed as self-desiccation. The drain of water in the coarse capillaries through the fine pores resulting in drying without any mass loss causing the formation of menisci in the capillaries. The menisci appearing in these capillaries create tensile stress within the cement paste, which shrinks under these stresses, called autogenous shrinkage. If there is an external water supply, no such menisci are formed as the water in the capillaries is continuously replaced by the external water (Aitcin et al., 1999). In case of a low water:cement ratio (w/c), the pore water is used up to hydrate the cement particles and the products of hydration fill the capillary pores leading to the impermeability to external water supply leading to self-desiccation and autogenous shrinkage. However, the shrinkage is mitigated by the more rigid structure of the hydrated cement paste at lower water-cement ratios (Aitcin et al., 1999).

The autogenous shrinkage for normal concrete are in the range of 40×10^{-6} at 1 month and 100×10^{-6} at 5 year period. Nevertheless, a value of 700×10^{-6} was reported for concrete with a w/c of 0.17

(Neville, 2007). It has been found that cement content, high temperature and fineness of the cement influences autogenous shrinkage. However, autogenous shrinkage is not significant at high water cement ratios. The research work of Davis (1940) shows that for a concrete with a water cement ratio of 0.61-0.94, the autogenous shrinkage was 5-10 times less than the drying shrinkage and hence the former could be neglected. On the other hand, lower the w/c of the order less than 0.4, the greater the potential autogenous shrinkage (Aitcin et al., 1999). The autogenous shrinkage generally accounts for 50% and 40% of the shrinkage of concretes with w/c of 0.3 and 0.4, respectively.

Curing has an important role in controlling the shrinkage of concrete especially in the case of high performance concrete where autogenous shrinkage is predominant because of the low water cement ratio. Seigneur et al. (2001) have shown that autogenous shrinkage is reduced to half when curing is started three hours after casting rather than after 24 hours. The use of saturated lightweight aggregates has been found to reduce autogenous shrinkage (Aitcin et al, 1999). The use of mineral admixtures like silica fume, to a large extent, increases the autogenous shrinkage due to pore refinement within the concrete (Shah et al., 1998).

Drying shrinkage refers to the reduction in concrete volume resulting from the removal of water from the concrete by drying. Drying shrinkage is affected by a number of factors, like ambient temperature conditions, water cement ratio, specimen size, amount of aggregate and degree of hydration. The change in the volume of drying concrete is not equal to the volume of water removed. At first, the loss of free water takes place with little or no shrinkage. As drying continues, adsorbed water is removed and the change in volume of unrestrained hydrated cement paste at that stage is equal approximately to the loss of a water layer one molecule thick from the surface of all gel particles (Neville, 2007)

The aggregates have a two-fold volume fraction effect on reducing drying shrinkage; firstly, a high coarse aggregate content reduces the water and paste content, which minimizes shrinkage, and secondly, the presence of aggregates offers restraint to the shrinkage. (Berke et al., 1997; Nmai et al., 1998).

Higher the surface area-to-volume ratio of the concrete member, higher will be the shrinkage. Curing of concrete has some influence on the shrinkage, as prolonged curing will delay the drying shrinkage (Nmai et al., 1998). It is reported that the steam curing reduces drying shrinkage (Nmai et al., 1998).

3. MECHANISM OF ACTION OF SHRINKAGE REDUCING ADMIXTURE

Shrinkage reducing admixtures are regarded as nonionic surface-active agents, whose molecular structure is composed of both hydrophobic and hydrophilic groups bonded covalently (such compounds are termed as amphiphilic) (Rongbing and Jian, 2005; Rajabipour et al., 2008). When dissolved in water, amphiphiles are attracted to non-polar interfaces (such as water–air or water–oil interfaces). The adsorption of such a surfactant at interfaces causes a reduction in the interfacial energy, which is responsible for the reduction of surface tension of the water–air (i.e., liquid–vapor) interface, thereby, shrinkage (Rajabipour et al., 2008). SRAs act by reducing the surface tension of the capillary water, which results in the reduction of the capillary stresses that lead to shrinkage (Folliard and Berke, 1997). The chemical composition of the SRAs available in the market currently is usually based on polypropylenglycol ether.

The addition of an SRA to water reduces its surface tension dramatically, as shown in Figure 2.1 (Rongbing and Jian, 2005). It can be observed that beyond 10% SRA concentration, the decrease in surface tension is less significant, with a value of about 30 mN/m for 100% SRA concentration. A similar trend has also been seen by Pease (2005) and Lura et al. (2006), who state that a rapid decrease in surface tension of water is seen until an SRA concentration of 15% beyond which there is no significant reduction.

The stability of the surface tension beyond a certain SRA concentration can be attributed to the fact that the saturation limit of number of molecules that can be adsorbed on the interface is reached, which depends on the electrostatic repulsion between the polar heads of adjacent SRA molecules in the interface. Beyond this concentration, the excess molecules that cannot be adsorbed possibly remain in the bulk water either as monomers dissolved in water or they tend to aggregate and form micelles at low and high concentrations, respectively. The concentration above which the formation of micelles takes place is known as critical micelle concentration (CMC) (Rajabipour et al., 2008).

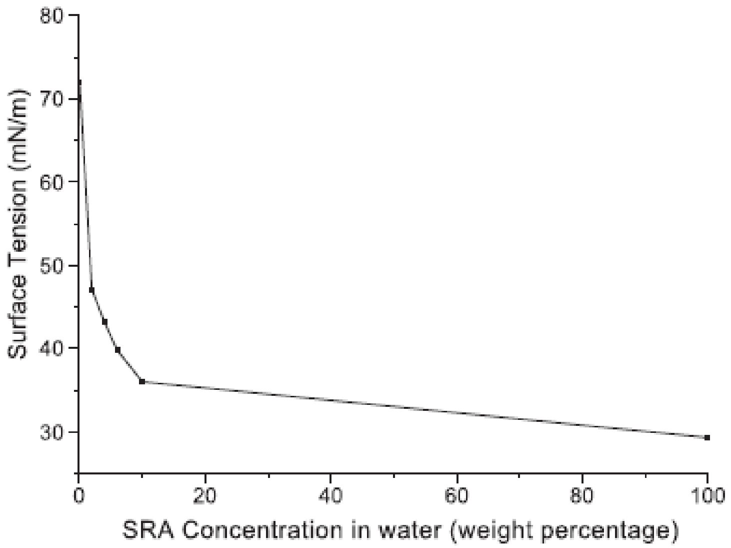

Figure 2.1 Reduction of surface tension of water due to SRA (Rongbing and Jian, 2005)

The effectiveness of SRA in decreasing the surface tension of water over a range of temperature was studied by Mora (2002) and Mora et al. (2009). Five conventional concretes with a design compressive strength of 35 MPa were used — three mixes with three different types of SRAs, and two control mixes with polycarboxylate and melamine based superplasticizer. The SRA dosage, by weight of cement, was fixed in all cases as 1.5%. The water cement ratio of conventional and high strength concrete are 0.45 and 0.35, respectively; for conventional and high strength concrete. A significant reduction in surface tension of the order of half the magnitude is observed in normal strength concrete in the range of 39–28 mN/m compared with the range of 70–67 mN/m for plain water, and it is observed that the effectiveness of SRA is not reduced at higher temperatures. Two high strength concrete mixes, with design strength of 65 MPa, both with superplasticizer, without and with the SRA, were also tested. The results (Mora, 2002 and Mora et al., 2009) reveal that in the liquid phases of the high strength concretes, the SRA E reduces the surface tension to the range of 40–35 mN/m when compared with the range of 70–67 mN/m for plain water.

4. EFFECT OF SHRINKAGE REDUCING ADMIXTURES

4.1 Effect of SRA on Strength

Most of the research work on concretes with SRAs shows that the compressive strength of concrete incorporating an SRA is lower than that of the reference concrete; the reduction in compressive strength documented in the literature varies from 8-15% at the age of 28 days for normal dosages of SRA (Shah et al., 1992; Folliard and Berke, 1997; Cope and Ramey, 2001; Ribeiro et al., 2003; Weiss et al., 1998; Gettu et al., 2002). Nevertheless, the difference in compressive strength between SRA concrete and the reference concrete cured at 50% RH after demoulding was found to be less than that of the specimens that were moist-cured (Shah et al., 1998). Ribeiro et al. (2006a) observed that the negative influence on the compressive and flexural strengths is higher at early ages, indicating a delay in hydration due to effect of SRA.

In the case of mortar cylinders cured under sealed conditions at 30°C with w/(c+sf) = 0.35 (8% silica fume), the addition of SRA resulted in some early age loss of compressive strength (He et al., 2006). Similar reduction in compressive strength due to SRA at early ages was observed by Bentz et al. (2001) in mortar cylinders with 8% silica fume cured under sealed condition, which was followed by an increase in 28 day compressive strength. This was attributed to the higher internal RH and the presence of the silica fume.

A reduction of 8-34% in the splitting tensile strength of concrete has been reported due to the incorporation of SRA (Cope and Ramey, 2001). At the same time, for the tensile strength and modulus of elasticity, not much difference was seen. Some results also show that the compressive strength of the dry-cured specimens was found to be less than those of moist-cured specimens and that the difference is found to be less when SRAs are present (Gettu. et al, 2002; Shah et al, 1998).

4.2 Effect of SRA on Shrinkage and Weight Loss

Research by Mora et al. (2001) shows that the incorporation of shrinkage reducing admixtures leads to less evaporation from the fresh concrete and lower plastic shrinkage cracking (Mora et al., 2001; Lura et al., 2006). This can be attributed to the lower capillary pressure in the drying mortar when the surface tension of water is decreased by the SRA.

Several experimental studies have shown that the addition of an SRA leads to a reduction of autogenous shrinkage or even its elimination due to swelling (Nmai et al., 1998; Bentz et al., 2001; Gettu et al., 2002; Pease, 2005; Rongbing and Jain, 2005). This is also significant at early ages; Pease (2005) found a decrease of 60% in the autogenous shrinkage at 24 hours in a mortar with a SRA dosage of 2.5% by weight of water. Bentz et al. (2001) observed higher relative humidity within the cement paste due to the SRA under sealed condition that could lead to the lowering of the autogenous shrinkage.

The reduction in autogenous shrinkage due to SRA has also been studied in cement mortars, where Rongbing and Jain. (2005) found that the autogenous shrinkage strains in sealed mortar specimens decreased considerably as the SRA dosage was increased; for a 3% dosage of SRA, by weight of cement, the shrinkage reduction was about 48%, after 60 days. The studies done by Seigneur et al. (2001) show that the combination of SRAs and proper curing provides a powerful technique in reducing shrinkage. Folliard and Berke (1997) have suggested that the SRA can compensate for the lack of curing through the reduction of shrinkage and subsequent cracking.

The incorporation of an SRA also leads to significant reduction in drying shrinkage. In free shrinkage tests of a 63 MPa concrete, Folliard and Berke (1997) found a decrease in the drying shrinkage strain of 35% at 28 days and 29% at 120 days with concrete specimens that were moist-cured for 1 day. The reduction of drying shrinkage was more pronounced when the SRA was used in conjunction with silica fume, with 43% reduction in drying shrinkage after 120 days when compared to control mix without silica fume (29% reduction in the case of mix without SRA after 120 days)

The influence of SRA is observed to be more effective in the case of concrete with higher reduction in shrinkage than in mortars. The reduction of drying shrinkage in concrete, to a large extent depends on the type and dosage of the SRA (Shoya et al., 2000; Shah. et al., 1998; Rongbing and Jain, 2005). With the addition of 1% SRA, by weight of cement, a shrinkage reduction of 25% and 30%, respectively, was observed at the age of 50 days, while a dosage of 2% caused a reduction of 45% and 42%, respectively, for normal strength concrete (33 MPa strength) and in high strength concrete (63 MPa strength) (Weiss et al., 1998). In addition, the initial rate of shrinkage was found to be lower, in both normal and high strength concrete, due to the addition of the SRA.

Though the magnitude of drying shrinkage is higher at lower RH, Shoya et al. (1990) observed that the reduction of shrinkage due to the action of the SRA is more in the RH range of 20-45% than at higher RH. (Nmai et al., 1998).

The decrease in drying shrinkage due to the SRA mortar has been studied to a limited extend. Rongbing and Jain (2005) showed (see Figure 4.1) that the reduction in drying shrinkage of cement mortar increases significantly with an increase in the SRA dosage, by weight of cement, up to a dosage of 2%; the values of shrinkage for the dosage of 3% are only slightly lower than those obtained with the dosage of 2%. It was also stated that the drying shrinkage rate decreases with an increase in the SRA dosage. Similar reduction of shrinkage of about 25% at 90 days was reported by Ribeiro et al. (2006b), which was attributed not only to the reduction in hydrostatic tension due to lower surface tension of the capillary water but also due to the presence of SRA in the pores after the water drying.

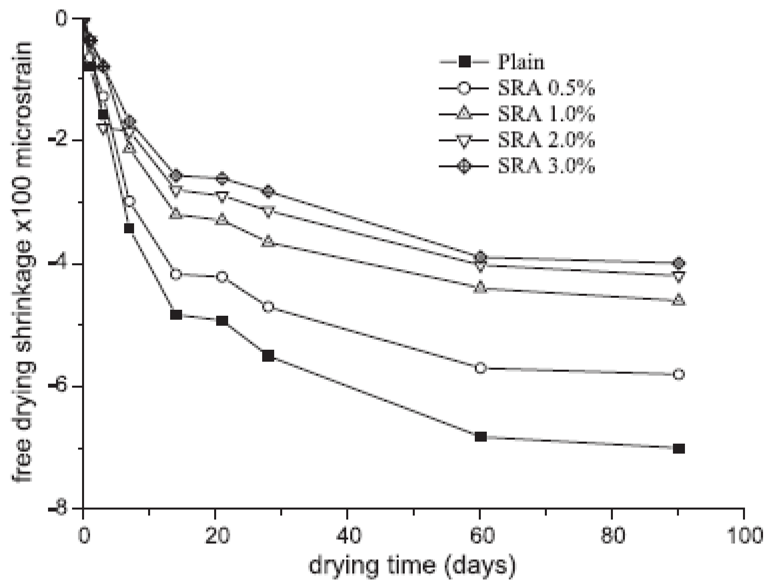

Figure 4.1 Reduction of surface tension of water due to SRA (Rongbing and Jian, 2005)

Furthermore, the addition of the SRA to water results in the increase of the drying rate of water due to the reduction in the surface tension. However, this increase in drying rate is not observed in the case of cement pastes and mortar (Bentz et al., 2001; Lura et al., 2006) This can be attributed to the initial drying at the surface of the paste that leads to a concentration of the SRA within the remaining surface pore solution and further drying out, as opposed to the ‘‘drawing’’ of water from the pore solution (with higher surface tension) beneath it, as hypothesized by Bentz et al. (2001). The lower total drying rate was also related to the fact that the water molecules from the interior that evaporate must first diffuse through the tortuous boundary layer, which is formed because of the drying of the surface, before reaching the external environment, resulting in a reduced mass transfer coefficient.

. On the other hand, the work carried out by Ribeiro et al. (2003, 2006b) and Weiss and Berke (2003), concluded that there is no significant difference in weight loss between the reference concrete and the SRA concrete. Similarly, the work done by Shah et al. (1998), shows there is no direct relation between free shrinkage and water loss.

5. APPLICATION OF SHRINKAGE REDUCING ADMIXTURE

In general the use of the SRA has been limited by the cost consideration. For example, in the European market, Collepardi et al. (2005) estimate an extra cost of about 12–20 €/m3 of concrete (considering an SRA dosage of about 4 kg/m3 and a price of 4–5 €/kg). Holland (1999) has estimated that the incorporation of SRA adds $25 more (depending on the dosage) to the concrete cost.

SRAs have been used in concrete in a wide range of applications such as in slabs-on-grade (Berke et al., 1997), water retaining/hydraulic structures, industrial floors/pavements marine concrete/structures, concrete overlays where there is a high chance of plastic shrinkage cracking, concrete repairs, precast concrete, topical applications, bridge decks, car parks, high performance concrete using corrosion inhibitors etc.

The application of SRA in floor slabs has been successful in a number of projects. For example, in a North American mass merchandise chain warehouse, a 6m × 23m freezer slab was cast using SRA in 1998; in the Grace manufacturing facility at Enoree, South Carolina, a 24m × 37m slab was cast using SRA in 1998; in Virginia, USA, SRA was used in 30m × 15m warehouse slab in 1999; in a warehouse floor slab at Georgia, USA in 1998 (Eclipse in Flooring, 2009); in Columbia Colstor Fish Processing Plant at Woodland, Washington, USA (Eclipse Floor, 2009). SRA was also used in the construction of the slab foundations for the Bass Lake Business Center, a new office-manufacturing complex in Plymouth, Minnesota. The project included three 12 × 25-foot foundation slabs, each 24 inches thick, and about 10,000 square feet of 10-inch-thick slab to support smaller pieces of equipment (Balogh, 1996).

The SRA application extends to projects like strengthening of Avonmouth Bridge in 1995 and in the construction of new San Francisco-Oakland Bay bridge. Concrete containing SRA also used by the Virginia Department of Transportation in a test overlay for the Lesner Bridge, Norfolk. The concrete contained 5.6 liters of SRA per cubic yard (Balogh, 1996).

6. CONCLUSION

In this paper an overview of the various forms of shrinkage and their mechanism were discussed in detail. This was followed by a brief introduction of shrinkage reducing admixtures, along with their mechanism of action in reducing shrinkage. A detailed review on the effect of these admixtures (SRA) on strength, shrinkage and weight loss was also presented. In general it can be concluded that incorporation of SRAs reduces the compressive strength by 8-15%. On the other hand a drastic reduction in shrinkage of the order of 35% to 60% can be achieved by using SRAs. Furthermore, eventhough the addition of SRAs results in the reducing the surface tension of the concrete pore water; the reduction in weight of concete due to evaporation was observed to be less or even similar to the reference concrete without any SRA.

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Building Information Modelling for Improving the Performance of the Architectural Design Process: An Information Flow Perspective

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ABSTRACT

Purpose of this paper
This research aims at investigating the role of Building Information Modelling (BIM) in improving the performance of architectural design process through information flow.

Design/methodology/approach
In order to achieve this aim, a research methodology, consisting of literature review and case studies is designed to accomplish three objectives.

- First, building a comprehensive background of the research topic through covering the concepts of the design process, information flow and BIM.
- Second, presenting and analysing two case studies to explain the role of BIM towards improving the flow of information during the design process.
- Finally, outlining the research conclusions and recommendations.

Findings
Although the research paper recognized certain barriers preventing the adoption of BIM as a means for enhancing the flow of information in the design process, especially with small-to-middle-sized firms, it revealed the opportunities of using BIM successfully in enhancing the general performance in the design process.

Practical Implications
Adopting and applying BIM during the design process will greatly enhance and facilitate the information flow and improve the collaboration and cohesion of the design team. This will improve their performance throughout the design process and reduce effort, error, cost and duration of the project. This will also lead to the satisfaction of all people involved in the project, especially the client.

Originality / Value
Applying BIM during the architectural design process is a new approach, especially in Egypt. Other researches tackled the use of BIM in different fields, but little concern was directed to the architectural design process. The research highlighted the impact of BIM on enhancing the flow of information in the different stages of the design process.

Keywords: The design process, information flow, Building Information Modelling.

1 INTRODUCTION

The environment of business is always facing challenges, such as lack of applying and adopting advanced technologies, the growing expectations of the clients, transformations in competitions, policy, law, technology and economy (Gilson, Stal., 2003; Othman, 2008). This urges the design and construction organizations to innovate and use their resources effectively and effeciently to develop their peformance and maintain competitiveness. It is practically realized that it is important for construction firms to enhance their performance, achieve the clients' requirements, increase the methods of carrying out business and increase market share. Although BIM has been successfully utilized in many fields of industry and has profoundly improved performance in these fields, its application and adoption is still limited in the design and construction organizations (Halim and Othman, 2013). This research paper is to investigate the application and adoption of BIM to the architechtural design process and its special impact on the flow of information in that process.

2 RESEARCH OBJECTIVES & METHODOLOGY

To achieve the aim of this paper, a research methodology consisting of literature review and a case study is designed to accomplish the following objectives;

a) Building a comprehensive background about the research topic through covering and explaining the concepts of the design process, the flow in information and BIM.
b) Presenting and analysing two case studies to explain the role of BIM towards improving the design process.
c) Finally, outlining the research conclusion and recommendations.

3 LITERATURE REVIEW

3.1 Design Process and Design Theories

The complex tasks of architectural design do not have definitive formulation or best solution. Design is the "process of deciding what a structure will look like and how it will function" (Fales, 1991). In fact, the design process is "an approach for breaking down a large project into manageable chunks" (Discover Design Handbook, 2012). It aims at properly understanding and implementing the requirements of the owner/client. Moreover, it involves the collaboration of such members as engineers, architects, project managers, owners and clients. The design process has two opposing views: the "Glass Box Theory" and the "Black Box Theory" (Jones, 1980). With the "Glass Box Theory", the design process is rational and transparent. With the "Black Box Theory", which is commonly preferred, the designer's creative act is the most important thing in the design process.

3.2 Purpose and Challenges of the Design Process

The design process has three main purposes: the proper understanding of what the client needs and requires, finishing the project in time with the least waste or delay and avoiding future problems. It has also two main challenges: misunderstanding of the client's needs and improper transformation of such needs in the design.

3.3 The Design Quality and Architectural Team

The design should be of high quality addressing the needs of the clients, economically viable and flexible, and allow for alternative solutions. Whereas the design team should be efficient, effective and capable of achieving the client's needs and the organization's objectives. The team share responsibility, pour their experience in the design and collaborate with one another. They all work as one productive well-structured unit (Al-Jamal, 1997). The more the team is highly qualified, flexible and unified, the easier and more effective the flow of information among them. The better the design is, the more satisfied is the client.

3.4 Stages of the Design Process

Choong (1985) pointed out the stages of the work plan of the design process as follows: inception, feasibility, outline proposal, scheme design, detail design, production information, bill of quantities, tender action, project planning, operation on site, completion and feedback.

These stages vary in different purposes, such as preparing a general outline of requirements and plan future action by meeting the client for briefing; determining general approach to layout, design and construction in order to obtain approval of the client on outline proposal; accompanying report, obtaining final decisions on every matter related to design, specification, construction and cost; and handing over the building to the client for occupation, remedying any defects, settling the final account, and completing all work in accordance with the contract.

3.5 Information Flow

Information flow is the "movement of information between people and systems. It is a central factor in the performance of decision making, processes and communication" (Titus and Bröchner, 2005). It is the designers' raw material and indication of their effective and efficient performance with their team (Boeykers, 2008). The flow of fast and accurate information is important for the design team to take action and avoid the waste of valuable time and effort.

3.5.1 Types and Problems of Communication and Flow of Information

Mullins (1996) refers to five types if communication patterns of networks, each of which has its specific features and nature: the wheel, the circle, the all-channel, the "Y" and the chain, which are represented in the figure (1). A major problem of the information flow in the design process is the lack of classification, discipline and structure, i.e. it does not follow a specific system. Another problem that makes it difficult for the information to flow in a flexible, smooth manner is the different needs of the design team. This makes it urgent to have a system that can automatically and instantly review and record the changes all through the life-cycle of the project, especially during the design process. Improving the flow of information in the design process can be carried out through a four-staged system: diagnosis and evaluation; changes implementation; control; and standardization (Alorco'n, 2002). Figure (2) represents these four stages.

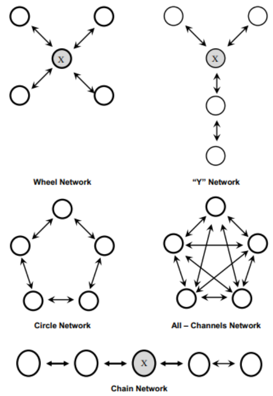


Figure (1) Communication Patterns

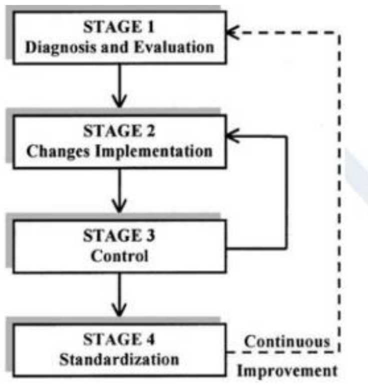


Figure (2) Stages of information flow improvement

3.5.2 The Traditional Method of Information Flow and Its Defects

The traditional method of the flow of information views the architect/designer as an all-in-one entity who has all the approved information and the necessary database of the project. The main tools of information flow are represented in the form of 2D CAD section, elevations, plans, drawings and sketches. They also take the form of oral discussions and several meetings with all the members involved in the design process. Most of the work is paper-based reflecting and coping with the accepted view and principles of all the members participating in the project. If a change takes place in any stage of the design process, there should be alternations and adjustments in the work and information about this change should be conveyed to the rest of the working group in the design process. All this takes too much working and reworking of the plans, drawings, sections, elevations and sketches. This is a lengthy and laborious activity that wastes time and effort as well as costs extra money. Some information might be lost in the process, miscommunicated or delayed. This does not satisfy the working team or the client (Baldwin et al, 1999).

Lack of collaboration and proper communication and coordination among the members of the design team constitutes another problem in the smooth flow of information. Another defect which wastes time and causes delay in the flow of information is the real action initiation stage of the project. There is no data sharing with other groups working on the project where remarks and general activities affect the designs and the plans. Each group is working on its special island separated from the other groups. Due to the defects of the traditional method of the flow of information in the design process, there is need for a system and/or a tool which overcomes such defects and makes the flow of information more flexible, accurate and easier. BIM is the key to achieve these requirements (Phelps 2012).

3.6 BIM (Building Information Modelling)

BIM (Building Information Modelling) is defined as "an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure" (BIM and the future of AEC, 2000). BIM as a tool is used in almost every field of engineering. It improves the design quality and its delivery process. It is effective in improving and facilitating coordination and collaboration among the members of the design team. BIM is able to achieve productivity gain. It has a variety of advantages, such as improving quality, reducing network and minimizing project management. In addition, BIM has the ability to identify errors early, reduce costs and facilitate coordination and communication. In fact, BIM has become internationally acclaimed as the best practice mechanism for main construction projects.

3.6.1 BIM and Design

BIM can be applied at an early stage of the construction project and all through its entire life cycle. It is especially useful in the design process as it makes the design more precise, accurate and improves its interpretation. It allows for fewer changes and saves the project total costs. Its automation feature reduces face-to-face interaction and conflicts within the designing team members and increases their collective coordination and collaboration. Through BIM, the team share and visualize information in a 3D content and form (Franco, 2018).

3.6.2 BIM as a Better Tool in the Architectural Design Process

BIM is highly effective in making the design process more flexible at each of its stages. It uses interpretational tools which guarantee model fidelity throughout the entire life cycle of the project. It allows for the inclusion of so great amounts of detailed information and mental images that there will be no other place for anyone imagination and/or reflection. BIM allows for the creation of the experience of virtual reality (VR) and immense visualization produced directly from the designed model(Hattab and Hamzeh, 2001). In short, BIM facilitates the design process and makes the flow of information more fluid. Moreover, it integrates analysis tools with visualization, extends workflow and leads to multidiscipline collaboration. BIM creates a historical finger-print-like document for the whole project, as it has all the data and information related to the project in each of its stages. It can become a standard-like model for similar future projects (Rundell, 2006).

3.6.3 BIM and the Flow of Information

As a tool, BIM allows information to be located well controlled and well exchanged within the different stages of the design and the construction of the project. This has advantage of improving work quality and decreasing multiple decision making and actual changes as the system virtually addresses the problems that might occur during the design and/or the construction process and consequently reduces the total cost of the project. In fact, Garber (2009) stresses this unique potential of BIM in the field of communication, information flow and the collaborative method of data feedback among those people involved in the design/construction process. He refers particularly to the great ability of BIM to integrate in a single software a database of information about such elements as construction management, simulations, analysis, and lifecycle management of the construction project. With the application of BIM as a tool to the design process, almost all the defects of the traditional way have vanished.

BIM has a vast spectrum of benefits that it can be described as a revolutionary change and upgrading of information flow not only in the design process but all the other subsequent processes, till the final implementations of the architectural project. BIM has the ability to absorb and share all the information related to cost analysis, estimation, scheduling and building analysis (Kymmel, 2008). It allows the information to flow among all the targeted participants in almost no time and as soon as it is fed into the BIM system. The real power of this revolutionary tool is its potential to have a collaborative, integrated mechanism that can be applied to all the elements of the project. It enables the working teams to have a highly effective collaborations, communication, sharing and exchanging of information. All this leads to the reduction, if not elimination, of waste of time, effort and total cost of the project to the satisfaction of not only the designers and architects working on the design process, but also the management team, the contractors, the subcontractors, the other engineers working on the site, the owner and finally, the client. In short, BIM overcomes the untimely incomplete sharing of information, the idle time wasted, the delays in the flow of information, rework and remaking of adjustments (as these actions are done automatically through BIM), and the bad or unsatisfactory quality of the design. Through the BIM technology, all the members involved in the design process has a clear, easy, quick and updated access to all the information related to the project, such as financial performance, scheduling, materials data and requirements from the beginning to the end of the project (Eastman and Teicholz, 2008). BIM technology has reduced errors throughout the design phase. In USA, foe example 58% of the designers who make use of BIM in their design realize that it greatly decreases omissions and design errors, especially as the design gets more and more finalized (Cheng, 2006). Table (1) shows a quick comparison of flow of information in the traditional method and BIM based method during the design process.

Table (1) Traditional system vs BIM system

Point of Comparison	**Traditional System**	**BIM System**
Tools	2D CAD, papers and sketches	3D software applications (e.g. Revit, ArchiCAD, Vectorworks, IntelliCAD, RhinoBIM, etc.)
Information Flow	Slow, confused and crumbled	Quick, flexible and transparent
Information Sharing	Delayed or even lost	Spontaneous and complete
Collaboration	Sometimes difficult and unsuccessful	Effective and smooth
Visualizing the model of the building	Partial and gradual visualization in a form of 2D CAD, paper form plans and snapshots	Live model in a whole intact software form
Alternations and changes	Tiresome requiring rework of previous plans and sketches	Easy and spontaneous automatically applied to the model
Time of having plans and making sketches	Relatively long time with great effort	Relatively short time with less effort
Contact with fellow team member	Face-to-face meetings and discussions	Remote virtual meetings via email or online conferences
Type of plans	Individual, separate	Collective, unified
Information documentation	Hard to keep and sometimes partially or totally lost	Easily/permanently documented & available even for future reference
Cost of change application	The cost of the papers, sketched and drawing tools used to make the rework of the plans and sketches	Minimum cost; only that of the electricity used to keep the computer devices

Table (1) Traditional system vs BIM system		
Point of Comparison	**Traditional System**	**BIM System**
		working while applying the changes
Exchange of information among members in different states/locations	Hard and lengthy, sometimes impossible	Easy, spontaneous and instant
Probability of conflicts and misunderstanding	High probability	Low probability
Task/action time	Relatively long time spent to carry out the task/action	Relatively very short time is needed to carry out the task/action
Addressing the client's needs, requirements, and final satisfaction	Not always accurate	Highly accurate
Nature of tasks	Sometimes laborious and some non-value	Always required and valuable
Scale of variety in tools	Limited scale restricted to 2D CAD, paper and sketches	High variety of BIM software applications such as ARCHICAD, Revit, Vectorworks, etc.

3.6.4 Barriers to BIM Adoption

There are six barriers to BIM adoption. These barriers are technological, financial, organizational, governmental, psychological and process. These barriers are interconnected and intertwined in nature. The main reason behind most of these barriers is attributed to the small project size which has limited fee for the design. This does not allow for covering the costs required for the digital innovation brought about by BIM application and adoption in construction projects. The limited resources of the construction organization lead to the psychological barrier of people's fright of profit loss relative to the expensive costs of BIM implementation. Therefore, it is frequent to find managers reluctant to give support to BIM adoption in their firms. The managers' discouraging attitude towards BIM represents the organizational barrier that stand as negative aspect discouraging BIM adoption. Process barrier is reflected though upgrading the computer devices and software to be ready to accept and deal with 3D modelling and processing. This might be very expensive, especially with small architectural organizations (Bernstein and Pittman, 2004). In order to investigate practically the relationship between BIM and the information flow in the architectural design process, as well as how far BIM brings about any improvement in the total performance of the design process, it is convenient to present a case study. Which focuses on the role of BIM in enhancing the flow of information in the architectural design process.

3.7 Case Studies

3.7.1 Case Study: The Grand Egyptian Museum (Selim, 2017).

Basic Information
This case study detects the benefits and the feedback of applying BIM technology on the architectural design of the Grand Egyptian Museum (Figure 3). The study is to focus on the flow of information among all parties preoccupied with the project.

Figure (3) Grand Egyptian Museum

Project Basic Information	
Project name	Grand Egyptian Museum
Area(s) of expertise	Governmental, Cultural and Religious
Contract type	Build
Location	Cairo, Egypt
Floor area	480,000 m^2
Building Period	2012 – 2018
Architect	Henegan Peng Architects
Total Budget value	€ 810 million

The purpose of the case study

The purpose of this study is to focus on how far the parties/members involved in the design and implementation of the project have gained from using BIM and its different software applications in their work on the project throughout its different stages generally, and the initial design stage specifically. Kemet Corporation is the BIM construction management responsible for providing the coordinated BIM model and API features through Autodesk Revit for automating the workflow in this case. The design drawings mainly aim at generating a coordinated model with clash reports as well as suggested solutions.

Case Study Process

The process of this case study passes into three stages as follows:

Stage 1

People involved in the design process of the project apply BIM in the following domains, design validation, logging and Reporting, coordination drawings, full shop drawing and BOQ extraction

Stage 2

Resolving Conflicts BIM is essential in this stage due to the large structural and architectural details which require the exchange/transfer of information among all the members of the design team so as to solve contradictions and conflicts from different perspectives and approaches to the model. as shown in the following figure (4).

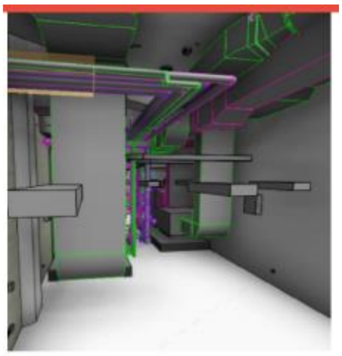


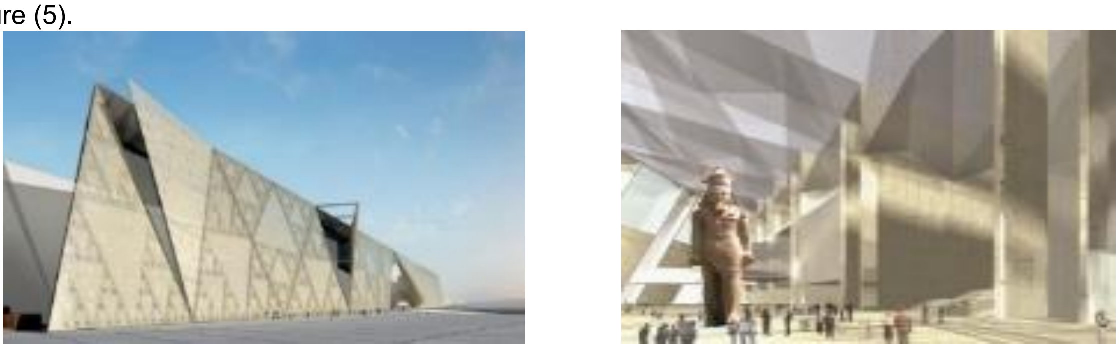
Figure (4) Photo of solved conflicts

Stage 3

Creating/drawing an executive model with all the details necessary for the services of the site, especially the boards of the structural openings of the thickness of the concrete walls in the museum, which reaches *600mm* thickness. It is necessary to determine on the model the dimensions of each hole in the wall carefully before starting its actual construction. This process needed a lot of discussion. Suggestions were made and exchanged so as to reach the final design that satisfied the nature of the required final model. This was the process where information was excessively shared and exchanged among all the members involved in the design process. This was the stage where BIM adoption as a tool of enhancing information flow was highly successful.

Case Study Results

From the feedback of the working teams in the design and construction processes, it is observed that BIM has contributed greatly to creating a reality simulation of the project which helps in properly and accurately having an idea of the final form of the project at a very early stage as shown in the following figure (5).



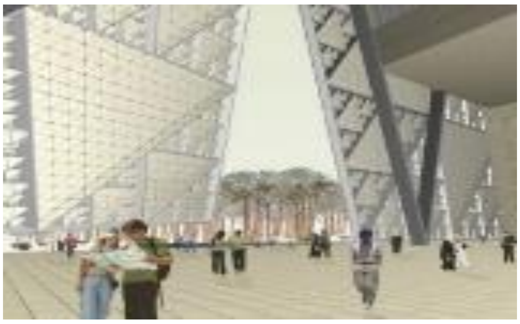


Figure (5) Final forms of the project

BIM is a great tool that can handle and correct errors by managing information and documentation. As a result, we can conclude that using BIM:

- Improves coordination and collaboration among these involved in the design process.
- Decreases non-value design tasks and eliminated time waste and effort
- Helps greatly in clash detection and elimination
- Contributes to conflict resolutions
- Enables a greater control of the whole design process (Selim, 2017).

BIM Applications Adopted

Revit is used with the 3D and 4D model to link the model timeline to the schedules of Primavera and Navisworks program to produce a moving diagram showing the development of the project.It is worth stating that the most notable benefits of BIM in the museum are resolving conflicts and saving time.

Case Study Conclusion

It has become clear enough that the adoption of different BIM applications, such as Revit, Primavera and Navisworks, are of great positive effects on the design process and information flow in that process. Different tasks are carried out concurrently and smoothly during the design process, which have contributed much to saving costs, time and effort. This minimizes greatly the non-value tasks, tiresome rework of designs and allows for automatic alternations and error corrections throughout the different stages of the design process. It enables the important exchange and flow of information among people located in different locations. Its ability to resolve conflicts and time saving are recorded as its most important benefits in this project.

4. Conclusion

It is clear enough that BIM adoption in the architectural design process is of great importance in enhancing and speeding up the flow of information in an accurate and effective manner among all the members involved in that process. It saves the total cost and time duration of the project. Moreover, it raises the productivity of the architectural firm. It increases the collaboration and coordination of the design team members and saves a lot of their efforts which was formerly exerted on drawing and redrawing, making and remaking of plans, designs, drawings and sketches. Using BIM in the design process is a revolutionary technique/method relating and unifying all the members/parties/systems involved in the design process together. It keeps them all the time informed and updated with all the required information. BIM can impose proper organization and facilitate communication, collaboration and flow of information among all those involved in the design process. All data will be stored and available for anyone in the architectural project to have access to and make use of. In addition, no piece of information will be lost or received after the required date. The important thing about applying BIM to the architectural design process is the fact it creates a historical finger-print-like document for the whole project. It can become a standard-like model for similar future projects.

5. Recommendations

The present study suggests the following recommendations:

- Teaching the information flow through BIM application as a basic university course for engineering students, especially architecture and civil engineers.
- Having a historical finger-print-like document for major construction projects in Egypt for future reference and/ or re-evaluation and maintenance.
- Introducing the job of BIM information flow coordinator to facilitate and speed up the exchange and flow of information for the entire community of the construction and management team

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Challenges and benefits of implementing communication management practices for successful construction projects in Eswatini (Swaziland)

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ABSTRACT AND KEYWORDS

Purpose
Communication management in the construction industry is viewed as a practice in combating construction project delivery problems. In Eswatini, it is established that projects experience poor project delivery associated with poor communication management practices. This study seeks to identify the challenges and benefits of implementing communication management practices, described in subject literature and use it to understand the impact informed by local culture to improve project performance.

Methodology
A quantitative research approach was used, and data was collected using structured questionnaire survey, administered to the relevant construction stakeholders in Eswatini who are involved in construction projects. IBM Statistical Package for Social Sciences (SPSS) version 25.0, was used to analyze the descriptive and inferential statistics of the challenges and benefits of implementing communication management practices to determine the factorability, mean score and reliability of the constructs.

Findings
Results revealed that the challenges were associated with personal interaction difficulties, personal behavioral problems and personal cultural problems. The benefits were related to organizational communication benefits and project communication benefits. The constructs were reliable in relation to the Cronbach alpha coefficient.

Limitations
The study was not conducted across Eswatini; hence the findings cannot be fully generalized.

Practical implications
This research provides empirical evidence of the impact of communication management practices by identifying the factors that contribute to challenges and benefits of implementing communication management practices that influence construction projects performance success in Eswatini.

Keywords: Communication management practices, Construction projects, Construction industry; Eswatini

1. INTRODUCTION

Construction industry plays a vital role in Eswatini's economic and social development with representation of approximately 5% input on gross domestic product (GDP) (Construction Indaba Report, 2015). However, from a review of Eswatini economic performance, a survey report from the Ministry of Economic Planning and Development (MOEPD) along with Central bank, (2017), indicated that poor communication is a challenge in infrastructure delivery of businesses such as the construction industry. Thus, hindering their economic growth. Ayodeji *et al.,* 2017) suggests that inadequate communication was a challenge that caused poor quality performance in construction projects of Eswatini. Therefore, it is apparent to undertake this study, in order to draw attention on construction communication in Eswatini construction industry. If poor communication was a problem in construction as a business, certainly efforts of understanding the impact of communication management practices influenced by local context could possibly provide a basis for better realization of communication management practice role to construction project performance in Eswatini. This study anticipates that the awareness will give construction practitioners a tool in form of a list factors for managing effective realization of the challenges and benefits of communication management practice for improvement.

In relation to this gap two specific research questions were stated:

- What are the challenges and benefits of implementing communication management practices experienced by practitioners in successful construction project delivery in Eswatini?
- What is the reliability of the challenges and benefits of communication management practices for successful construction project delivery in Eswatini?

2. CHALLENGES OF IMPLEMENTING COMMUNICATION MANAGEMENT PRACTICES

In the context of Eswatini construction, several barriers of communication management practice need to be understood in order address the issues of poor project performance associated with communication. Based on these views, Table 1 indicates a comprehensive literature of fifteen (15) challenges of implementing communication management practices proposed to impact projects.

Olaniran, (2015) revealed that some professionals may not understand some aspects of a project if little information is available thus leading to project failure. Luka *et al*., (2014) explained that poor communication had often resulted in poor and distorted information that affects the level of work done on site. As result, slowing down project completion and leading to extra costs.

Peansupap (2005) indicated that the magnitude of information communication technology (ICT) adoption in construction practices remains low compared to other industries. They found that the low levels of adoption on technology are due to the low levels of information technology (IT) skills that prevents effective communication in projects. Chassiakos (2007) pointed to the limited availability to classes for users where the need for computer skilled staff in construction results in reluctance or difficulty to adopt.

Luka *et al*., (2014) established that inappropriate communication media for specific purposes/audience causes poor implementation of technology. Čulo (2010) indicated imposing a technology that is inappropriate to the audience or project may result in un-accessed information, which remains idle.

Maame (2012) stated that lack of poor listeners, information filtering, and language difficulties due to lack of communication skills can hinder business success. Molwus (2014) amplified that it is important that stakeholders possess certain level of communication skills to meet project objectives.

Olaniran, (2015) indicated that when instructions on project plans and strategies are not received on time, it would certainly affect the work output on project site negatively.

Gunasekaran (2016), stated that language pose communication management practice problems that impact completing projects on time with allocated budget and quality. Perumal *et al*., (2011) supported that the cultural issues with language hindrances increase possibilities of misunderstanding as there may be communication problems due to differences and expressions in different professions that strain the project. In relations to technological advances, Hijiazi *et al*., (2008), further supported that technical language used in transmittals increase conflicts and misinterpretations between different stakeholders.

Adedapo (2013) stated that poor and horrible writing or lettering can affect the level of work in projects resulting with nervousness considered a barrier that results in mistakes. Olarinan (2015) expounded that this could lead to poor distorted information that could have adverse effects on the level of work done on site that would lead to slow project completion and lead to extra costs.

Hoezen *et al*., (2006), found that stakeholder's frame of reference has a great influence that often leads to restricted communication due to opposing interests. Hijiazi *et al*., (2008) study on construction communication using IT specified that usually various frame of references increase conflicts and misinterpretations between different stakeholders. Adedapo (2013) highlighted instances such as inferiority complex of artisans and operatives can lead to misinterpretation of information. Molwus (2014) also stated that if stakeholders know that they have been classified as having low interest, influence, power or legitimacy on the project, it may stir up ill feelings and cause them to begin to form coalitions with other stakeholders in order to exert themselves, leading to protests affecting the project.

Different sets of beliefs, values and norms with different cultures that have different cultural rules could directly affect the way one communicates with others and could impede communication (Louw *et al.*, 2005). Giritle *et al*., (2014) inferred that when an individual in construction enter an organization, they bring their complicated needs and attitude into the organization, where the train of thought is vastly different, and their interpretation has a significant contribution to communication. Rimmington (2015) explained that individual's perception when transferring information is the influence and distraction a message that brings out communication problems that affect construction project performance.

Hoezen *et al*., (2006) studied that little time is spent on a brief could negatively affect communication management practice. Luka *et al*., (2014) clarified that unclear objectives provided during project briefing between project proponents and its stakeholders lead to project failures and disputes.

Louw *et al.*, (2005) unearthed that communication problems due to distance are influenced by the physical context where content and form of communication as well as interpretation of messages become affected. From this standpoint, Čulo *et al*., (2010) ascertained that many project communication problems have occurred between geographical distributed or virtual teams. It was further described that these problems occur where differences between regional cultures come to play and then manifest in a variety of ways that include differences in fluency language, social attitudes and behaviors that hinder projects.

Louw *et al.*, (2005) indicated that the nature of the relationship in an interpersonal communication encounter could influence the status of the relationship between participants leading to unfriendliness, informalities, and seriousness that could hinder communication in turn projects.

Louw *et al.*, (2005) revealed that people's expectations of communication are defined by their past experiences. Giritli (2014) established that instances of past relevant conflict and parties could directly influence the attainment of organizational objectives if not resolved. This in turn suggest that it can degrade the quality, increase cost, decrease customer satisfaction and tarnish firm reputation.

Louw *et al.*, (2005) revealed moods and feelings that stem from unfamiliarity that each person brings to an interpersonal encounter could unearth adverse communication consequences. A study by Mitkus (2013), the impact is because of psychological defences of parties that could consequently impact a project negatively.

Naidoo (2011) founded that cultural concerns permeate all communication, since messages are formed and interpreted through cultural backgrounds of participants. Louw *et al.*, (2005) explained that cultural beliefs have undesirable effects to communication management practice. PMI, (1996) and Gunasekaran (2016) established that language and cultural barrier pose a challenge on communication to complete projects on time with allocated budget and quality.

Table 1 indicates the challenges stifling the implementation of communication management practices.

Table 1: Challenges stifling the implementation of communication management practices

Challenges	Source
Limited availability of information	Olaniran (2015) and Luka *et al*., (2014)
Limited access to selected communication technology	Chassiakos (2007) and Peansupap (2005)
Imposing a technology that is inappropriate to the project	Luka *et al*., (2014) and Čulo *et al*., (2010)
Poor listening skills of personnel	Molwus, (2014) and Maame (2012)
Unclear and delayed instructions	Olaniran (2015)
Language difficulties	Gunasekaran (2016); Perumal *et al*., (2011) and Hijiazi *et al*., (2008)
Poor writing skills of personnel	Olaniran (2015) and Adedapo, (2013)
Personal prejudice	Molwus, (2014); Adedapo, (2009); Čulo *et al*., (2010) and Hijiazi *et al*., (2008)
Preconceived and unwillingness to change beliefs	Rimmington (2015); Giritle *et al*., (2014) and (Louw *et al.*, 2005).
Misalignments of project stakeholder's visions	Luka *et al*., (2014) and Hoezen *et al*., (2006)
Distance between the construction headquarters and construction sites	Čulo *et al*., (2010) and Louw *et al.*, (2005)
Unfriendliness and rigidness between project stakeholders	Louw *et al.*, (2005)
Hostile past encounters between personnel	Giritle *et al*., (2014) and Louw *et al.*, (2005)
Different moods and feelings of employees	Mitkus (2013) and Louw *et al.*, (2005)
Diverse cultures between project stakeholders	Gunasekaran (2016); Naidoo (2011); Louw *et al.*, (2005) and PMI, (1996)

3. BENEFITS OF IMPLEMENTING COMMUNICATION MANAGEMENT PRACTICES

PMI's Pulse research (2013), has reported that effective communication management practice to all stakeholders is the most critical success factor in project and benefits construction projects. From this basis, it is crucial for Eswatini construction industry, characterized by inefficiency and poor services delivery, to understand the benefits in order to enhance competitiveness in line with best practices globally and for sustainable performance improvement. Based on this overview, 11 communication management practices were identified as benefits in Table 2.

Čulo *et al.,* (2010) observed that communication institutes a feedback mechanism that is the basic ingredient needed to maintain the support, commitment and loyalty of the project stakeholders. Methula (2015) established that when communication is managed well in organizations, it can build strong relationships, set clear expectations and institute feedback. Furthermore, a citation by Richard (2015) explained that when communication is focused on individual needs and provides information feedback, it boosts trust and loyalty, which are the key elements in building strong relationships.

Gunasekaran *et al*., (2016) and Garbharran *et al*., (2012) revealed that communication management practice plays an important role in leading and integrating people to make a project successful. Perumal *et al*. (2011) provided emphasis that communication practices promote collaboration and cooperation that are key elements for timely, economical, and successful deployment of construction projects. Čulo *et al*., (2010) clarified that effective communication creates a bridge between diverse stakeholders involved in a project, connecting various cultural and organizational backgrounds, different levels of expertise, various perspectives and interests in the project execution or outcome.

Faniran *et al*., (2000) indicated that communication practice provides significant opportunities for averting or reducing the effect of stakeholder's conflicts which is likely costlier if allowed to occur during a project. Methula (2015) cited Ragusa (2010) understanding that communication brings out reduction of potential misunderstanding that leads to conflicts.

Early literature equated output of good communication management practice with success, primarily in terms of time, cost and quality standards (Walker *et al*., 2008). In relation to time, Melton (2007) established that some projects have a defined and fixed target completion date and if this date is missed then the organisation may not be able to realize the benefits.

Miller (2016) opined that without effective civil communication an information exchange, construction projects cannot achieve productive project outcome for cost certainty, timely delivery, quality products and services. Johannessen *et al.,* (2011) cited in Methula (2015) that found that project communication was associated with the classical value of time, cost and quality, where if functioned efficiently was recognized to be the most important factor of achieving results.

Čulo *et al*., (2010) discovered that efforts have turned out to using effective means of communication since communicating information has been identified to have some direct impact on scope, time, cost, risk or quality of a task. It was substantiated that all processes and activities in construction projects centre on communication management practice since the success of a project relies as much on the quality of data as it does on completing the works on time and within budget (Kleim 2008).

PMI (2013) established improving communication management practices not only maximizes success, but also minimizes risk. Muszynska (2017) accentuated that project communication ensures the realization of tasks is possible in scope and manages project risks and responds to them appropriately. Yong *et al*., (2015) indicated that the risks are related to aspects of safety and health. Mitkus, (2013) illuminated that good communication management stimulates construction practitioners' awareness of their obligation and the procedures for health and safety to prevent concerns and clashes that may occur. Health and safety awareness promotes completions of projects without major accidents or injuries among the parties involved (Khoshtale 2016).

Molwus, (2014) founded that project success is attained in construction when the project outcome (realized asset) has become a matter of fully matching the client's needs at the time of realization. Hence, Chan *et al*., (2000) discovered that communication enhances achievement of user expectation. Moreover, it was also related to be associated with a specified level of environmental performance (Chan *et al*., 2000 and Yong *et al*., 2015).

Kliem (2008) and Louw *et al.*, (2005) revealed that the physical, social, historical, psychological and culture context of environment can dictate the effectiveness of communication on project success. Research from Naidoo (2011) discovered that the context is an important aspect of the communication process.

Čulo *et al*., (2010), conveyed the view that communication keeps everyone up to date on project progress. Constant update as the project progress in communication during a shared project vison has been shown to enhance project success (Garbharran *et al*., 2012). Luka *et al*., (2014) further clarified that keeping everyone up to date can be achieved through instances of meetings that help overcome communications barriers and increase performance levels.

Gunasekaran *et al*., (2016), discovered communication practice play an important role in leading, integrating people and taking decisions to make a project successful. According to Čulo *et al*., (2010) communication facilitates a buy in and ownership of major decisions and milestones.

Table 2 tabulates 11 benefits of using communication management practices.

Table 2: Benefits of using communication management practices

Benefits	Source
Ensures support, commitment and loyalty of project stakeholders	Methula (2015); Richard (2015) and Čulo *et al*., (2010)
Encourages collaboration and cooperation	Gunasekaran *et al*., 2016; Garbharran *et al*., 2012; Perumal *et al*. (2011) and Čulo *et al*., (2010)

Benefits	Source
Reduces project stakeholder's conflicts	Methula (2015); Ragusa (2010) and Faniran *et al*., (2000)
Reduces delays and encourages completing work on time	Melton (2007) and (Walker *et al*, 2008)
Reduces costs and encourages completing work within budget	Miller (2016) Methula 2015 and Johannessen *et al.,* (2011)
Improves the specified level of quality	Čulo *et al*., (2010) and Kleim (2008)
Ensures adherence to health and safety procedures	Muszynska (2017); Khoshtale (2016); Yong *et al*., (2015); PMI (2013) and Mitkus, (2013)
Enhances the achievement of user expectations	Yong *et al*., (2015); Molwus, (2014) and Chan *et al*., (2000)
Enhances specified level of environmental performances	Yong *et al*., (2015); Naidoo (2011); Kliem (2008); Louw *et al.*, (2005) and Chan *et al*., (2000)
Keeps everyone up to date	Luka *et al*., (2014); (Garbharran *et al*., 2012) and Čulo *et al*., (2010)
Allows project stakeholders to take decisions	Gunasekaran *et al*., (2016) and Čulo *et al*., (2010)

4. METHODOLOGY

Quantitative research approach was adopted for this study. A questionnaire survey was developed from extensive literature. Empirical testing was undertaken from a purposive sample of practitioners registered with the Construction Industry Council (CIC). A pilot study was conducted with practioners in Eswatini construction industry and determined the content validity of literature review analysis. Structured questionnaire was used for data collection.

The final questionnaire presented to the respondents consisted of one construct for the challenges consisting of 15 measures and another construct for the benefits consisting of 12 measures. The respondents were required to indicate their level of agreement the measures. The measures were rated on five-point Likert scale, where 1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree. In order to present the statistics appropriately, a number of ranges were established, and where; strongly disagree (SD) =1.00-1.80, disagree (D) =1.81-2.60, neutral (N) =2.61-3.40, agree (A) =3.41-4.20, strongly agree (SA) =4.21-5.00. This approach of interpreting data has been used in the studies of Renault (2018).

The final questionnaire was presented to 387 non-random sampled respondents. The data was collected using email method, of which 86 questionnaires were returned. However, 66 were deemed usable representing 22.22% response rate. Wahab *et al*., 2010 indicated that the response rates for mailed questionnaires are usually low, thus, a response rate of 15% to 25% is still considered appropriate and acceptable whilst according to Fryrear (2015) a response rate of 10% to 15% is still considered appropriate. Therefore, the current response rate is appropriate for analysis.

Other parts of the questionnaire were designed to profile the participants in terms of their; age, organization, profession, education and experience in construction projects. The IBM statistical package for social science (SPSS) version 25 was used to conduct descriptive statistical analysis of the data computing the frequencies, mean scores and standard deviation. and The SPSS was further used to determine the factor analyzability of the challenges and benefits of the communication management practices using inferential statistics. Principal axis factoring (PAF) was used to develop scales and measures to identify underlying structure (Pallant 2013). The benefit of using PAF is that it verifies the conceptualization of each construct and examine whether there is more than one factor and whether the factor does represent the underlying respective structure (Azmy 2012). The internal reliability of the constructs was determined using Cronbach alpha. This approach is supported by Pallant (2013) that suggest the acceptable Cronbach alpha cut-off value of 0.70. Table 3 indicates reliability analysis. The results proved the survey instrument had a good internal consistency with

Cronbach's alpha values greater than 0.70.

Table 3: Challenges and benefits of implementing communication practices

Description	No. of items	Alpha value
Challenges		
1. Personal interaction difficulties	5	0.821
2. Personal behavioral problems	4	0.813
3. Personal cultural problems	2	0.773
Benefits		
1. Organizational communication benefits	6	0.925
2. Project communication benefit	5	0.924

5. FINDINGS AND DISCUSSIONS

Respondents' Profile

The majority (71.2%) of the respondents are contractors, while 22.7% were consultants and a minority i.e. 6.1% were allied professionals. Whereas, 34.8% of the respondents are between 41 and 50 years while 31.8% are between 31 and 40 years. The respondents had different professional backgrounds. The project managers and construction managers were 28.8% and 24.2% respectively. Whilst civil engineers, quantity surveyors and electrical engineers were 13.6%,12.1% and 10.6% respectively along with architects and mechanical engineers indicating a combined minority of 6%. The respondents work experience varied with at least 82%, above 5 years and 91% having a diploma or above qualification.

Challenges of implementing communication management practices for construction project delivery

Based on the survey results in Table 4, the challenges that deterred the respondents from implementing communication management practices in Eswatini construction projects were established. The empirical findings established three factors established from the 15 measures identified in the literature subjected to PAF analysis. Results indicated that correlation matrix was above 0.30 and higher, which indicated factor analysis was possible for the data. For MSA, most items showed adequate relationship above 0.60. Communalities at extraction showed a good 60% of common variance amongst the items.

The KMO value was found to be 0.791 which was adequate for factor analysis. The Barlett's test of Sphericity was significant at $P < 0.05$. The Eigen value criterion indicated three Eigen values greater than 1 which reflected the proportion of the variance explained by factors. Factor 1 was named "*personal interaction difficulties*". The second factor was named "*personal behavioral problems*"and the third factor named *personal cultural problems*. The proportion explained by factor 1 was of 21.67 %. Factor 2 was 20.85% and factor 3 was 14.48%. The cumulative percentage explained by all factors was of 57.00%.

Based on the highest to the lowest ranking using the overall mean value, the rankings were personal behavioral problems (MS=3.23, SD=0.863) ranked 1st, personal interaction difficulties (MS=3.18, SD=0.726) ranked 2nd and last but not least personal cultural problems (MS=3.12, SD=1.019). Although, personal behavioral problems were ranked first and personal cultural problems ranked third, the mean scores were between 2.61 and 3.40 suggesting that the respondents are neutral. They do not agree or disagree with these three factors stifling the implementation of communication management practices. However, personal cultural problems attained standard deviation above 1, suggesting the respondents had varied opinions on the measures defining personal cultural problems.

The measures that aligned with *personal behavioral problems (PBP).*

namely: hostile past encounters between personnel, different moods and feelings of employees, unfriendliness and rigidness between project stakeholders and diverse cultures between project stakeholders were found to be consistent with literature of Čulo *et al*., (2010); Kleim, (2008) and Louw *et al.*, (2005) understanding on how communication management practice is challenge influenced by the context of environment. Hostile past encounters between personnel, aligned with the historical context, while different moods and feelings of employees with psychological context. Whereas, unfriendliness and rigidness between project stakeholders is associated with the social context. The diverse cultures between project stakeholders was due to the cultural context.

This then suggest that all four items within *personal behavioral problems* are a challenge not peculiar to Eswatini construction projects. However, despite this outcome the industry stakeholders should be aware of all the challenges and ensure they can overcome them when they are experienced in the construction projects in Eswatini.

Table 4: Challenges of implementing communication management practices

Factors	N	Minimum	Maximum	Mean	Std. Deviation	Rank
Personal behavioral problems (PBP)	66	1.00	5.00	3.2323	.86349	1
Personal interaction difficulties (PID)	66	1.20	5.00	3.1848	.72600	2
Personal cultural problems (PCP)	65	1.00	5.00	3.1231	1.01946	3
Valid N (listwise)	65					

Benefits of implementing communication management practices for construction project delivery

Nine theorized measures underlying the benefits of using communication management practices established in literature review were subjected to PAF analysis. Empirical results identified two factors from the construct. The correlation matrix of the 9 items were above 0.30 and higher, which indicated factor analysis was possible for the data. For measure of adequacy (MSA), all items showed adequate relationship above 0.60. Communalities at extraction presented 80% of common variance amongst the items.

The KMO value was found to be 0.869 which was appropriate and fit for factor analysis. The Barlett's test of Sphericity was significant at $P < 0.05$. The Eigen value criterion indicated two Eigen values greater than 1 which reflected the proportion of the variance explained by factors. This showed that there were two common factors. Factor 1 was named "*organisational communication benefits*" and second factor was named "*communication project communication benefits*". The proportion explained by factor 1 was of 33.13 % and factor 2 at 29.71%. The cumulative percentage explained by all factors was of 62.84%.

Based on survey Table 5, the respondents were questioned on the extent to which they agree on the benefits of using communication management practices. Empirical results categorized organization communication benefits ranked 1st (MS=3.99, SD=0.690) and project communication benefits (MS=3.87, SD=0.664) ranked last. The mean values were in the range of 3.41 and 4.20 suggesting that, the respondents agreed that implementing communication management practices is beneficial to the project. However, the standard deviations were above 0.5 suggesting that the respondents had different opinion on the factors related to benefits of communication management practices. It can be suggested that when communication practices are used, communication within the organization and the project itself are enhanced.

The survey results aligned with findings from literature review. Good project communication was found to maximize success (Walker *et al*, 2008; Kleim, 2008 and Yong *et al*., 2015). It was further established that communication had a positive correlation with organisation outputs like organizational commitment, performance, organisation citizenship behaviors and job satisfaction (Husain 2013). Such findings demonstrate that Eswatini construction practitioners are aware of the global development and the rational that organization and the project and communication process are inextricably related process (Methula 2015).

Table 5: Benefits of implementing communication management practices

Factors	N	Minimum	Maximum	Mean	Std. Deviation	Rank
Organizational communication benefits (OCB)	66	1.67	5.00	3.9965	.69082	1
Project communication benefits (PCB)	66	1.80	5.00	3.8758	.66450	2
Valid N (listwise)	66					

6. CONCLUSION AND FURTHER RESEARCH

Eswatini construction industry faces the challenge of poor construction communication that leads to poor performance due to poor communication management practice. The objective of this study is to discuss the impact of communication management practice for successful project delivery in Eswatini. Its main contribution is to establish specific and reliable insight on the challenges and benefits of implementing communication management practice related to Eswatini context (based on theoretical and empirical framework). It is important that Eswatini practioners incorporate understanding of the impact of communication management practice to buttress the significance of communication management practice in construction projects, worth focusing on as that can assist communication encountered problems as well as avoid them. This study presents results obtained through questionnaire survey from Eswatini. Using PAF, three factors were determined from the 15 underlying measures to the challenges construct, namely: personal behavioral problems, personal interaction difficulties and personal cultural problems. From the 11 basic measures to the benefits construct, two factors were established that include organization communication benefits and project communication benefits. Based on the Cronbach alpha coefficient evidence indicate that the factors were reliable.

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Characterization of the bond strength of Glass Fibre Reinforced Polymer rebars in concrete beams

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ABSTRACT AND KEYWORDS

Purpose of this paper

This paper presents the results of an experimental study of the mechanical properties of Ribbed Glass Fibre Reinforced Polymer rebars that could potentially be used as reinforcement in Civil engineering applications as well as their limitations in that matter.

Design/methodology/approach

The experimental work consisted of two tests, which were the tensile tests of the GFRP rebars followed by the flexural tests of GFRP and steel-reinforced concrete beams. Both tests were conducted using a Universal Testing Machine and parameters such as the tensile strengths of the rebars, their modes of failure, the deflections of the beams and the bond behaviour of the GFRP rebars in concrete beams were monitored throughout tests.

Findings

The results of the tensile tests showed that the average experimental tensile strength of GFRP rebars was only 56.65% of the nominal tensile strength provided on the supplier datasheet. Moreover, it could be seen that the failure of the tensile strengths of the rebars was mostly governed by the resin matrix failure. The results of the flexural tests, on the other hand, helped characterize the bond of the GFRP rebars in concrete. They showed that GFRP reinforced concrete beams developed about twice the deflection produced in steel-reinforced concrete beams which consequently led to relatively low bond strength while compared to steel reinforced concrete beams or only 86.67 % (10.95 MPa) of steel-reinforced specific beams bond strength (12.63 MPa). These results not only characterized the bond of GFRP rebars in concrete beams but also showed the limitations of application in civil engineering.

Keywords: Glass Fibre Reinforced Polymer rebars, tensile strength, bond strength.

1. INTRODUCTION

Civil engineering infrastructures exposed to aggressive environments, such as marine structures, bridges and highways exposed to deicing salts, excessive moisture, temperature and chlorides are often subjected to a reduction of alkalinity of concrete which results in the corrosion of reinforcing steel (ACI 440 R1-03, 2005). The corrosion of reinforcing steel ultimately causes concrete deterioration and loss of serviceability (ACI 440 R1-03, 2005). Various solutions were investigated to protect and maintain the concerned structures. However, none proved to be a long term solution, which raised the need for an affordable and non-corrosive reinforcing material (George & Parappattu, 2017). Glass Fibre Reinforced Polymer (GFRP) rebars was one of the solutions introduces in the late 1970's

(George & Parappattu, 2017). GFRP rebars are lightweight materials made of glass fibres and a polymeric resin matrix (CNR-DT 203/2006, 2007; George & Parappattu, 2017). They are produced through a pultrusion process which qualifies them as one of the most inexpensive reinforcing material in the market (George & Parappattu, 2017). GFRP rebars have since been used in the recent past, as internal reinforcement instead of steel reinforcement and many successful applications worldwide have demonstrated their practical use in civil engineering (ACI 440 R1-06, 2006; Tuakta, 2005). GFRP rebars also became a reinforcing material of choice due to their high tensile strength in the direction of the reinforcing fibres (ACI 440 R1-06, 2006). However, the downsides of these materials is that they are very susceptible to bending forces in the transverse direction (Ochola, 2004), their transversal tensile strength is relatively low while compared to their longitudinal tensile strength, they are characterized by a lack of ductility in tension (Billah & Alam, 2012) and their compressive strength is negligible (Marfia, et al., 2004). That implies larger curvatures, midspan deflection and more extensive cracks than in steel-reinforced concrete (ACI 440 R1-03, 2005; Ding et al., 2014). That also induces significant prying forces on the reinforcing rebar and the spalling of the concrete could be accelerated (ACI 440 R1-03, 2005). This anisotropic behaviour affects the shear strength of the GFRP rebars, hence, the bond behaviour of GFRP rebars to concrete. Moreover, their mechanical behaviour differs from that of steel reinforcement. This implies changes in the design philosophy of concrete structures while using GFRP reinforcing bars (ACI 440 R1-03, 2005). This also means that the understanding of the GFRP rebars characteristics is of the utmost importance before any implementation in any concrete structures since there is a complexity arising from the composite material itself and the combination of GFRP rebars and the concrete (Ceroni et al., 2006). This study was carried out to gain an insight into the tensile behaviour of GFRP rebars and their failure in tension through experimental tests, but it was mostly part of a large-scale preliminary investigation on ribbed GFRP rebars behaviour as a potential reinforcement for concrete structures.

2. EXPERIMENTAL PROGRAM

Figure 2.1 Ribbed Glass Fibre Reinforced Polymer rebars

The innovative work consisted of two primary tests, which were the tensile tests of the reinforcement, followed by the flexural tests of concrete beams to characterize the tensile behaviour of ribbed GFRP rebars in concrete structures.

2.1 Research materials

2.1.1 Reinforcements

There are many types of GFRP rebars with different surface treatments available on the market namely sand coated, helically wrapped, helically wrapped-sand coated, grooved surface and ribbed rebars (Baena et al., 2009). This study investigated ribbed GFRP rebars. Figure 2.1 shows the type of longitudinal reinforcing bars that were used in the study.

Figure 2.2 Fibrous thread wrapped along with the rebar.

The rebars were characterized by a fibrous thread wrapped at constant rib spacing around the rebars, as shown in Figure 2.2:

The supplier's specifications of the rebars are reported in Table 2. 1.

Table 2.1 Specifications for 12 mm diameter ribbed GFRP rebars.

Specifications	Unit	Value
Effective cross-section	mm^2	113
Tensile strength in the core	N/mm^2	850
E_f-modulus	N/mm^2	40000
Weight	g/m	240-270
Diameter	mm	12.0 ± 0.3

However, the actual physical parameters of the rebars, such as the diameter, the cross-sectional area of the rebar and the circumference of the rebar were difficult to determine because of the surface deformation of the rebar. The method described in ASTM D618 was used to identify those parameters. This method consisted of plunging 5 rebars of 265 mm long in graduated measuring cylinders filled with water, as shown in Figure 2.3.

Figure 2.3 Cross-sectional test of GFRP rebars.

The specimens were kept for 24 hours in a laboratory environment where the average temperature was 24.6 °C℃ and relative humidity of 38 %. The lengths of the samples were measured, and the volumes of water in the graduated cylinders were recorded before and after immersing the rebars. This helped measure and determine the actual physical parameters of the rebar, such as the effective cross-section, the circumference and the actual diameter of the rebars listed in Table 2.2.

Table 2.2 Calculated physical parameters of 12 mm ribbed GFRP rebars.

Specification	Unit	Value
Effective cross-section	mm^2	106.06
Circumference	mm	36.51
Diameter	mm	11.62

The steel rebars had the following specifications (supplier data):

- Ultimate tensile strength of 450 MPa;
- Young modulus, Es= 200 000 MPa; and
- Diameter of 10 mm.

2.1.2 Concrete mix

Ready-mix concrete was supplied by a local company named Wearne Readymix (pty) ltd. The concrete had a ratio of 70/30 OPC (ordinary portland cement)/fly ash mix. The ready mix concrete used in the preparation of beams had an average compressive strength of 23.17 MPa at 28 days, tested through cube testing in a laboratory environment.

2.2 Experimental tests

2.2.1 Tensile tests

Ribbed GFRP rebar samples were tested to failure, to investigate their tensile strength and the variables affecting it, using the Computer Control Electro-hydraulic Servo-Universal testing Machine, as shown in Figure 2.4. The technical specifications of the machine used are:

- Max load: 2000 kN
- Load accuracy: ≤ ±1%
- Deformation accuracy: ≤ ±1 %
- Load Resolution: 1/10000

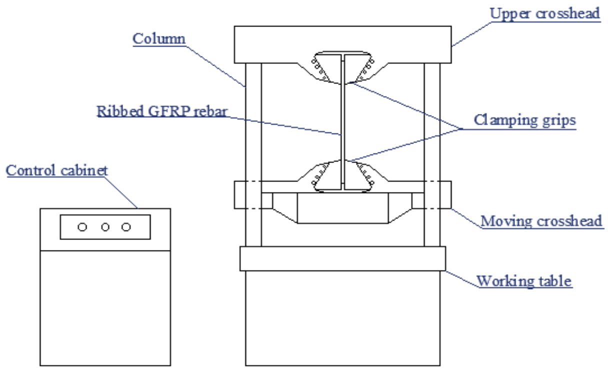

Figure 2.4 Tensile test: load frame configuration.

The tests were performed according to ASTM A370 and ASTM D3916. The tensile load was applied to rebars at a minimum constant loading rate of 70 MPa/minute as recommended by the ASTM A370.
2.2.2 Flexural tests

Subsequently, to the tensile tests, flexural tests were performed on 12 ribbed GFRP reinforced concrete beams to characterize the reinforcement material behaviour and on 4 Steel reinforced concrete beams to benchmark the results. The concrete beams had a length of 1160 mm and a cross-sectional area of 170 mm x 220 mm. The experiments were performed according to ASTM D7264/7264M using a UTM also used for the tensile tests. The flexural tests set-up is displayed in Figure 2.5.

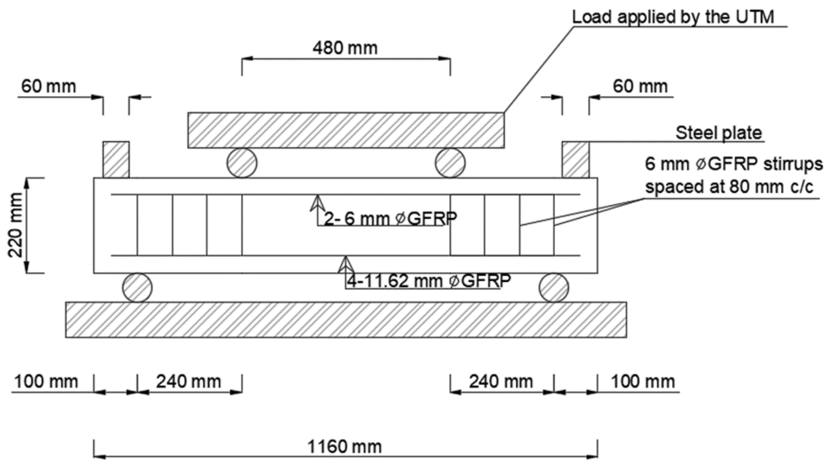

Figure 2.5 Flexural test set-up.

3. RESULTS AND DISCUSSION

3.1 Tensile tests results

The general coding applied for the specimens in the tensile tests is as follows: The letter A indicates the reinforcing bar, which is ribbed GFRP and the number 1 indicates the rebar number in the series. Table 3.1 summarizes the supplier specifications of the rebars (Table 2.1) and the experimental specifications values of the rebars derived from the cross-section test (Table 2.2) and the tensile tests.

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Table 3.1 Results of the tensile tests of the ribbed GFRP rebars.

Specifications	Unit	Supplier values					Experimental values				
		Sample					Sample				
		A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
Cross-sectional area	mm^2	113					106.06				
Diameter	mm	12					11.62				
Maximum Tensile Load	kN						53.49	56.11	57.08	55.92	61.82
Maximum Tensile strength	MPa	850					466	489	526	521	533
Average Maximum Tensile strength	MPa						507				
Standard deviation	MPa						28.45				

The experimental specifications values of the rebars were way more modest than the suppliers. The cross-sectional test of the rebar showed that the average cross-sectional area of the rebar was 106.06 mm^2, which represented about 94% of the supplier's value; and the average experimental diameter of the rebar was of 11.62 mm which was close to an average of 97% of the supplier value. The tensile strength of the rebar found experimentally ranged between 466 MPa (A1) to 533 MPa (A5) as seen in Table 3.1. The rebars barely reached 59.65 % (Maximum average tensile strength of 507 MPa, in Table 3.1) of the supplier tensile strength, which was about 850 MPa.

All the specimens exhibited no severe damages on the surface, but inside, as seen in Figure 3.1 (a and b). GFRP rebars are made by combining fibres and the resin that glue the fibers together. The resin needs to be strong enough to sustain the effect of Poisson ratio when the rebar is pulled. This study revealed that the resin holding the longitudinal fibres was not strong in tension and would fail due to the high Poisson ratio the rebar was subjected to in tension (ACI 440 R1-06, 2006). These phenomena were mostly observed at the midspan of the rebars

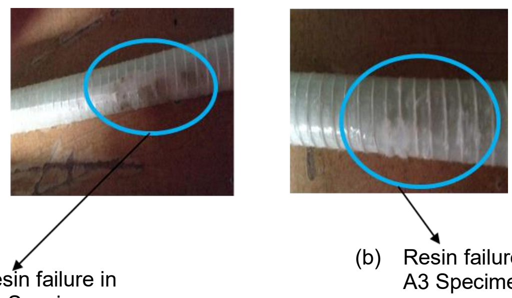

Figure 3.1 (a) A1 specimen resin failing, (b) A3 specimen resin failing.

To characterize the rebars used in this study, it could be said that they only reached up to 59.65 % of the nominal tensile strength (Table 3.1) on the supplier sheet due to the brittle resin matrix used in the manufacturing process. The tensile strength obtained in the tensile tests represented the tensile strength of the resin matrix and not the tensile strength of the entire composite material.

The behaviour of GFRP rebars in tension was not linear and was characterized by no clear yielding phase (ACI 440 R1-06, 2006). This showed the lack of ductility of the material (Issa et al., 2011; Billah & Alam, 2012). The rebars failed suddenly after reaching their maximum load. In this case, this can be explained by the severe damage of the resin matrix as it arrived its peak load.

Thus, the average maximum tensile strength of ribbed GFRP rebars used in this study was evaluated to be equal 507 MPa or 59.65% of the nominal tensile strength on the supplier datasheet. These results helped understand the mechanical behaviour of ribbed GFRP rebars in tension.

3.2 Characterization of the bond behaviour of ribbed GFRP rebars in concrete beams through flexural tests

The effects of the GFRP rebars mechanical properties on the bond strength behaviour were examined by using steel-reinforced concrete beams as a benchmark. The following symbols are used in this section to identify the different beams:

- For a beam named RCGFRP25: RC denoted Reinforced Concrete, GFRP denoted the type of reinforcement which was ribbed Glass Fibre-Reinforced-Polymer and the number ‘25’, indicated the specimen’s number.
- For a beam named RCS9: RC meant Reinforced Concrete, S denoted the type of reinforcement which was steel and the number ‘9’, denoted the specimen’s number for that type of reinforcement.

The results of the flexural tests are presented in Table 3.2.

Table 3.2 Results of the beams flexural tests at serviceability.

Sample	Reinforcement type	Concrete compressive strength (MPa) f_{cu}	Maximum load (kN) P_{max}	Maximum bending strength (MPa) σ_{max}	Maximum bond strength (MPa) μ_{max}
RCGFRP25	GFRP rebar	23.17	365.41	31.98	9.27
RCGFRP26	GFRP rebar	23.17	232.46	20.34	5.90
RCGFRP27	GFRP rebar	23.17	351.36	30.75	8.92
RCGFRP28	GFRP rebar	23.17	348.04	30.46	8.83
RCGFRP29	GFRP rebar	23.17	358.49	31.37	9.10
RCGFRP30	GFRP rebar	23.17	338.59	29.63	8.59
RCGFRP31	GFRP rebar	23.17	431.36	37.75	10.95
RCGFRP32	GFRP rebar	23.17	414.96	36.31	10.53
RCGFRP33	GFRP rebar	23.17	410.68	35.94	10.42
RCGFRP34	GFRP rebar	23.17	410.81	36.95	10.43
RCGFRP35	GFRP rebar	23.17	412.93	36.13	10.48
RCGFRP36	GFRP rebar	23.17	410.63	35.93	10.42
RCS9	Steel rebar	23.17	417.46	36.53	12.31
RCS10	Steel rebar	23.17	424.54	37.15	12.52
RCS11	Steel rebar	23.17	424.65	37.16	12.52
RCS12	Steel rebar	23.17	347.93	30.45	10.26

The results from Table 3.2 showed that GFRP reinforced concrete beams only developed up to 86.67 % (10.95 MPa) of steel-reinforced concrete beams bond strength (12.63 MPa). This justifies the limited deflections of steel-reinforced concrete beams (before failure) while compared to GFRP reinforced concrete beams, as seen in Figure 3.2.

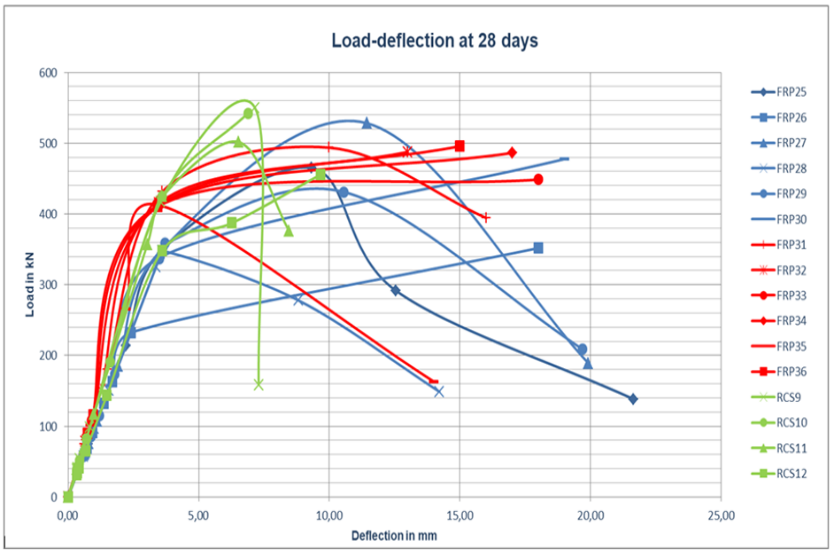

Figure 3.2 Load-deflection curves for GFRP and Steel reinforced concrete beams.

The large deflections of GFRP reinforced concrete beams were justified by the fact that the young modulus of ribbed GFRP rebars E_f (40 000 MPa) was 5 times less than steel rebars' E_s (200 000 MPa) and their relatively low transversal tensile strength as compared to steel rebars (ACI 440 R1-03, 2005). This phenomenon could also be explained by the fact that the resin holding the longitudinal fibres failed due to the high Poisson ratio the rebar was subjected to in tension as found in the tensile tests. Thus, the failure of the resin matrix determined the failure of the whole rebar structure. This led to the damage of the bond in the tension zone as they developed large prying forces and deformations (ACI 440 R1-03, 2005; Ding et al., 2014). It was also found that the maximum experimental mid-span deflections of ribbed GFRP reinforced concrete beams was of 19 mm and that of steel-reinforced concrete beams was of 8.46 mm. This meant that steel-reinforced concrete beams developed about 50% less deflection while compared to ribbed GFRP reinforced concrete beams. Table 3.1 also showed that the average tensile strength for ribbed GFRP was 507 MPa and was significantly higher than steel tensile strength, which was 450 MPa. However, it seemed that the average longitudinal tensile strength of the rebars had no direct effect on the bond strength of the beams. This was indicated in Figure 3.2 by the fact that steel-reinforced concrete beams developed smaller deflections than GFRP reinforced concrete beams as also stated by other authors (Ding et al., 2014).

It could also be seen from Table 3.2 that ribbed GFRP reinforced concrete beams only developed up to 86.67 % (10.95 MPa) of steel-reinforced concrete beams bond strengths (12.63 MPa). This justifies the limited deflections of steel-reinforced concrete beams (before failure) while compared to GFRP reinforced concrete beams, as seen in Figure 3.2.

4. CONCLUSIONS

The objective of this study was to characterize the bond strength of ribbed GFRP rebars in concrete beams through the mechanical properties of GFRP rebars to understand the limitations of the use of ribbed GFRP rebars in civil engineering applications worldwide. This was achieved through the experimental investigation of GFRP rebars properties such as the tensile strengths and modes of failure, followed thereafter by the study of their behaviour in concrete beams. The innovative work consisted of the tensile tests of the rebars and flexural tests of the reinforced concrete beams reinforced with the ribbed GFRP rebars. Both experiments were performed on a Universal Testing Machine (UTM). The tensile tests of ribbed GFRP rebars revealed that:

The tensile strengths of ribbed GFRP rebars used in this study were evaluated and found to be 59.65% of the nominal tensile strength provided on the supplier datasheet.

The experimental study also revealed that the failure of the GFRP rebars in tension was mostly due to the failure of the resin matrix, which happened to be brittle. This was observed through the tensile tests that showed that the fibres of the rebars were intact while the damages were localized in the matrix resin. This showed that the average maximum tensile strength of the rebar represented the average bond strength of the matrix resin and was only of 59.65% of the rebar nominal tensile strength.

The combined results of the tensile tests and flexural tests hence helped characterize the behaviour of ribbed GFRP rebars, and the following conclusions could be drawn:

Steel reinforced concrete beams developed 50% less deflection than ribbed GFRP reinforced concrete beams due to their relatively high young modulus and transversal tensile strength as compared to ribbed GFRP rebars.

It could also be seen that ribbed GFRP reinforced concrete beams only developed up to 86.67 % (10.95 MPa) of steel-reinforced concrete beams bond strength (12.63 MPa) and that was due to the limited deflections of steel-reinforced concrete beams while compared to GFRP reinforced concrete beams.

5. RECOMMENDATIONS

The results of the study showed that the bond behaviour of ribbed GFRP rebars was more governed by their transversal tensile strength than the longitudinal one, which was not investigated in this study. The study will recommend that more research should be done on that property of the rebars to help characterize the bond of GFRP rebars in concrete structures.

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Critical Review on impact of Education, Skills Training and R&D Investment in Construction Business Development

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ABSTRACT AND KEYWORDS

Purpose of this paper: The study aimed to critically evaluate the impact of education, skills training, and research and development (R&D) among the surviving SMME contractors in the South African construction market.

Design/methodology/approach:
This study adopted a qualitative research approach, rooted in the phenomenological paradigm and utilising the in-depth interviewing method. The researcher purposively selected 34 out of 74 SMME contractor that are locally bred and owned construction organisations.

Research Limitation/Implications: The findings in this study cannot be entirely generalised, as the study is based on a small sample in the context of the South African construction market.

Findings: The research findings showed that SMMEs in the construction industry, acknowledged that education, skills training, and research and development have a significant impact to their organisational growth and development. The study indicates that many organisations have poor performance and productivity as a result of the lack of educated employees in the area of construction technology and management.

Practical Implications: The study provided phenomenological insight on the impact of education, skills training, and R&D among the surviving SMME contractors in the South African construction market.

Keywords: Construction industry, education, Research and Development investment, skills training

1. INTRODUCTION

The terms-education, skills training, and research and development (ESTRD) are amongst the strategic approach many orgainsations are utilising to improve their productivity and employees' capability to perform (Nickels *et al.,* 2010). According to the Partnership for 21st Century Skills (2008), the 21st century business environment has relied on education to be the bedrock of competitiveness for organisations' and national economic sustainability. Hence, advanced economies, innovative industries and firms, and high-growth jobs require more educated individual(s) and business owners. This is also the case for SMME contractors; as the Organization for Economic Cooperation and

Development (OECD) (2007) research report on the business' innovation and sustainable growth affirmed that an organisation's sustainability and competitiveness rely heavily on its leadership and innovative skills which mostly emanates from basic knowledge, through education, science and skills training.

Hana (2013) argued that education has been regarded as a key factor for economic success in many organisations, because it is the generative centre of innovative knowledge and solutions. Education remains a fundamental factor in the innovation and assimilation of new technologies in the construction industry. Supporting this view, Nadim (2012) research claimed that 80% of firms (especially the small businesses) within the construction industry experience skills shortage. Without appropriate skills training, the SMME contractors risk facing a lack of competitiveness, which may as well, reduce their economic growth (sustainability).

Education plays a critical role towards human capital and business development, as Burns (2007) reported that there is a stronger connection between educational attainment and business growth in many professional fields such as the construction industry. Nadim (2012) acknowledged that the construction industry players and academia have been strategically collaborating, as they desire to improve the industry practices through skills development. Burns (2007) further claimed that educated business owners (such as Small, Medium and Micro-Enterprise (SMME) contractors and entrepreneurs) are most likely to develop and grow sustainable organisations. The construction workers and business owners need to be educated, in order to possess the technical capability and managerial know-how that are needed to respond flexibly to complex problems, to communicate effectively, to manage information, and to work in project team(s) and produce new knowledge (Partnership for 21st Century Skills, 2008:6). Megginson *et al.* (2003) stated that the post-industrial era has created a business environment where 80% of the jobs in the market require higher-level skills and knowledge. These changes in the market have resulted into the shortage of skilled workers. As such many potential employees lack the education, experience and skills knowledge needed in the market (Megginson *et al.,* 2003). Moreover, the phenomenon of skills shortage has caused a major challenge for SMME contractors' quest to employ skilled workers and to develop and grow sustainable construction businesses.

The importance of research and development initiative reflects on quest of continuous improvement of services and products' performance within any given entity. According to the OECD (2007), research knowledge has become an increasingly essential factor for growth and competitiveness of nations, industries and organisations. Pheng *et al.* (2010), are of the view that research and development in the area of information and communication technology could create opportunities for creating a competitive advantage for both large and SMMEs.

1.2 Research Problem Identification

Globally, the chronic business failure amongst the Small, Medium and Micro-Enterprises are mainly anchors on the inadequacy of basic education, skills training and business experience, and lack of engagement and application of research and development initiatives.

1.3 Objective of the Study

The study aimed to critically evaluate the impact of education, skills training and R&D among the surviving SMME contractors in the South African construction market. Thus, the study focused on the cidb Register of Contractors within grade 4-6 SMME contractors.

1.4 The Importance of the study

The research geared towards promoting among the start-up and struggling SMME contractors the importance of education, skills training, experience, and R&D in the development and growth of sustainable construction businesses.

2. LITERATURE REVIEW

2.1 The Need for Skills Training in the Construction Industry

According to Megginson *et al.* (2003: 231), successful and effective small businesses do not emanate from the ability of the owners only, but also from their employees' competencies, organisational motivation, and levels of education, industrial experience and training development. However, Hana (2013: 82) argued that individual and organisational training play an important role, as it contributes to the internal strategic learning, and serves to generate a source of new innovative ideas within the business. It is evident that skills training is a necessity for the effective development of the construction industry. The construction industry (being a project-based sector) and requires collaborative skills and efforts between the business owners and their employees. According to McCabe (2010), the levels of skills and expert knowledge within an organisation and the industry need to be reviewed and improved constantly through continuous training and education. Therefore, improving business performance through skills training techniques would provide the SMME contractors with unique opportunities to develop competitive projects services and products. Thus, in turn, it would enable them to gain a competitive advantage and economic sustainability.

Hana (2013) further adds that managers', business owners' and entrepreneurs' skills and educational background contribute largely on how competitive their market positioning is perceived in the given sector (such as construction industry). According to Forte, Barros and Nakamur (2013), skills training within an organisation involve providing employees with valuable knowledge and competitive skills that would encourage and motivate them to perform effectively and to continuously improve their organisational business operations.

2.2 The Importance of Employees' Skills and Education in the Development of an Organisation

Nickels *et al.* (2010) maintain that organisations (such as SMME contractors) and their employees can get training, be educated and acquire skills, at any stage of their business development. Skills training and development activities include employee's orientation, on-the-job training (including mentorship), apprenticeship, off-the-job training, and job simulation (e.g. use of software for design testing). Therefore, management skill training would strategically develop employees and set the tone for competitive business operations. Hana (2013) argues that successful development in organisations would depend on their employees' skills, knowledge, experience, creative and innovative activity and educational qualifications. Employees' skills are paramount for an organisation to be sustainable. The skills training focus on continuous learning, research, development and experience. Nickels *et al.* (2010) explain that while the "skills training" approach focuses on short-term skills acquisition; whereas the formal educational training and development focuses on long-term skills acquisition. The latter builds significant capabilities within firms. However, skills training and formal education seek to assess and evaluate organisational needs. In addition, organisations should seek to evaluate the impact of skills training and formal education within its organisational progress.

2.3 The Importance of SMME Contractors' Skills in Project Development

Nadim (2012) defines skills as the capabilities of an individual(s) (such as SMME contractors) to undertake a project task. Therefore, skills are important in construction projects, as these can be linked to competence and new innovative and competitive skills. With new materials, equipment, systems, processes and practices constantly maturing and evolving in the construction industry; it is imperative that these skills (SMME contractors' skills) are improved. Rankhumise (2013) claims that most successful contractors and entrepreneurs have innovative and competitive skills that lead to their success. It can thus be argued that these skills have the capability to accelerate business development. These factors include: specialist and innovation skills, expertise and interpersonal competence, leadership, having a healthy business judgement sense, and entrepreneurship skills.

Rankhumise (2013); and Nickels *et al.* (2010) further support the view that contractors can be more effective, if they combine their skills, including technical capability, conceptual skills, expertise, interpersonal competence, and good personal attributes and characteristics, in an efficient manner. These skills can unleash SMME contractors' ability to take calculated-risks; to strive towards achievement; to inspire commitment to their business; perseverance; good relationships with others; and to acquire the required knowledge that could result in organisational growth and improving a functional management approach (Rankhumise, 2013); and Nickels *et al.,* 2010). These competitive and innovative skills are capable of enhancing SMME contractors' achievement, improving their business performance, and sustainability. However, Nickels *et al.* (2010) argue that technical skills involve the ability to perform tasks in a specific discipline, whereas interpersonal competence and conceptual skills enhance the ability to communicate, motivate, and work through and with people. It also helps to strategically direct an organisational vision towards their ultimate goal. The cidb (2011) suggested that SMME contractors are required to have key skills and competencies, in order to run a successful contracting business. These skills and competencies include business management skills, technical ability, management (supervision and operational) and complying with legislative issues. These core competencies and skills are measured against acceptable standards, necessary for running a contracting enterprise and for supervising construction works.

An organisation with adequate managerial competence would be able to handle project tasks effectively and deliver project contracts, in accordance with set standards. The SMME contractors must view training as a critical business factor. Pheng *et al*. (2010) advocated that training and investing in human capital remain the essence of building managerial competence within an organisation with a view to achieving a competitive advantage. Bogus (2006) supported the claim that technical training, social skills (such as oral communication and problem solving), and critical thinking can be integrated through workshop activities. These could enhance the SMME contractor's business capability and aid firms in developing into competitive organisations.

2.4 Research and Development (R & D) Investment as a means of Technological Advancement

According to Nadim (2012) technological advancement and increase in competition in the construction industry have called for focus on transforming organisational skill profiles. Highly trained individuals (specialists) could be redirected into 'generalists' (multi-skilled) through research and development investment. This approach would give the various organisations the competitive edge to work across multi-disciplinary projects and to make decisions on finance, design, construction, operation, facility maintenance and management (Nadim, 2012). Megginson *et al.* (2003) added that organisations (such as SMME contractors) should be able to develop their managerial competence and gain a competitive advantage at all cost. This would be possible by adopting an innovative training and skills development programme to upskill their workforces through direct research and development. This would increase their workforce productivity; minimise errors on operations; lead to minimum supervision; and result in improved employee satisfaction. Johnson *et al*. (2011) viewed organisational knowledge as a collective business intelligence specific to an organisation, which is accumulated through formal systems, shared experience and knowledge, and research and development which is key to its growth.

According to Pheng *et al.* (2010) Technological innovation through R&D are pillars of the knowledge-based economy, therefore, how the organisation exploits and use these technologies holds the key to their business performance in a given market. Johnson *et al.* (2011) argued that an organisation can create new products and innovative services through essential research and adopting a research and development approach. This approach may involve effective knowledge sharing, making use of computerised information within an organisation's system, and by technologically codifying their financial and market strategies, and other valuable data. Most organisations (who achieved their sustainable competitive advantage through the research and development approach) have engaged in it by adopting strategic alliances with other organisations or individuals (s). And through strategic alliances, the research based-knowledge and investment-driven competence skills, knowledge and experience are shared as critical business advantages.

3. RESEARCH METHODOLOGY

According to Dane (2011) research is a critical process of asking and attempting to answer questions in the real world; as this can be done a questionnaire, interview, experiment and other different methods. Thus, research methodology involves three processes, namely: data collection, data analyses and interpretation, which are aimed at proffering a better understanding of the study phenomenon (Leedy and Ormrod, 2013). This study adopted a qualitative research approach, rooted in the phenomenological paradigm and utilising the in-depth interviewing method. Phenomenology is the philosophical name for the method of investigating or inquiring into the meanings of our experiences; as Miles, Huberman and Saldana (2014) stated that phenomenological paradigm tends to look at data thematically, to extract essences and essentials of research respondents (SMME contractors) perceptions and its meaning. The research aimed to critically evaluate the impact of education, skills training and R&D investment among the surviving SMME contractors in the in Port Elizabeth, South Africa.

The 34 selected SMME contractors are the cidb Register of Contractors within grade 4-6 contractors, that having operating beyond the first five years. This method in the study is considered the most appropriate and effective to elicit useful and authentic information through sharing of experiences, opinions and perspectives through the interviews with the SMMEs construction business owner's and executive managers as firms' representatives. The insightful knowledge and data generated from the study were coded, and thematically discussed, interpreted and presented accordingly.

4. RESEARCH DISCUSSION AND FINDINGS

The researcher purposively selected 34 out of 74 SMME contractor, which are locally bred and owned construction organisations, which can be classified as medium sized contractors. The assumption was that these contractors were amongst the 10% - 20% who have survived and remained competitive beyond the first five years of their entrance into the industry. This research's intention was to capture a clear and in-depth understanding of the impact of education, skills training, and R&D investment towards growing a sustainable construction business.

4.2 The Contractors' cidb RoC Grading

Table 4.1 presents the contractors' cidb grading, which indicates that, out of 34 interviewees, 8 firms (24%) are contractors in the cidb grade '6GB and 6CE'; 13 firms (38%) were contractors in the grade '5GB and 5CE'; and another 13 firms (38%) in the cidb grade '4GB and 4CE' respectively. The various grades amongst the interviewees were significantly well represented. The data were insightful, significant and meaningful, as most interviewees had significant levels of experience in the South African construction industry.

Table 1: Research Participants (Interviewees) (The cidb contractors' grading)

Respondents	**Response**	
Cidb Grade in Port Elizabeth	Number	%
4GB & 4CE	13	38.00
5GB & 5CE	13	38.00
6GB & 6CE	8	24.00
Total	**34**	**100.00**

Source: Author's construct

4.3 The Interviewees' Working Experience in the Construction Industry

Figure 1, indicates the working experience of the interviewees in the construction industry, which ranged from seven (7) to thirty-five (35) years. In Table 4.1 revealed that 44% of the interviewees had a working experience of between seven (7) and fifteen (15) years; 32% had worked for 16 to 25 years; and 12% had worked for 26 to 35 and 36 to 45 years respectively.

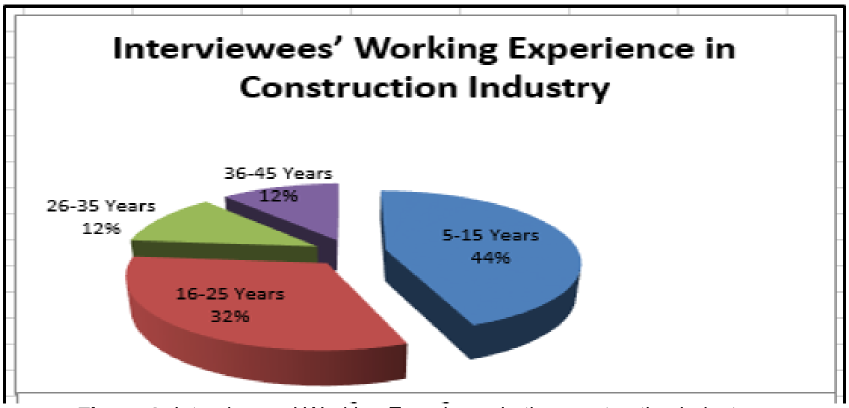

Figure 1: Interviewees' Working Experience in the construction industry

4.4 Interview questions on: Education, Skills Training, and R&D in the Construction industry

a. Could you please explain the impact of education, skills training, research and development in your organisation?

Thematic analysis and Discussion

The information gathered during the study interviews was coded and analysed thematically. However, the interview was purposively composed into themes as its links and reflects that of the research questions. These themes were emerged by pertained to the research interview questions on the impact of education, skills training, and R&D investment.

The Impacts of Education, Skills Training, and R&D (ESTRD) on Construction SMMEs

Seventeen (17) respondents (5Ds, 6Es and 6Fs) believed that education, skills training, and research and development are very important to their organisational growth. Respondent E1 narrated the scenario of an organisation that is lacking educated employees in the area of construction technology and management. Those organisations would not perform adequately and this led to their poor level of productivity. The experience narrated by respondents E1 resonate with the findings of Burns (2007) that there is a stronger connection between educational attainment and business growth in many professional fields such as the construction industry. Therefore, education plays a critical role towards human capital and business development, and it follows that if an organisation that hires uneducated and unskilled people, would struggle to survive in the construction market as, the industry highly knowledge-driven and encourages a competitive business environment.

Impact of project management education, technical skills, and skills training in the construction business

Respondent F2 reported that: "*About two or three years ago, we employed people without good construction project management education, and this resulted in poor project delivery (in terms of cost, time and quality). It caused us a lot of embarrassment*". E11 stressed that *"employees with technical skills and innovative mind sets are more likely to be promoted to senior management positions than the ones that do not possess these qualities; because they add significant value and contribute to organisational growth and improvement of service".* E11 also further noted that "*we also engage in research in the area of recycling and re-use of building materials"*. Respondent F4 supported this, but stressed that skills training and development are very important at all levels (top or lower) of staff within an organisation, as it results in better performance. It follows, therefore, that every organisation needs educated and skilled employees to succeed. These findings corroborate with works of The OECD (2007) and pheng et al (2010) that research knowledge and innovative development have become an increasingly essential factor for growth and competitive advantage of nations, industries, business (both large and SMMEs) especially in the area of information and communication technology.

Education, skills training, and R&D did enhance our workforce productivity. We have a skilled workforce and we constantly up-skill and train our employees in the areas that require improvement. The up-skilling has made us better and informed of the changes in the market" (D4).
"Yes, we constantly engage our employees in skills training in the areas of their individual responsibility. This significantly improves their competencies, capability and adds value to the overall performance and growth of the organisation" (D5).
"We have educated and qualified construction professionals working in this firm and their inputs have contributed significantly towards the growth of the organisation. Indeed, skills training is an important aspect of our organisational strategy for the improvement of services. We are, currently, training some of our employees in advanced health and safety management and quality assurance" (D2).
Furthermore, E3 explained that: *"Skills development and education form the cornerstone of our organisations and provides a huge competitive effect on our business. Moreover, we engage in a lot of on-site and in-service skills training and career development for our employees, who deliver specialised services".*
"We take some of our operatives and train them on how to operate the plant and equipment as required in the execution of our projects. Training has a significant impact on our business, because without trained, skilled, competent and efficient employees, our organisation would not have functioned and grown to this level today" (E3).

Skills training and performance improvement

E6 stated that: *"To me, these ESTRD factors are the backbone of my business success. Hence, I keep on up skilling myself and training our employees on a regular basis, in order for them to understand the emerging trends and developments in the industry".* Thus, education, and skills development have been key to our successful performance. E6 also disclosed that: *"I absolutely do not mean that people without education cannot succeed in the market, but in the case of construction business, education and technical skills have made a difference*. Supporting this, F7 stated that education is a plus and added advantage to organisational service; however, we do appreciate the natural talents and the persistence of our employees through on-the-job training and development. These findings validate the viewpoints of Rankhumise (2013); and Nickels *et al.* (2010) that contractors can be more effective, if they combine their skills, including technical capability, conceptual skills, expertise, interpersonal competence, and good personal attributes and characteristics, in an efficient manner. In addition, the findings also corroborate with Bogus (2006) that technical training, social skills (such as oral communication and problem solving), and critical thinking could enhance the SMME contractor's business capability and aid firms in developing into competitive organisations.

D9 stated that: "*As the CEO of my organisation, I have been constantly improving my skills and competencies through short courses; furthering my education and training in entrepreneurship and enhancing business management, project management, production management, quality assurance and enhancing leadership skills. In addition, all that I have learnt during my training has been gradually transferred to my key employees. This education and skills training has had a major impact on the improvement of the quality of our service and business performance."*
F3 explained that their organisation does enrol their employees in various professional courses such as: health and safety; surveying, scaffold erection, and inspection management. F3 further maintains that, they have a lot of training opportunities for their employees, especially in improvement of critical skills and competences. He stated that, *"of course, education has made a significant contribution to the growth and development of our organisation to this level. Moreover, we only employ educated workers; because, to have an effective and efficient project team, most of the employees must be well educated and skilled to function optimally"*. Furthermore, E12 stressed that: *"The value of having educated employees on the workforce cannot be over emphasized. Thus, we constantly train our employees in the areas of their weakness, both through in-house and outsourced experts. Our organisation regards education as a critical factor for smooth business operation and sustainable performance".* These findings corroborate the views of Forte, Barros and Nakamura (2013) that skills training provides employees with valuable knowledge and competitive skills that propel them to continuously improve their individual performance and collective organisational business operations.

5. CONCLUSION

Education, skills training, research and development are pivotal to contractors' business growth; and enhance their innovative skills and knowledge of how to strategically compete and survive in the industry. This is because, uneducated and unskilled employees in the construction industry inadvertently cause poor performance. Thus, most SMME contractors tend to employ staff and workers, because they add significant value and contribute to organisational growth and improvement in service delivery.
Moreover, strategic knowledge and skills from training, R&D processes, and training of employees on health and safety; project management; project design; surveying; scaffold erection; green building; and recycling and re-use of building construction materials; and management inspection, all enhance organisational competitiveness and cost-effectiveness of project designs.

6. RESEARCH RECOMMENDATIONS

The SMME contractors should strategically build their competitive capabilities and competencies through the acquisition of relevant training, qualifications, experience and professionalism. This is a prerequisite for developing the functional-business structure, and coordination of the business activities with respect to sustainability in the industry.

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Innovation in the South African Built Environment: A 3D Printing Perspective

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ABSTRACT AND KEYWORDS

Purpose of this paper
The study investigates innovation in the built environment through the field of 3D printing. It is established that numerous problems arise, even as early as in the design and concept stage of a project. This is due to the design concept not being communicated with enough detail.

Design/methodology/approach
An explorative mixed method approach was used for this sample study. A selected sample of 24 professionals within the field of quantity surveying, architecture, project management, contractors, and engineering were surveyed through a combination of interviews and questionnaires.

Findings
The data acquired through the study highlighted that challenges arising in the life cycle of a project can be reduced by making use of an innovative technique such as 3D printing, however the cost associated with 3D printers will hinder the implementation thereof in the building industry.

Research limitations/implications
The study was limited to one innovation technology and pilot study towards a larger study on innovation. The chosen technology, in the most part is still an emerging technology, especially in South Africa.

Practical implications
Innovation and the application of new technologies has carefully evaluated, seeing that it is dependent on multitude of industries, governing bodies, regulations, and social communities

What is original/value of paper
The paper contributes to the understanding of dependence of innovation on different criteria to make it viable in the construction industry.

Keywords: Additive Manufacturing, Innovation, 3D Printing, Project Life Cycle (PLC)

1. INTRODUCTION

The construction industry has been identified as an industry of fixed methods, traditionalism and an absence of innovation (Xue, 2014: 113). Several areas in the building environment requires modification so that costs can be reduced as well as the total project time. Innovation will benefit both the client(s) and contractor(s) during the entire life-cycle of the project. Innovation is a technique that should be balanced and implemented slowly as the gaps in the construction industry cannot be covered overnight (Perera, 2018: 312).

Fin Ostravik summarises the construction industry's dilemma as follows (2015: 25): "Complexity creates uncertainty and makes stakeholders more prone to stick with established methods and solutions in their work than they would have been if the level of complexity were lower".

Several problems arise, even as early as in the design and concept stage of a project (Hardie, 2010: 7). This is due to the concept not being proposed effectively enough. Delays in the construction phase occur because of the design not being executed flawlessly and on time as it ought to be, by reason that the design is too complex for labourers to construct. The above mentioned are just a few difficulties that could possibly be resolved by implementing an innovative technique such as 3D printing (also known as additive manufacturing) (Head, 2017: online). There can never be enough innovation in the built environment. As technological inventions become more advanced, the construction industry must adapt and be receptive to the changes. By accepting new developments into the industry, the built environment will surpass the barrier of being traditional and old-school (Tay, 2016: 177).

The subsequent study focuses on the role innovation plays in the built environment and the accompanied challenges that prevents the implementation thereof. If the necessity for innovation outweighs the supplemented challenges, technological advancements can improve the way we build (Croisel, 2017: 23). The innovation of 3D printing can lead to faster construction, higher quality materials, and less wastage if it is accepted and implemented in the built environment. The research of the study aims to corroborate that with the use of innovative 3D printing techniques throughout the project life cycle, innovations can be communicated, tested, and complications during construction can be reduced.

The research questions ask: Why is innovation, such as 3D printing, needed in the construction industry if it is functioning satisfactorily and what will the effect be on the industry? The hypothesis states that with the use of innovative 3D printing techniques throughout the project life cycle, innovations can be communicated, tested and complications during construction can be reduced. The objective of the study was to analyse a relative “novel” technology and evaluate its implementation rate within the construction industry.

Widen (2012: online) highlights that applying innovation to the built environment is not as simple as it may seem. The construction industry relies completely on the fixed methods available to carry out a building project. Professionals in this industry would debate, why change a system that works? Being innovative doesn’t necessarily mean to remove what is working, rather improving certain aspects and applying certain technologies differently.

2. AN OVERVIEW OF INNOVATION IN THE BUILT ENVIRONMENT WITH A 3D PRINTING PERSPECTIVE

2.1 Brief historical overview

The first concept regarding 3D printing was theorised in the 1950’s through robotic bricklaying. The relevant automation of this concept started in the 1960’s with pumping concrete (Ding, 2017: 85). Charles W. Hull developed the first idea of 3D printing in 1983 by way of stereo lithography. Stereo lithography became the first technological invention of swift prototyping which promotes the fast, detailed, and repeatable manufacturing of objects with computer assistance. The reason that 3D printing was incorporated in the built environment was mainly because of the great precision it can build complicated geometric objects with. The first 3D printer utilised in the construction industry was in 1984 (cited: Goldberg, 2018: online). This contrasts with belief that this is a new “novel” technology.

There has been an increased trend and research on the subject as is shown in figure 2.1:

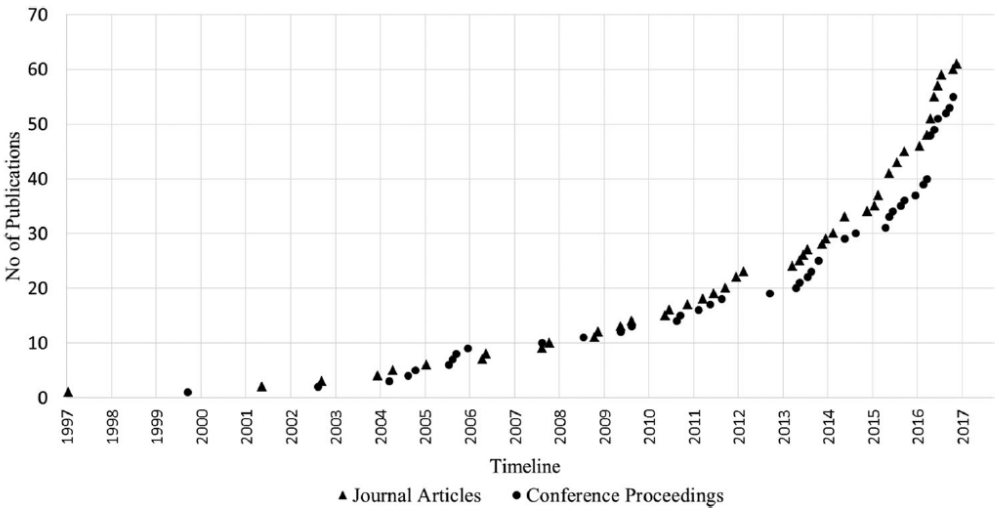

Figure 2.1: Trend of publication output over the years.
(Source: Tay et. al, 2017: 263)

The adoption of 3D printing has accelerated over the past few years because of the technological advances in both equipment and materials, new entrants to the industry, strategic moves by established construction companies as well as a political push in some countries (De Laubier, 2018: 4-6).

2.2 The necessity of innovation in the construction industry

Innovation must be a productive way to transform and revolutionize something. Even if the construction industry is functioning satisfactory it doesn’t necessarily mean there is no room for improvement (Embley, 2015: online). When innovation is applied and incorporated effectively, construction companies will be able to manage, control, and measure innovative ideas at every level of the project life cycle, with economic benefits contributing to the built environment.

For innovation to be adopted as a practice within the construction industry, the built environment must standardise the innovation technique to guarantee that the advantages to the industry will continue. When innovation thrives in a knowledge grounded industry, skilful workers is attracted, a competitive market is established, and training and creativity are encouraged (Ferlaino, 2014: online).

2.3 Three-dimensional printing as an innovative technique

The mobility of the printer is seen as the primary advantage as it can be transported all over the world which will eliminate the cost of material transport and storage on or off site. Developing buildings with complex shapes may be one of the most beneficial attributes according to Bos (2016: online). Three-dimensional printing in the built environment can contribute to an increased production level, larger client satisfaction, an improved company image, and the improvement of technical and managerial capability (Kreiger, 2015: 156). With 3D printing as an innovative technique to the construction industry, the boundaries that came with traditional building techniques can be overcome.

The varieties of suitable materials conducive for 3D printing in construction includes, polymers, metals ceramics and mortar or concrete (De Laubier, 2018: 4). The different examples of 3D printing over the life cycle stages of a project are presented in Table 1 below.

Table 2.1: 3D printing examples over the life cycle stages of a project

3D PRINTING OVER THE PROJECT LIFE CYCLE	
1. Concept	• The use of sections of 3D prints from previous projects.
2. Design	• Basic printed 3D architectural models • Evaluating constructability of new engineering and architectural components. • 3D printing equipment (offsite or on-site) • Specialty materials evaluation (e.g. load testing) • Software generation for 3D printable models
3. Implementation	• Producing and assembling works.
4. Commissioning	• Maintenance - Repairs, remodelling and printing spare parts

(Modified: Burke, 2007: 48; Tay et. al, 2017: 261-276; De Laubier, 2018: 14)

Innovation in the built environment can help to advance decision making and performance across the life cycle of a project. The technology of 3D printing is still new and comes with limitations, but high prospects are on the front regarding the future of 3D printed structures and building material components. 3D printing can change the way we design and present buildings and improve the building process as we know it.

3. RESEARCH METHODS

Omair (2015: 153) states that research can be divided into two categories: quantitative and qualitative. Quantitative research comprises of studies using statistical analyses to attain their discoveries whereas qualitative research includes studies that do not enumerate their outcomes through statistical analysis. Through some previous studies done on the topic, a quantitative approach together with a qualitative analysis are the most suitable research method for this study.

An explorative study of professionals in the construction industry located around South Africa are represented in this study are. They work at diverse career levels, different construction sectors, such as civil construction and general building, manage different construction projects, and at different phases in these projects.

The data collection tool used in this study is a Confirmatory Data Analysis (CDA) which can be defined as an approach that, after data procurement, proceeds with the obligation of a prior model and analysis, estimation, and testing model parameters (Lawrence, 2015: 533). The targeted population of the respondents for the study were a selective sample and be seen as a pilot study for further study.

A selected sample of 24 professionals within the field of quantity surveying, architecture, project management, contractors, and engineering were used. Even though only a small sample of the South African construction industry was targeted, an excellent response rate of 100% was achieved. The target population was a selective sample with the goal of finding a credible sample from the respondents.

Thirteen questions were asked, with the objective to establish if innovation is required in the built environment by looking at the innovative technique of 3D printing.

4. RESULTS

4.1 Results of empirical study

The 13 questions of the semi-structured questionnaire are summarized into categories and the results were as follows:

Category 1: Background of the respondents

Engineers represents the largest sample size of the respondents at 50.00%, followed by Quantity Surveyors at 20.83%. Table 4.1 illustrates that the respondents of the study have a relative high rate of experience. Most of the respondents' work was within Gauteng and the Free State, indicative of the sample distribution. The average monetary value of projects on which respondents are involved in is estimated more than R 35 million. Most of the projects are multi-disciplinary projects, ranging from technical engineering projects to complex buildings. This suggests that the respondents work on large and complex projects where innovation are in demand.

Table 4.1: Profession and experience of the respondents

PROFESSION			YEARS OF EXPERIENCE							
		Total %	0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	Total %
Architect	3	12.50		1			1		1	12.50
Quantity Surveyor	5	20.83			3		1		1	20.83
Structural Engineer	6	25.00	1	1	2	1			1	25.00
Civil Engineer	3	12.5	2		1					12.50
Elec./Mech Engineer	3	12.5			2	1				12.50
Project Manager	2	8.33	1					1		8.33
Contractor	2	8.33		1			1			8.33
TOTAL	24		4	3	8	2	3	1	3	

The sample from the respondents carries significant weight as some of the respondents have ample of experience in the industry. As the respondents are from various professions in the built environment, comprehensive results were obtained through the questionnaire.

Category 2: The importance of innovation and the awareness thereof

It was established that 50.00% of the respondents indicated that innovation in the built environment is extremely important with 70.83% of the respondents indicating that the costs 3D printing hinder the implementation thereof.

Table 4.2: Whether the cost associated with 3D printers will hinder the implementation thereof

	Total %	Responses
Yes	70.83%	17
No	29.17%	7

Figure 4.1 depicts respondents' perception towards the importance of innovation in the build environment.

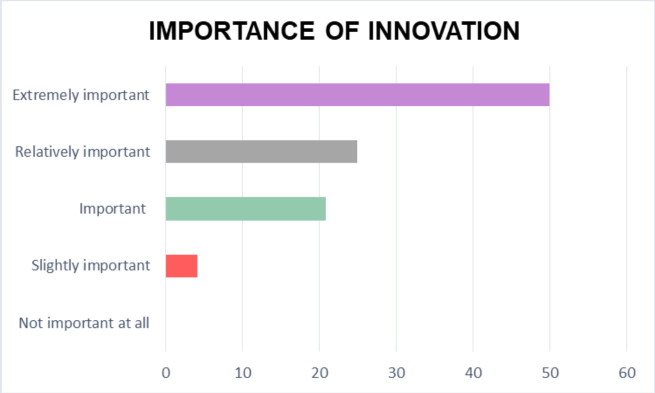

Figure 4.1: The importance innovation carries in the built environment

Category 3: Whether 3D printing reduces challenges and if the industry is financially ready

Majority of the respondents (66.67%) specified that challenges arising in the life cycle of a project can be reduced by making use of an innovative technique such as 3D printing. 58.33% of the respondents believe the construction industry isn't financially equipped to implement an innovative technique such as 3D printing and also that the cost associated with 3D printers will hinder the implementation thereof in the building industry.

Category 4: Where innovation is most required and most difficult to implement

As indicated in figure 4.2, innovation is mostly required during the design and planning phase of a project and innovation will be the least difficult to implement during the design and planning phase. However, when compared to table 4.2, it suggests that even though innovation during the design and planning phases are needed, 3D printing will not be a viable innovation to explore because of the costs involved.

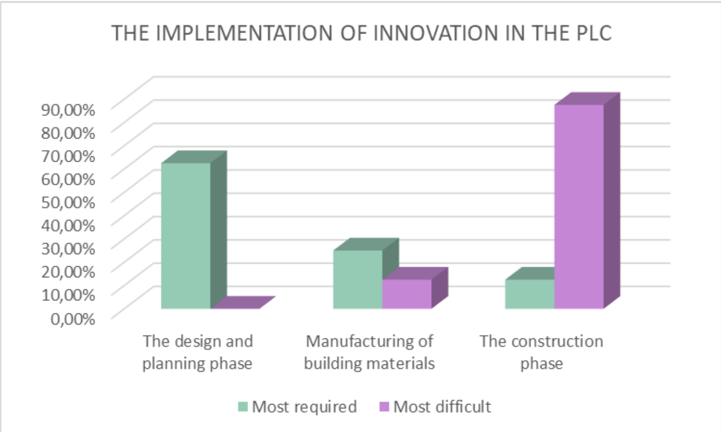

Figure 4.2: Where innovation is the most required and most difficult to implement in the PLC

Category 5: Open ended questions

In table 4.3 the respondents indicated that the construction industry is not prepared and developed enough to implement an innovative technique such as 3D printing.

Table 4.3: Why innovation is required in the industry and what will the effect be thereof

WHY INNOVATION IS NEEDED	TOTAL	RESPONSES
The industry won't be able to compete with other industries financially	29.17%	7
Innovation can speed up the construction process (shorter building time)	20.83%	5
Higher quality construction and a more economical use of building materials (less wastage)	16.67%	4
More accurate design and plans	16.67%	4
The creation of new jobs	4.17%	1
Decreases risks on site	12.50%	3
		24
THE EFFECT ON THE INDUSTRY		
More capital required for hiring or buying 3D printers	33.33%	8
Labourers will require more training	16.67%	4
Unemployment due to machinery taking over jobs	50.00%	12
		24

The key conclusions made from Table 4.3 is that if the construction industry doesn't progress it won't be able to compete with other industries financially. Innovative techniques could speed up the construction process and also be valuable as it results in higher quality construction, more economical use of materials (less wastage), shorter building time (increased efficiency), and more accurate designs or plans.

The effect that innovation techniques will have on the industry is that projects will necessitate more capital to hire or buy equipment such as 3D printers, the labourers required on site will have to be more skilled (more trained) to operate new machinery and equipment, and if more technologically advanced equipment are used on site, soon most labourers will be unemployed.

4.2 Hypothesis evaluation

The hypothesis stated: With the use of innovative 3D printing techniques throughout the project life cycle, innovations can be communicated, tested, and complications during construction can be reduced.

The hypothesis is substantially supported overall by the results obtained from the respondents. Even though the respondents indicated that innovation is required in the built environment, factors such as the costs associated with 3D printers can impede the implementation thereof. Certain questions fully support the hypothesis and others only partially support it, this is an indication of how various professionals within the industry can have a different opinion.

5. CONCLUSION

From the literature study it is concluded that technological innovations are transforming the way that buildings and infrastructure are designed, constructed, and operated. Innovation in the built environment can help to advance decision making and performance across the life cycle of a project. The technology of 3D printing is still new and comes with limitations, but high prospects are on the front regarding the future of 3D printed structures and building material components. 3D printing can change the way we design and present buildings and also improve the building process as we know it.

The empirical study indicated that innovation in the built environment is extremely important as the respondents are aware of 3D printers being used in the industry as an innovation technique. Most of the results reflected that challenges arise throughout the PLC can be reduced by making use of an innovative technique such as 3D printing. However, the practicality of the technology and the cost involved will favour the technology's use differently in the different PLC's.

Even though the hypothesis was substantiated, the practicality of the use of 3D printing was brought into question. The main conclusion made from the study is that an innovation such as 3D printing requires a multitude of industries, governing bodies, regulations, and social communities to be in synchronisation for it to reach its full potential.

Innovation is undeniably required in the built environment as it could potentially contribute to more cost-effective projects and also more sustainable buildings. When innovation is applied and incorporated successfully, construction companies will be able to manage, control, and measure innovative ideas at every level of the project life cycle. Innovation techniques can help to progress decision making and performance across the life cycle of a project. Innovation is something that must be introduced to the construction industry gradually over time, as the industry will always rely on its fixed and traditional methods.

The relationship between the 3D printing, Building Information Modelling (BIM), Virtual Reality (VR), the PLC and the value chain of construction should be research further.

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Integrating Building Information Modelling and Risk Management for Enhancing the Performance of Health Care Facilities during the Design Process

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ABSTRACT

Purpose

This research aim is to investigate the role of integrating building information modelling (BIM) and risk management (RM) as an approach for enhancing the performance of health care facilities during the design process.

Design/methodology/approach

To achieve this aim, a research methodology, consists of literature review and case studies, was designed to accomplish three objectives.

- Developing a comprehensive background about the research topics including the design process of healthcare buildings, building information modelling (BIM) and risk management (RM).
- Presenting and analysing case study to prove the rightness of this theory.
- Finally, outlining research conclusions and recommendations useful to introduce framework outline on how building information modelling and risk management can be integrated and applied successfully in the design process

Findings

Integrating building information modelling and risk management has a significant role on improving building performance in terms of reducing risks, Saving cost and time and enhancing delivered values.

Research Limitations

This research focused on analyzing healthcare buildings only.

Practical Implications
Adopting the suggested approach of integrating BIM and RM will enhance the performance of the design process of health care buildings.

Originality / Value
In the previous literature, the main focus was found on how the integration between building information modeling and risk management can be done to enhance the whole construction process unlike this research that focus on the design process alone and how it can be enhanced for a better building performance.

Keywords: healthcare buildings, building information modelling, risk management, design process, building performance.

1. Introduction

The construction industry is a unique business that is known for its complex nature worldwide. This nature is the result of many factors that influence its performance such as project type, size, location and environment. Moreover, different participates are involved such as clients, architects, engineers, contractors, suppliers and labour where each one has his / her own aim, vision and point of view. Furthermore, the unstable economic and political conditions throughout the project life cycle and awarding the project at short notice represent a risk that encounter the construction process (Mohamed, 2018). This complex nature of the industry imposes a challenge that gets harder day by day. Therefore, new methods have to be used to overcome the problems faced. This paper investigates the role of integration between BIM and RM as an approach for enhancing the efficiency of health care facilities during the design process. Despite both approaches have significant impacts on the architecture, engineering, construction industry, each one has its unique aim, functions and principles. Integrating both approaches will create a synergy that cannot be overlooked.

2. Research Objectives and Methodology

In order to gain the above mentioned aim, a research methodology was developed based on literature review and case study to accomplish three objectives

- As a start, the literature review was designed to build a comprehensive background on the research pillars in order to where the design process of investigate the relationship between them.
- Second, concluding the effect of BIM/RM collaboration impact on building performance.
- Third, reviewing a case study that shows the effect of using BIM in risk reduction.
- Finally, outlining the research conclusions and recommendations introducing a Hypothesize of a BIM/RM framework into the design process.

3. Literature review

3.1 The Design Process
Design is a solution generation process where it solves the existing problems and the problems that can appear later in the planning phase (Mahmoodi, 2001). It depends on creative thinking and aesthetics which are not measurable. For architects, the initial ideas does not have a scientific foundation. However, to them it just feels right. It reflects their own creative way in expressing how they see a place. (Mahmoodi, 2001) According to Bryan Lawson 2015, there is no correct process, the process result from the need of action based on findings. (lawson, 2005). The design process is considered the most important phase in the construction process. It is the critical planning phase that

cause project's success or failure as it involves all the decisions to be made to solve the existing and predicted problems. These decisions does not only affect the project on the short term however they extend to the project life cycle.

3.2 Healthcare Buildings

"Just as the arteries of a body make up a complex web of functions, developed over millions of years: hospitals are continually evolving to permit optimum output" (Gene Klow, 2015).

Healthcare buildings is known for their complexity in planning. It is known for its large scale, design briefing of multiple functions and complex technicalities. Designing a healthcare building has many considerations as coordinating a well functioned layout while providing healthy environment for patient recovery and an efficient working space that fits long term usability. Moreover, healthcare buildings are known for their speed of change which creates the first challenge for architects in the design process as designers must consider yet unknown and variable planning objectives (Joint Commission Resources, 2009).

For the second challenge, the design must be fitting to different users. The users can be divided into two groups the first is the silent one represented by patients and their families that can be represented by the designers when their needs are considered. While the second group are the working crew where their needs differ based on the hospital operating system which change the technical design aspects and functions zoning. (Kutz, et al., 2003)

For an efficient healthcare design several aspects must be taken into consideration while Programming. (Joint Commission Resources, 2009):
1. The working crew requirements based on their operating system. Moreover, Guidance from consultants specialized in this area must be considered
2. Communication and brainstorming of ideas from the entire team must be considered to record all ideas then refining them to the most adequate ones.
3. Cost, time, criteria of design of the country and previous cases must be checked as relationships of functions and space planning is done.
4. New technologies as well as future ones must be considered so that the design would be adaptable to change.

3.3 Risks in The Design process

As the complexity of project increase, the risks of errors occurrence increase. The following list is a conclusion based on multiple sources that gather the risks that might be encountered during the design process in general. (Mohamed, 2018) (Likhitruangsilp, Handayani, & Malvar, 2016) (Mcmahon & Busby, 2005)

1. Budget overruns of the design.
2. Lifecycle cost overrun.
3. Design Time is too long (time waste) or too short. (tight schedule)
4. Insufficient environmental analysis.
5. Environmental requirements inconsideration.
6. Non consideration of law, regulations or code compliance.
7. Inconsideration of public opinion and needs.
8. Brief changes by client or change of requirements at late stages of design or construction.
9. Design variations by the architect.

10. Decision making which solution is the best.
11. Lack of experience of participates.
12. Skills gap between designers and managers.
13. Lack of coordination and communication between design team.
14. Lack of coordination and communication between design firms and authorities. (results in problems considering approvals)
15. Errors in construction documents resulted from uncoordinated work.
16. Materials and technology specification failure due to their unavailability.
17. Failure to fulfil contract requirements.
18. Design errors and clashes.

4. Building Information Modelling

Building information modelling (BIM) is defined as "a digital representation of the physical and the functional characteristics of a facility" (ASHRAE, 2008). Design using BIM software provides a more efficient and effective process as it gathers all the data in one central file that presents all the project information throughout its lifecycle.

The first introduction of the concept of BIM was more than 40 years ago by professor chuck Eastman in the United States which was called design descriptive system. (Eastman et al, 2011). It aimed to creating drawings only once with no repetition even if changes are required. Through its development over years, it expanded not only to be visual 3D representation, it went further to gather all data of the model creating a compatible model that can be used from the first design stages till the maintenance and operation stages including detailed drawings and specifications of the project. (Ebbett, 2016).

The benefits of using BIM are unlimited but they can be summed up as following

For owners	❖ Improve building performance ❖ Improve quality ❖ Estimated initial cost and reduced life cycle cost of different alternatives ❖ Visualization of the design before its implementation
For designers	❖ 3D visualization of design in early stages ❖ Production of accurate coordinated 2D drawings ❖ Automatic correction in all drawings if design adjustments occur ❖ Design time reduction ❖ Improve communication and collaboration between design team (all disciplines) ❖ Efficient energy consumption and application of sustainability concepts ❖ Easier quantity surveying ❖ Accurate Cost estimation and scheduling
For construction	❖ Help in fabrication ❖ Estimate and solve Design errors and clashes before construction ❖ Better implementation of construction techniques

The need for BIM increases day by day as the construction industry is getting more complex and fragmented. The development in techniques and materials as well as the technical specification needed for complex project as well as the increased customer needs will result in the insufficiency of using only BIM. Therefore, it should be integrated with different techniques as value management, risk management, and lean construction as well as many other methods

5. Risk Management

Risk management is a process which identifies the project risks, analyze them, and determine the actions to avert the threats on any project. All steps in the risk management process should be included to deal with risks, in order to implement the process of the project. As a result of the complex unique nature of construction process, risk management is a very important for project's success. (El-Dash, Abd-Raboh, & El-Dars, 2015). The risk management process consists of three main stages risk identification, risk analysis, and risk response followed by risk review in order to track the implemented actions and examine their efficiency (McNair & Markewicz, 2011).

Case study to highlight the effect of BIM-based process on managing risks of design process: Kathleen Kilgour Centre, New Zealand (Ebbett, 2016)

General overview:

- **Title:** Innovative design and operation through BIM for risk reduction
- **Project Name:** Kathleen Kilgour Centre, radiotherapy clinic at Tauranga Hospital
- **Project Location:** New Zealand
- **Project duration:** 2012 - 2014
- **Project Aim:** designing high performance building that provide high quality environment for users and workers.
- **Case Study Aim:** investigate the use of BIM as a risk reduction tool

Process:

In this project, BIM was used as a planning tool to enhance the project outcome. First, BIM execution plan was introduced by the design team to manage the deliverables in the early stages. Then, this plan was shared with the other project stakeholders in the first workshop. The workshop aim was to gain a common aim and objective giving clarity on how the process will continue maximizing the benefits that can be gained through BIM and setting clear goals.
Revit software was used by consultants of different disciplines to design the 3D model. After architectural, structural, interior and service models were developed, they were combined into one single model that was analyzed afterwards for clash and errors detection as well as coordination. Later on, review meetings were set with the key designers with the owner in order to finish the design according to the client's feedback. It appeared that using 3D model instead of 2D drawings introduced a clearer image of the building's aesthetics and functionality, see figure 1.

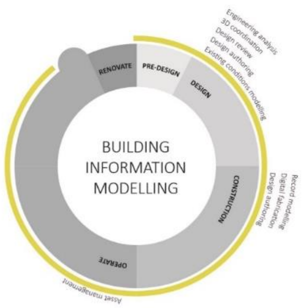

Figure 1: BIM uses in the study case, source: (Ebbett, 2016)

Challenges:

The radiology center is not grand by scale however it is technically very complex. The design details have to be reviewed with the client several times to be accurate ensuring that all requirements and specifications are met. Moreover, the space distribution, equipment's requirements, space design were considered carefully to reach the optimum configuration and best placement locations. The use of BIM helped significantly to overcome this challenge through visualization so that the communication between the client and the designer was easier. Although BIM helped significantly, however the lack of model object library imposed a difficulty in working, see figure 2.

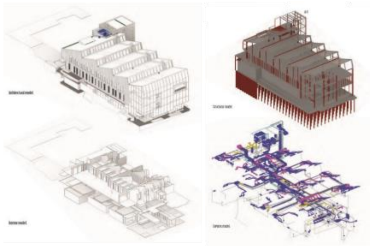

Figure 2: complex system modelled using Revit, source: *(Ebbett, 2016)*

The second challenge was the coordination and communication between the sixty consultants that was involved in this project who was geographically dispersed.

This challenge was overcome by using virtual online design meetings. Moreover, Cloud based software was used for issuing, sharing and tracking models, drawings and specification documentation.

The third challenge was the tight schedule that was required for the Kathleen Kilgour Centre to be finished in. This was achieved with collaborative and integrated project delivery methods enabled by BIM. It was further assisted by the use of capped lump sum procurement which allowed early engagement of the main contractor in a staged and fast-tracked program and consenting process.

Results:

BIM has introduced an innovation to healthcare design through this project. It worked as an efficient risk reduction tool reducing errors and clashes that were expected due to the complexity of the required technicalities. It improved the coordination, communication and data sharing reducing the rework required due to design alterations.
BIM introduced a visualized version of the design helping client to explore the project easily and view different options which resulted in a better understanding which allowed better feedback so that the project would fit the purpose effectively. To conclude, This case showed how efficient BIM can be if used to reduce risk opening up more questions on the potentials that BIM can achieved if it collaborated with existing effective techniques of risk reduction

Findings
Relation between building performance and risks in the design process

As previously stated 18 risks has been identified through literature that could be encountered during the design process. The following table suggests Risk categorization according to risk types and relate them with building performance values creating a check list for risk identification.

Risk type	Risks in the design process	Cost	aesthetics	Functionality	Flexibility	productivity	Safety	Energy consumption	Sustainability	environmental
Technical	Design errors and clashes. Incomplete Design	■					■			
	Errors in Construction Document			■		■				
	Inadequate Site Investigation								■	■
	Materials and technology specification uncertainty							■		
	Laws, regulations and code compliance			■	■					
	Brief Changes by the client	■		■						
Management	Skill gap between Designers and managers			■			■			
	Uncertain Productivity	■				■		■		
	Lack of coordination and communication between design Teams					■				
	Lack of coordination and communication between design firms and authorities					■				
Environmental	Unfamiliarity with Local Condition							■	■	
	Insufficient environmental analysis.	■						■	■	
Financial	Budget overruns of the design.	■								
	Lifecycle cost overrun.	■								
	Resources wastage due to allocation (Human-Material)	■								
Others	Design Time is too long (time waste) or too short. (tight schedule)		■		■					
	Lack of experience of participates	■		■			■	■		
	Inconsideration of public opinion and needs		■	■						
	Decision making (different design options)	■		■	■	■		■		■

The previous table can help designers determine the risks related to the building performance values chosen by their clients' preference so that they can analyze from the primary stages

BIM/RM collaboration in the design process

With BIM as an innovation in the construction industry, some major transferal of standard risk level occurs. According to Eastman "a detailed BIM model is a risk mitigation tool". Thus, it can be said that BIM is a tool for reducing the risks in design and enhancing performance of the design and construction process.

Research on integration of BIM with risk management is limited. However, literature published in the last two decades revealed that BIM tools and techniques enhance the design process by improving the visualization of the design allowing visual clash detection that help in identifying risks, improve energy performance by conceptual model and detailed model simulations. Moreover, it improves communication and collaboration between different disciplines reducing risk associated with coordination and work flow improving building performance.

This paper concludes with a hypothesis that BIM can be used as a tool while Risk management can be used as a culture so that the principles of risk management is applied through BIM usage to enhance building performance. It is suggested that a framework applied during the technical drawings preparation and documentation phase would be applied as follow

Phase 1	Phase 2	Phase 3
Risk identification	Risk analysis	Risk Response
Using results of literature Review for identification of probable risks Using checklist stated before	Using BIM tools and probability and severity matrix	Using BIM tools to test different options, compare them till reaching the best decision.

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6. Conclusion

The objectives of this paper aimed to investigate the potential of integrating Building information modelling and Risk Management for enhancing Building performance of healthcare buildings. For this, the paper discussed the main pillars where this assumption is built upon as the Traditional Design Process of healthcare buildings showing its risks, the risk management process and building information modelling.

Throughout the investigation of the literature, the following can sum up the key conclusion of this paper

- Although design process is a problem-solving process, it depends on creative thinking which impose risks.
- Designing Health care buildings is a complex process as it depends on various variables.
- Designing Health care buildings has two main challenges which are adapting fast to the unknown and fit to various user types
- Building information modelling is digital representation of the design where it benefits the owner, designers and construction.
- Risk management process is systematic approach for identifying, analysing and responding to risks encountered during the design process where it has many tools and techniques.

It can be concluded that there is a direct relation between risk reduction, BIM-based design process and building performance where risk reduction technique act as a secondary process implemented during designing while the BIM technology act as the tool for its implementation improving different values of building performance of the design leading to customer satisfaction and improved product.

7. Recommendations

Further studies related to the actual application of integration of BIM/RM in the design process should be studied using several case studies for further investigation of the quality outcome as well as challenges that may come up.

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Moderation of Self-Directed Learning on the Relationship between Complex Questions and Cognitive Loading in Students of Construction Programmes

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ABSTRACT AND KEYWORDS

Purpose of this paper
The aim of the research was to assess the moderating effect of self-directed learning on the relationship between complex questions and cognitive loading.

Design/methodology/approach
The research used a self-administered questionnaire survey to collect data from a purposively selected sample of university students. The students were drawn from three public universities in South Africa studying towards undergraduate degrees in construction studies. The data were analysed using hierarchical linear regression and moderation analysis using the PROCESS macro by Andrew F. Hayes in IBM SPSS.

Findings
Self-directed learning has a moderating effect on the relationship beween complex questions and cognitive loading. The effect is enhancing in nature meaning that as the level of self-directed learning increase, cognitive loading also increases when students are asked to respond to complex questions.

Research limitations
The results of the research are limited because the survey is based on purposive sampling. Also, the research is based on measurement instruments whose reliability and validity have not been extensively tested. Therefore, future studies can replicate the study with a random sample and with other instruments which have been extensively tested.

Practical implications
When students with little prior subject knowledge are asked to respond to complex questions, the level of self-directed learning demanded should be kept to a minimum or appropriately scaffolded or better still, both, to mitigate against the consequent levels of cognitive loading. Otherwise it would be appropriate to provide strong and explicit guidance to the students to avoid the consequent levels of cognitive loading which are known to impede learning.

Keywords: Moderation, Cognitive Loading, Complex Questions, Self-directed Learning, Construction Education

1. INTRODUCTION

Subjecting students who have little prior subject knowledge to complex questions has been shown to induce high levels of cognitive loading in the students (Zulu, Haupt & Tramontin, 2018; Sweller & Paas, 2017; Leppink, 2017; Kirschner, 2002). Questions are considered to be complex when their answers need to be collected from information scattered in many different documents (Chali, Hasan, & Mojahid, 2015) or from different bodies of knowledge in different disciplines (Zulu et al., 2018). Cognitive loading refers to the mental load exerted on working memory when performing cognitive functions such as perceiving, thinking and learning (Sweller & Paas, 2017). Cognitive functions are performed in working memory whose capacity is limited to about seven items at a time but can only process two or three items simultaneously (Kirschner, 2002). Therefore, the limits of working memory can be overloaded when subjected to more information than it can handle in the moment and subsequently impede learning in students (Leppink, 2017). Subsequently, subjecting students to complex questions when they have little prior knowledge of the subject will induce high levels of cognitive load (Sweller & Paas, 2017; Leppink, 2017; Kirschner, 2002).

Therefore, arguably, lower levels of cognitive loading induced in students will work to yield more effective learning than when the memory limits of students are ignored and the cognitive load is left to exceed the memory limit. This argument is supported by the cognitive load theory (CLT) which posits that since working memory has a very limited capacity, it can be easily overloaded with activities that impede rather than aid learning. Not withstanding the argument against the use of complex questions in students with little subject prior knowledge, administering complex questions to students is still very common practice in constructivist pedagogy (e.g. Harinarain & Haupt, 2016; Spronken-Smith et al., 2008 among others). Using complex questions is still expected to challenge students to acquire knowledge they previously did not possess and therefore achieve learning.

A recent study found that engaging students in self-directed learning (SDL) does not lead to signaficant levels of cognitive loading because students are able to monitor their own learning and manage the subsequent levels of cognitive load (Zulu et al., 2018). SDL is the ability for students to engage in independent learning activities without direction from anyone (Khiat, 2017). It involves students identifying their own learning needs, setting learning goals, identifying appropriate learning resources, choosing and applying appropriate learning strategies and evaluating learning outcomes (Ibid).

While it is understood that complex questions induce cognitive loading and that cognitive loading impedes learning, it is not known whether SDL would moderate the relationship between complex questions and cognitive loading. Therefore, this study sought to assess the moderating role of SDL learning on the relationship between cognitive loading and complex questions. The resulting conceptual model is shown in Figure 1.

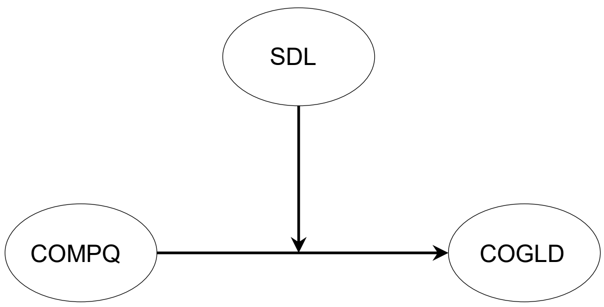

Figure 1: Conceptual Model of the Moderating Role of Self-directed Learning on the Relationship between Complex Questions and Cognitive Loading

The effect of SDL on the relationship between complex questions and cognitive loading is important because modern pedagogy based on constructivist principles relies quite heavily on subjecting students to questions which are fairly complex while demanding students to engage in SDL. Therefore, an understanding of the effect of this relationship would help to inform both the theory and practice of pedagogy which relies on these concepts.

2. RESEARCH DESIGN, STRATEGY AND PROCEDURES

To achieve the research objective, the study followed a quantitative design and a deductive approach to assess the hypothesis that self-directed learning has a moderating effect on the relationship between complex questions and cognitive loading. The quantitative design and the deductve approach were chosen because they lend themselves to hypothesis testing. The data were collected using a structured questionnaire in a cross-sectional survey with non-probability sampling. Non-probability sampling was chosen because it is not expensive to use considering the limited resources available for the study. The target population for the study was public universities offering construction programmes in South Africa. Three universities were conveniently selected for inclusion in the sample. The questionnaires were circulated to a captive audience of students either before the start or at the end of lectures. To ensure ethical research conduct, informed consent was obtained from the students after explaining to them the objectives of the study and what was required of them. The students were informed of their right to decline participation or to withdraw from the exercise for any reason and at any time. Both anonymity and confidentiality were assured. An initial sample of 534 students was obtained. After data cleaning, a usable sample of 521 questionnaires was retained for analysis. The demographic information of the sample is shown in Table 1.

Table 1. Sample Demographic Statistics

Year of Study	Frequency	Percentage
First year	188	36.10
Second year	116	22.30
Third year	99	19.00
Fourth year	118	22.60
Total	**521**	**100.00**
Gender	**Frequency**	**Percentage**
Male	314	60.30
Female	207	39.70
Total	**521**	**100.00**
Programme of Study	**Frequency**	**Percentage**
Architecture	102	19.60
Construction Management	232	44.50
Quantity Surveying	144	27.60
Property Studies	43	8.30
Total	**521**	**100**

1.1 Survey Instrument

Cognitive loading was operationalized mainly as the extent to which students are overwhelmed by the amount of assigned work and the extent to which they were expected to remember information which was complex, difficult and confusing to understand. This conception is shared by others (Hadie & Yusoff, 2016) and is also supported by findings which show that high levels of cognitive loading lead to students being overwhelmed (Scheiter, Gerjets, Vollmann, & Catrambone, 2009). The concept of complex questions was operationalized as the extent to which students were given assessment problems which were difficult to understand, had no defined solution and required combining information from different subject areas and sources in tandem with the conception of complex questions by Chali, Hasan, & Mojahid (2015) and by Zulu, Haupt & Tramontin (2018). The concept of self-directed learning was operationalized as the extent to which students were expected and encouraged to engage in self-directed learning. The resulting research instrument is shown in Table2.

Table 2. Research Instrument

Cognitive Loading		
1	COGLD1	I was expected to remember too many things from each lecture
2	COGLD2	I was overwhelmed with the amount of information I was expected to remember
3	COGLD3	I was given too much information during the lectures
4	COGLD4	The information I was given during lectures was confusing
5	COGLD5	The information I was given in class was complicated and difficult to understand

6	COGLD6	I was overwhelmed with the amount of work I had to do
7	COGLD7	I was given too many projects, assignments and tests
Complex Questions		
1	COMPQ1	I was given assignments and tests which were difficult to understand and solve
2	COMPQ2	I was given problems which did not have enough information for me to solve them
3	COMPQ3	I was required to solve questions which were not clear as to what I was expected to do
4	COMPQ4	I was given questions which could be interpreted in more than one way
5	COMPQ5	I was given problems which were not easy to understand clearly
6	COMPQ6	I was given questions which were not expressed clearly
Self-Directed Learning		
1	SDL1	I was required to find additional knowledge and information on my own
2	SDL2	I was given work which required me to learn new concepts on my own
3	SDL3	I was expected to expand on what was taught in class on my own
4	SDL4	I was required to learn on my own

Using the collected sample data, the research instrument was subjected to factor analysis to assess whether the measurement items factored as expected. The data were first assessed for adequacy using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. The results are shown in Table 3. The KMO value of .887 indicates that the sample is adequate for factor analysis (Tabachnick, & Fidell, 2013; Kaiser, 1974). Factor extraction was performed using Principle component analysis while factor rotation was performed using Promax rotation with Kaiser Normalization. The resulting factor loadings are shown in Table 4. No cross loadings were present when factor loadings less than .5 were suppressed (e.g. Anderson, & Gerbing, 1988). Two items from the variable cognitive loading had factor loadings less than .5 and so were dropped from the construct.

Table 3: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.887
Bartlett's Test of Sphericity	Approx. Chi-Square	4096.221
	Df	136
	Sig.	.000

Table 4: Factor Loadings and Reliability and Validity Statistics

	Factor Loading	Item-total Correlation	Mean	SD	Alpha	CR	AVE
Cognitive Loading							
COGLD1	.807	.585	3.166	0.808	.822	.815	.472
COGLD2	.858	.605					
COGLD3	.858	.659					
COGLD4	.557	.617					
COGLD5	.553	.608					
COGLD6							
COGLD7							
Complex Questions							
COMPQ1	.715	.638	2.852	0.882	.885	.886	.568
COMPQ2	.841	.756					
COMPQ3	.845	.767					
COMPQ4	.751	.579					
COMPQ5	.880	.744					

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COMPQ6	.795	.704					
Self-Directed Learning							
SDL1	.818	.644	3.880	0.806	.803	.814	.526
SDL2	.814	.672					
SDL3	.840	.676					
SDL4	.636	.499					

The constructs were then assessed for reliability and validity and the results are shown in Table 4. All item-total correlations exceeded the recommended .5 threshold and all the Cronbach's alpha and composite reliability (CR) exceeded the recommended threshold of .7 (Byrne, 2006; Cronbach, & Meehl, 1955; Nunnally, 1978). The average variance extracted for cognitive loading fell below the recommended threshold of .5 (Hair, Money, Samouel, & Page, 2007) while those for the remaining two constructs exceeded the threshold. Malhotra and Dash (2011) argued that AVE is often too strict and reliability can be established through CR alone. Therefore, given that the CR and Cronbach's alpha exceeded the recommended thresholds, the reliability and validity of the measure for cognitive loading were considered acceptable.

3. FINDINGS

To test the hypothesis that reflective thinking moderates the relationship between complex questions and cognitive loading, a hierachical multiple regression analysis was conducted. For there to be a potential moderation effect, the regression models with the dependent, independent, moderator and the interaction term between the independent and moderator variables, must be significant. The results of the regression analysis are shown in Table 5. Initially, a regression of complex questions (independent variable) and cognitive loading (dependent variable) was performed to assess whether the two variables are significantly associated with cognitive loading. The variables were significantly associted at 99% confidence interval (CI) (R^2=.253, p=.0001). A second regression model with the interaction term between complex questions (independent variable) and self-directed learning (moderator variable) added to the model was performed to assess whether there was potential moderation by self-directed learning (moderator variable). The model was also significant at 99% CI (R^2=.256, p=.0001).

Table 5: Model Summary

				Change Statistics				
Model	R	R Square	Adjusted R Square	R Square Change	F Change	df1	df2	Sig. F Change
1	.506[a]	.256	.253	.256	89.127	2	518	.000
2	.512[a]	.262	.258	.262	61.143	3	517	.000

The results from the hierarchical regression analysis suggest that there is potential moderation by self-directed learning on the relationship between complex questions and cognitive loading. In order to further assess the nature of the moderation effect, the PROCESS macro in IBM SPSS was used. The results in Table 6 and Table 7 show that the interaction term between the indepenent and the moderator variable is significant at 95% CI (p=.043).

Table 6: Model Summary

	Coeff	se	t	p	LLCI	ULCI
Constant	3.179	.0311	102.122	.0001	3.117	3.240
COMPQ	.444	.0356	12.473	.0001	.374	.514
SDL	.080	.0396	2.009	.045	.002	.157
Int_1	-.0841	.0415	-2.026	.043	-.166	-.003

Product terms key:
Int_1: COMPQ x SDL

Table 7: Test(s) of highest order unconditional interaction(s):

	R^2-change	F	df1	df2	p
COMPQ x SDL	.006	4.104	1	517	.043

The results therefore confirm that self-directed learning moderates the relationship between complex questions and cognitive loading. The results can be seen visualy in the interaction plot in Figure 2. The figure was developed using the data for visualising the conditional effect of the predictor generated by the PROCESS macro. The interaction plot in Figure 2 shows an enhancing effect which means that increasing the moderator increases the effect of the predictor variable. Therefore, increasing the amount of self-directed learning increases the amount of cognitive loading due to complex questions.

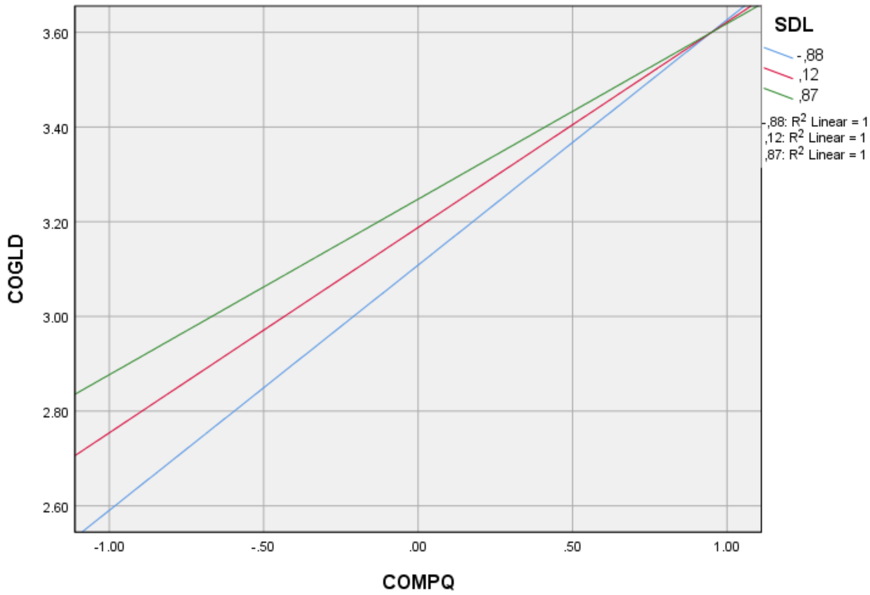

Figure 2: Visualisation of the Conditional Effect of the Focal Predictor

4. DISCUSSION OF FINDINGS AND CONCLUSION

SDL has a moderating effect on the relationship between complex questions and cognitive loading. The moderating effect is enhancing in nature which means that as the level of SDL increases, the amount of cognitive loading due to complex questions will also increase. This means that asking students to engage in SDL when they have been presented with complex questions will lead to increased levels of cognitive loading in the students. Increased levels of cognitive loading are known to impede learning (Sweller & Paas, 2017; Leppink, 2017; Kirschner, 2002) and so subjecting students to SDL when they are presented with complex questions will consequently impede learning. The results also show that lower levels of SDL when students are presented with complex questions lead to comparatively lower levels of cognitive loading. Therefore, when students are presented with complex questions, the level of SDL demanded of them should be reduced. Otherwise, appropriate support in the form of various types of scaffolding activities should be provided to help the students cope with the cognitive loading.

The results therefore suggest that a more strongly guided approach is neccesary when students are presented with complex questions in order to mitgate against the effects of cognitive loading. This suggestion is consitstent with the recommendation by Kirshner (2002). Preferably, it would be appropriate to avoid asking students to engage in SDL when the questions presented to them are complex relative to their level of knowledge (c.f. Kirshner, 2002).

The results also corroborate other findings which showed that subjecting students to complex questions leads to increased levels of cognitiv loading (e.g. Zulu, Haupt & Tramontin, 2018; Sweller & Paas, 2017; Leppink, 2017; Kirschner, 2002). Therefore, complex questions should be used with caution when the students have little prior subject knolwdge.

The results of this research make a significant contribution to theory because the role of SDL in the relationship between complex questions and cognitive loading was previously unexplored. The results also make a contribution to the pedagogical practice in that they provide some insight into the effect of subjecting students to SDL when they have been presented with complex questions. The research also provides some practical recommendations in dealing with the enhancing effect of SDL on the levels of cognitive loading induced in students by complex questions.

5. LIMITATIONS

While the results of this research make contributions to both theory and practice relating to cognitive loading, the results have some limitations. The research used instruments which have not been extensively validated. Therefore, further research could be used using different instruments or a different methodology to validate the findings of this study. Also, the sample for the study was conviniently selected and so the results may not be generalisable.

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Performance Indicators for Lean Implementation in Construction: Free State perspectives

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ABSTRACT

Purpose of this paper: This study seeks to identify the key performance indicators and critical success factors for lean construction implementation in South Africa.

Design/methodology/approach: This study relies on comprehensive review of contemporary literature review and purposefully selected semi-structured interviews for data elucidation. Data was descriptively designed to obtain the views of constructors with regard to the KPIs and CSFs for lean implementation. Interview transcripts were subsequently analyzed, based on preset themes.

Findings: Findings provides a review of the identified KPIs and CSFs for lean implementation in construction and the iron triangle of project management inclusive of H&S dominates the performance measurement of projects in the Free State province. Critical success factors such as commitment of top management, culture change and education and training are identified as significant in implementing lean construction.

Research implications: The implication of this study is to increase the awareness of lean construction and to encourage implementing lean in the construction organization and projects, especially in South Africa.

Original/value of paper. This study's novelty stems from its bid to explore the, KPIs of lean implementation in South Africa and the measurements of critical success factors contributing to the benefits of lean in infrastructure projects.

Keywords: Construction, Critical Success factors, Key performance indicators, Lean construction

1. INTRODUCTION

The construction industry by its nature is a complex, project oriented, high risk and competitive business. It is one of the major contributors to the national economy and has a multiple impact on South Africa (Aigbavboa and Thwala, 2014). The construction industry is also the least innovative industry compared to other countries. Construction project failures are increasingly reported around the world and achieving success on construction project is becoming difficult due to finish on time, within budget and at an accepted quality level. This is because construction projects are vulnerable to various wastes, overruns, delays and errors (Al-Aomar, 2012). For this reason KPIs for lean implementation have been introduced to the construction industry.

The concept of lean construction Wandahl (2014) is concerned with the application of lean thinking to the construction industry (Sarhan and Fox, 2013). LC as defined by Ballard and Reiser (2004), as “a management philosophy defined by the ideal it pursues, the principles it follows in pursuit of the ideal and methods used to implement them”. LC is about reducing costs, cutting waste, innovating by engaging people and organizing the work place to be more efficient.

There has been a continuous search of KPIs in the implementation of lean in construction project and as well as performance measures (Netland, 2016). According to Yong and Mustaffa (2013) KPIs represent indicators which are “critical” to the success of the industry concerned. KPIs are different from organisation to organisation depending on their respective operation environment, policies and legal restrictions. But the most common KPIs are cost, time and quality. They are a standard set of measurement or key indicators, which can be applied to all industry (Yong and Mustaffa, 2013).

To facilitate the implementation of LC, researchers have identify the most significant KPIs in the implementation of lean in construction. This study seeks to identify the KPIs in the implementation of lean and measure their effects on project performance. The KPIs are a means to improve the effectiveness and efficiency of lean projects (Netland, 2016).

2. PERFORMANCE MEASUREMENT IN THE CONSTRUCTION INDUSTRY

Performance is described as the valued productivity output of a system in the form of goods and services. Units of performance describe the actual fulfilment of the goods and services relating to performance and are measured in terms of the features (Ofori-Kuragu et al., 2016). Key performance indicators are indicators that must be considered to ensure a successful implementation of lean; these indicators become critical if their compliance is absolutely necessary for achieving those objectives. They are presented internally and externally in the organization and the project, and understanding them is of maximum importance to provide a guide towards strengthening those conditions that contribute to the successful implementation of LC using the KPIs (Cano et al., 2015)

Performance measurement provides the information required for process control and makes it possible to set up challenging goals; in order to achieve this, simple and well-designed performance measurement systems (PMSs) need to be used for supporting the implementation of business strategies, such as the application of LC concepts within construction organisations. (Sarhan and Fox, 2013). Moreover, Sarhan and Fox (2013) further discussed that without the use of appropriate PMSs, it becomes very difficult for organizations to understand why poor performance continues, or how improvement could be achieved. Without PMSs managers cannot know whether they will be able to achieve their intended objectives and goals or not. To manage you must measure, if you don’t you are only practising. The importance of performance measurement is simultaneously in the values of the measures and in the discipline involved in the relationship analysis between results, activities and customers. The importance of identifying a company’s performance is evident throughout the worldwide markets, the results of which are to attract future investment, increase share value and attract high calibre employees. Therefore, it is important to consider how an organization’s performance is measured and how it can be communicated to the wider market (Pekuri et al., 2012). Understanding the relationships between measurements allows a better focus on achieving the organization’s mission and goals to implement lean construction.

2.1 Key Performance Indicators for Lean Construction

KPIs are a performance management tool, containing basic elements of measures and targets. The application of KPIs will assist an organization in focusing on key areas where performance is critical for achieving the vision, mission, and objectives of the organization. KPIs do not change, as they are usually a long-term consideration (Wester, 2013). According to Parmenter (2015), KPIs represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization. According to Radujković et al. (2010), there is a difference between outcome measurements and leading measurements.
Wester (2013) Stated that KPIs represent the measures of progress in the achievement of critical success factors. KPI will only facilitate the control by pinpointing the concerned areas; the success is dependent on how the project management will react. Cha and Kim (2011) Recommend that the company should use performance measurement system databases for benchmark purposes in order to improve the efficiency and continuous improvements within the projects, as well as the company. Key performance indicators represent a set of measures focusing on those aspects of organizational performance that are the most critical for current and the future success of an organization. The KPIs reflect a balance between cost, quality and time. The indicators must be the critical factors which can immediately alert the managers if something goes wrong so that it can react to it (Marx, 2012). Table 1 below is the identified KPIs for implementation of lean from literature.

Table 1: Identified KPIs for lean Implementation

KPI	**A brief description of the KPI**	**References**
Time	Construction time, the speed of construction and time variation	(Leong et al., 2014); (Marx, 2012); (Parmenter, 2015)
Cost	Tender sum, construction costs, costs due to variations and modifications.	(Ali and Rahmat, 2010); (Leong et al., 2014, Parmenter, 2015);(Marx, 2012).
Quality	The ability of the project to adhere to the setup specifications.	(Leong et al., 2014);(Parmenter, 2015);(Marx, 2012)
Health and Safety	Fatalities, accidents, and injuries.	(Marx, 2012);(Parmenter, 2015)
Client satisfaction	Completion on time	(Al-Aomar, 2012);(Parmenter, 2015)
Environmental impact	Air emissions, noise, solid waste and water discharge.	(Marx, 2012, Al-Aomar, 2012, Parmenter, 2015, Chan and Chan, 2004)

Waste	Number of defects, rework, errors, and omissions, the number of change orders, safety costs, excess consumption.	(Al-Aomar, 2012, Parmenter, 2015)
Speed	Quick delivery, speedy construction.	(Al-Aomar, 2012, Parmenter, 2015)
Value	Added value, profit, financial achievement, owner satisfaction	(Al-Aomar, 2012)

Source: (Emuze et al., 2017)

The KPIs could be applied in construction industry by contractors for:(Zou et al., 2007) overcoming uncertainty in contractor selection processes; Zou et al. (2007) unifying and standardizing data collection processes surrounding KPIs; Zou et al. (2007) enabling greater clarity in contractor evaluation; (Zou et al.) increasing the quality of measurement and benchmarking processes; Zou et al. (2007) providing essential pre-qualification measures for small to medium construction organisations; Zou et al. (2007) improving contractors' competitiveness, (which make up the majority of Jordan construction industry); (7) improving the quality and performance of construction process; (8) increasing levels of customer satisfaction; and (9) improving project management capabilities (Alkilani and Jupp, 2012).

2.2 Critical Success Factors for Lean Construction

Critical success factors (CSFs) focus the attention on the key dimensions of performance that the company must excel at it, if it is going to achieve its goals and meet customers' requirements. The CSFs emphasize the activities and processes that will have the greatest impact on performance (Han et al., 2012). Projects are organized to accomplish complex tasks that cannot be handled by lone individuals but by multidisciplinary teams in the construction industry. Project success depends on upon how well the personnel can work effectively to accomplish objectives within scope, cost, and quality constraints; hence, the need for performance management as a system for managing and integrating organizational and employee performance (Kaviya and Hema, 2015).

Success factors first came to the surface within the field of project management in the 1960s when studies with the aim of identifying the best practice of project management were carried out (Morris et al., 2012). CSFs are known as a tool for measuring performance in organizations to achieve their mission. In the implementing of lean, CSFs are becoming important as they could identify the case of failure or success of a project (Morris et al., 2012). Moreover, Alias et al. (2014) states that CSFs thus are, for any business, the limited numbers of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization. There are few key areas where 'things must go right; for the business to flourish. If results in these areas are not adequate, the organization's efforts for the period will be less than desired.

Table 2 below lists the possible CSFs for implementation of lean construction successfully. The list is drawn from relevant literature to enable the construction industry to be fully aware of the magnitude of commitments required to transform from traditional system of delivering projects to a new paradigm shift of lean thinking strategies.

Table 2: Critical Success factors for Lean construction implementation

Number	Critical Success factors	References
1	Appropriate training and education is critical for success	(Brady et al., 2011, Cano et al., 2015, Mitropoulos and Howell, 2001)
2	Managing Culture change	(Sarhan and Fox, 2013)
3	Involvement of all stakeholders and communication	(AlSehaimi et al., 2009).
4	Top Management commitment and involvement and effective leadership	(Netland and Aspelund, 2014). (Cano et al., 2015), (AlSehaimi et al., 2009). (Yong and Mustaffa, 2013)Yong et al. 2012
5	Employee participation empowerment	Sarhan & Fox (2013); Cano et al. (2015)
6	Team work	Cano et al. (2015)
7	Benchmarking and transfer of knowledge	Netland & Aspelund (2014)
8	Sustain continuous improvement	Netland & Aspelund (2014); Mitropoulos & Howell (2001
9	Better coordination and cooperation between parties	Alsehaimi & Koskela (2009);Cano et al. (2015)

Based on a review of literature, there appears to be an almost endless list of factors that influence the success implementation of LC. However, CSFs identified from table 2 above are the ones deemed vital for lean construction implementation.

3. RESEARCH METHODOLOGY

This study adopted a qualitative research design. The rationale behind the adoption of this design can be attributed to the desire of the authors to test the knowledge of representatives of the several participant groups who have a direct impact on the implementation of lean in a South African context. A qualitative research design provide the opportunity to undertake a detailed discussion hence providing the opportunity for the expedition of the revelation of significant issues important to the interviewee (Chell, 2004). Moreover, Creswell (2007) orates that this research design is excellently employed when there is need to describe the essence of a lived phenomenon based on the narratives of those who have shared such an experience. In the context of this study, interviewees were sought for based on their position of opportune to at least consider the application of lean construction concept.

Ten project managers were accepted to be interviewed while others sent apologies due to pressures of work. The study wished to conduct more interviews but could not achieve such a number owing to availability of interviewees. Hence, this can be outlined as a limitation of this study. Semi-structured interviews were deployed as a suitable data collection technique. The number of interviewees were suitable as Leedy and Ormrod (2010) opines individuals ranging from 5 to 25 are acceptable. The choice of this type of interviews was predicated on its provenance as a reliable data elicitation technique which provided the interviewer with considerable levels of flexibility in his/her desire to explore the worldviews of interviewees concerning a particular phenomenon (Bernard and Ryan, 2009). Such flexibility was reflected in the use of similar and not identical questions thus enhancing the interviewer's ability to take the interviewer's level of experience into consideration in the choice of questions.

Interview sessions lasted an average of thirty minutes, each. The sessions were recorded with permission of interviewees and subsequently transcribed, and sent back to the interviewees for verification. Questions asked during the interviews were centred on their understanding of lean construction as a concept to be adopted in construction. Secondly, a list of KPIs and CSFs found from literature were compared to the Interviewees response of KPIs and CSIs from the responses received. Search of presence of the KPIs and CSFs from the Interviewees was then ranked in order of importance from their response. Thematic analysis was applied in making sense of the data (Kulatunga et al., 2007). The emergent data is presented and discussed in subsequent sections.

4. PRESENTATION AND DISCUSSION OF FINDINGS

Although a plethora of KPIs and CSFs factors were identified from the data emanating from the literature verified interview sessions, only a few of these benefits which resonate among the various stakeholder groups would be highlighted and discussed here as the study is still in its early stages.

It was evident from the Interviewees that lean construction is still a novel approach in the South African construction Industry. However, for KPIs the following applied: Time as concluded by Leong, Zakuan and Samon (2014); Marx (2013); Parmenter, (2010), Cost Ali and Rahmat (2010); Leong et al (2014); Parmenter (2010), Marx (2013),Quality similarly found by Leong et al. (2014); Parmenter, (2010); Marx (2013) and Health and safety as reported by Marx (2013); Parmenter, (2010).

These four KPIs are still renowned as the most important KPIs in the South African construction industry. All the interviewees confirmed these four KPIs as the relevant ones for performance measurements in the construction industry. Since lean construction is about elimination of waste, interviewees were asked if elimination of non-value adding activities in projects not important as one of the KPIs. And all interviewees believed that if all four of the KPIs mentioned were achieved successfully then that meant that the process has eliminated the non-value adding activities in the execution of projects. They felt that the construction industry is a complicated sector and to achieve all those four at the same time in a project is already a huge task.

Moreover, when asked about the critical success factors for lean construction implementation in the South African construction industry, respondents had a lot to discuss on that point. All interviewees believed that lean construction is an important concept to introduce to the industry. All interviewees agreed that collaboration as Sarhan & Fox (2013); Cano et al. (2015) asserts as one important critical success factor missing currently in the construction industry, and change of culture will hamper such efforts. Lean construction requires transparency as opined by Ballard (2009) that all stakeholders must practice, and when Interviewees were asked if they were prepared to be transparent even revealing their books about the profit margins from the projects, four of the interviewees were hesitant claiming that such is confidential. This revealed that contractors have a tendency to pursue self-benefits than client satisfaction. Secondly, that projects are about maximizing profit rather than providing value for the client. This point of non-transparency contradicts the statements outlined by the contractors earlier about collaboration.as collaboration requires total commitment by all parties and that includes transparency.

Additionally interviewees stressed the importance of total commitment by top management as the vital CSFs for lean construction to be implemented in South African construction industry. This CSFs is in agreement with the findings of (Netland & Aspelund 2014; Cano et al 2015, Alsehaimi & Koskela 2009; Yong et al. 2012).

The interviewees further stressed the importance of education and training of the industry about the adoption of lean and its benefits. This finding resonates with the finding of Brady, Tzotzopoulos and Brooke (2011); Cano et al (2015); Mitropoulos & Howell (2001). Educating and sharing the small victories is a vital component of advancing the knowledge of lean construction. There are various forums for lean construction worldwide and in South Africa few are present but they have limited exposure on the entire construction industry. Lean construction institutes are visible globally and such is present in South Africa but not active as it is operated by individuals employed on a full time basis. One such group is Lean Built Environment Afrika which is active and providing continuous professional development courses in the South African construction industry already. Such platforms will engender sharing of knowledge and create continuous improvement in the industry for a successful implementation of the concept of lean in construction.

5. CONCLUSION

The study sought to identify the key performance indicators and critical success factors for a successful lean implementation in South African construction industry. However, the construction industry in South Africa is still grappling with acceptance the paradigm shift. The concept of lean is still in infant stage in the country and more needs to be done to make the concept to be embraced and adopted by everyone. The industry is still operating a business as usual currently and pockets of lean construction exists in isolation and non-significant to make a case for any implementation whatsoever. The iron triangle of project management is still the renowned KPIs employed for performance measurements

CSFs appear to be making progress as the findings from the respondents indicate commitment from the stakeholders interviewed on what needs to be done to fully implement lean construction in South Africa. One of the key issues to be addressed is education and training of the industry through CPDs and aggressive marketing of the concept to build awareness of lean construction into the industry.

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Properties of waste tyre rubber aggregate concrete with cement extenders and geopolymer binders – A review

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ABSTRACT

Purpose of this paper
This paper presents a review of the research work on the influence of using cement extenders and geopolymer binders with waste tyre aggregates on the mechanical and durability properties of concrete. The paper also present the gaps for future research on this topic.

Design/methodology/approach
Data from previous studies was collected and reviewed in this paper. The study is based on the porpoerties of cement extenders, geopolymer binders with waste tyre rubber aggregates as partial replacement of fine or coarse aggregates in concrete.

Findings
Based on the test results from limited number of studies on this topic, an improvement on mechanical and durability properties of concrete was observed when rubber aggregates were used along with cement extenders and geopolymer binders .

Practical implications
This study intended to promote waste tyre disposal management and also to design green and sustainable construction material, which can be used locally with available material in South Africa; waste tyre rubbers as aggregates, cement extenders and geopolymer binders as binding material in rubberised concrete.The use of waste tyre as aggregates, cement extenders and geopolymer binder in concrete production not only lowers the emissions of carbon dioxide because of the reduction of cement, but also lowers toxic gases which affect humans, animals and plants

Original/value of paper
The results from past literatures are reviewed and an insight on the mechnical and durability properties of concrete incorporating waste tyre rubber aggregate along with cement extenders and geopolymer binders has been developed.

Keywords: Cement extenders, Geopolymer binders, Rubber aggregate

1. INTRODUCTION

Production of tyres is increasing every year due to high vehicle demand. According to the South African Tyre Recycling Process Company (SATRP), 160,000 tons of scrap tyres are generated in South Africa each year. Out of which about 28 million used tyres are dumped illegally or burnt annually to recover the steel wires, which are sold as scrap metal (SATRP, 2017). The recycling capacity of South African tyre recyclers' plant is around 10,000 tonnes per annum which translates to around 1 million tyres of different sizes and types. Waste tyre disposal management is a big challenge, as they are non-biodegradable and when burned they produce dangerous fumes which have bad effects on the environment, soil and groundwater. Additionally, according to Sebola et al., (2018), in South Africa waste tyre are used for matting, sport surfaces, turf, playgrounds,civil engineering asphalt etc, but limited application in concrete industry.

However, continents like Asia, America and Europe are advanced in use of waste tyres in concrete industry and reaseaches as compared to Africa. Hence, most of their researchers (Bjegovic *et al.*, 2011; Dumne, 2013; Fiore *et al.*, 2014) found reuse of waste tyre in civil engineering (concrete technology) to be eco-friendly and cost-effective. Some of the advantages are conservation of natural resources and reduction in the rate of air, water and land pollution. Waste tyre aggregates are used in concrete to replace either cement or aggregates. waste rubber aggregates are classified into three different categories or classes; namely: shredded, chipped rubber, crumb rubber and grounded rubber or rubber powder (Ganjian et al, 2009). Waste tyre aggregates can be produced by mechanical milling; waste tyre under goes cracker grinding and granulation to get mechanically broken down into the different sizes ranging from several millimetres, then graded into difference size categories. Cryogenic milling is another waste tyre aggeregate production process, where the waste tyre rubber shreds are frozen below glass transition temperature using nitrogen liquid and then cooled. They are then crushed into smaller desirable sizes through the closed loop of the hammer-mill, then extracted and graded into different size categories, and the rubber aggregates are referred to as cryogenic rubber. While mechanically milled rubber aggregates are reffered to as crumb rubbers, rubber powder, shredded and chip rubber aggregates (Molefe, 2015).

Researchers discovered that adding waste tyre rubbers as aggregates in concrete, improved ductility, decreases weight and prevents the brittle failure of concrete structures. However, Dumne (2013) observed that with an increase in rubber content, mechanical and durability properties of concrete significantly reduces. Which denounce its usage in load-bearing structural components.However, it is observed that replacing cement with cement extenders in rubberised concrete, compressive, tensile and flexural strength of concrete along with permeability and porosity slightly improves with time due to slow heat of hydration and fineness of cement extenders that fill the pores between cement and rubber aggregates aggregates (Guneyisi *et al.*, 2004; Gesoglu and Guneyisi, 2007; Azevedo *et al.*, 2012).

Davidovits (1991) found that pozzolanic materials rich in silica and alumina, such as fly ash (FA), ground granulate blast furnace slag (GGBFS) and silica fume (SF) when mixed with alkaline solutions form alumino-silicate polymer yielding polymetric three-dimensional Si-O-Al, which is referred to as geopolymer binder or cement. Replacement of cement with geopolymer binder improved mechanical and durability properties of concrete, due to activators anion that plays an important role in microstructural development and aluminosilicate gel which act as the binding material for concrete (živica *et al.,* 2014).

Therefore, this paper present a review of mechanical and durability properties of waste tyre rubber aggregates concrete with cement extenders and geopolymer binders.

2. WASTE TYRE AGGREGATES ON MECHANICAL AND DURABILITY PROPERTIES OF NORMAL CONCRETE

Waste tyre rubber can be used in different types of concrete, such as lightweight concrete, non-shrinkage concrete, and concrete used for the manufacture of roadside barrier walls. However, there are concerns with respect to the reduction in mechanical and durability properties of concrete that incorporate waste tyre rubber aggregates. Ganjian *et al.*, (2009) investigated the influence of replacing of coarse aggregates with chipped rubber and cement with ground rubber respectively. The test results indicated a significant decrease in compressive and tensile strength with more than 5% replacement of cement and aggregates, on both chipped and grounded rubber aggregates. The reduction in strength was due to the lack of bond between the rubber aggregates and cement paste matrix. As a result the applied stress are non-uniformly distributed in the paste hence causes the cracks that accelerate concrete failure. From this point of view, rubber aggregates generate voids that promote the creation of high stresses in their perimeter. Thus, cracks are developed which if they spread adequately, led to an early breakdown of the specimens during the test (Bravo and Brito, 2012).

Similarly, when coarse and fine aggregates are totally replaced by 100% of chip rubber aggregates and 50% of crumb rubber respectively, regardless of compressive strength reduction, ductility improves significantly. However, crumb rubber aggregates were observed to perform better as compared to chipped rubber aggregates due to different grading and aggregates distribution and bond between the aggregates (El-Gammal, *et al.*, 2010). Gupta *et al.*, (2014) investigated the effects of different water/cement ratio (w/c), with fine aggregates partially replaced by rubber ash and rubber fibres up to 20% and 25% respectively. From the results, it was determined that mixes with 0.35 w/c achieved better compressive strength, flexural strength and density results. However they observed that for mixes with 0.55 w/c, the compressive strength increase marginally due to high workability which improved rubber aggregates packing in the mix. The flexural strength also improved slightly due to rubber fibres which provided a good connection between propagated cracks. From the results, it can be deduced that type of rubber aggregate and w/c have a positive impact on mechanical properties of concrete

On the other hand, Valadares *et al.*, (2012) replaced fine and coarse natural aggregates by 5%, 10% and 15% of grounded and cryogenic milled rubber aggregates. It was observed that water absorption increases with increase in rubber content, due to the lack of bond between the particle matrix that promotes a pathway for water. However, shrinkage and chloride penetration improved with increase in rubber aggregates. The replacement of fine aggregates (5%) with rubber powder (600 microns) led to anti-sulphate corrosion resistance (Yung *et al.*, 2013).

Replacing fine aggregates with 10% of rubber ash and rubber fibres; water absorption and carbonation increases, due to air content and improper compaction which creates a path for carbon dioxide and water. However, chloride-ion penetration decreases with rubber ash and rubber fibre increase (Gupta *et al.*, 2014). Furthermore, with 30 – 100% replacement of coarse natural aggregates with coarse waste tyre crumb aggregates, water absorption and porosity observed to be increased (Huda, 2014). Adamu and Uche (2014) replaced 5%, 10% and 15% of coarse and fine aggregates with 5 – 8 mm and 1 – 4 mm scrap tyre respectively. From their results, it can be observed that water absorption increased by 3.5% as results of high air content caused by the non-polar nature of rubber aggregates, which repel water and attract air.

Thomas, *et al.*, (2014) used a range of w/c ratios (0.4, 0.45 and 0.5), with substitution of fine aggregates with crumb rubbers up to 20%. With 5% substitution, water absorption decreased and started increasing gradually up to 20% replacement. Whereas, with 0.4 and 0.45 w/c ratios, water absorption was observed to be the same as control mix with 5% replacement. Thomas and Gupta, (2015) undertook further studies, by using rubber powder (0.8 - 2 mm) and crumb rubber (2 – 4 mm) to replace crushed stone coarse aggregates and river sand as fine aggregates up to 35% and 25% respectively. Up to 12.5% replacement of crumb rubber content, better resistance to water absorption, porosity and carbonation was noted. Similar trends was also obswerved by Su, *et al.*, (2015), where the replacement with finer rubber aggregates shows better performance than trplacement with larger aggregates; along with proper grading provides better resistance to water permeability compared to single-sized rubber aggregates.

Hence, there is marginal change in mechanical properties of concrete with aggregate replacement of less that 5%, on the other hand, there is significant reduction in mechanical and durability properties with more than 5% replacement of aggregates regardless of different w/c ratios, gradations and different types of material due to lack of bond between the rubber aggregates and cement matrix.

3. MECHANICAL PROPERTIES OF WASTE TYRE RUBBER AGGREGATE CONCRETE WITH CEMENT EXTENDERS AND GEOPOLYMER BINDERS

Flyash

Yilmaz and Degirmenci, (2009) studied the possibility of replacing fine aggregates with 0 – 0.25 mm, 0.25 – 0.50 mm and 0.5 – 1 mm of crumb rubber with replacement levels of 20% and 30%. They observed that compressive, flexural and tensile strength decreased with increasing rubber content for all curing phases. On the other hand, marginal increase in compressive strenght was observed with an increase in fly ash content. However, the highest compressive strength was obtained at 20%

replacement with 0.5 -1.0 mm aggregates sizes. Hence the strength was influenced by aggregates sizes of rubber aggregates. In addition, Guneyisi, (2010) found that compressive strength of self-compacting concrete incorporated with flyash decreases with increase in fly ash and fine crumb rubber aggregates.

However, Azevedo *et al.*, (2012) observed that compressive strength decreases with increase of crumb rubber content, as compared to normal concrete (C_Ref).(see Figure1). Furthermore, it can be bobserved from Figure 1 that for the same replacement level rubber (eg. 5% rubber content, the increase in flyash content from 30% (5RW_30CV) to 60% (5RW_60CV) compressive strength declined from around 50MPa to 39MPa respectively. However, compressive strength of concrete increases with time due to slow hydration.

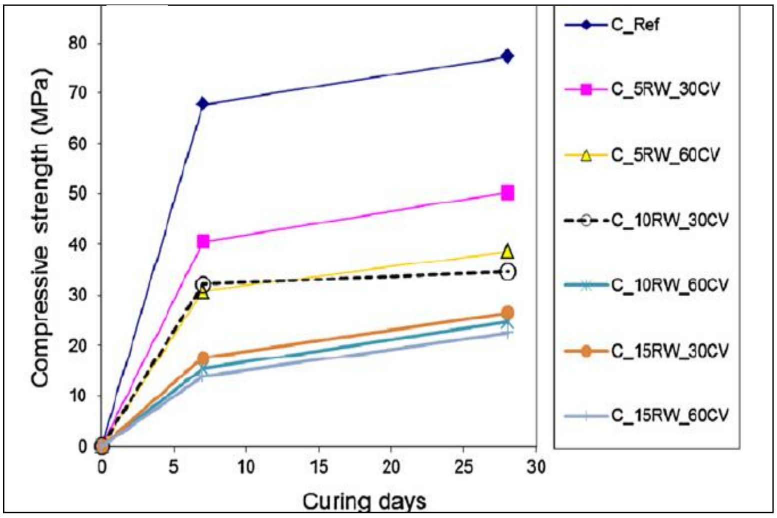

Figure 1: Compressive stength of normal concrete compared to rubberised concrete with flyash(CV) as replacement of cement (Azevedo *et al.,* 2012)

Bala *et al.* (2014), observed that at 20% replacement of aggregates with <4.75mm and 4.75 – 10 mm of fine,10 – 20mm coarse rubber aggregates and 10% replacement of cement with fly ash achieves better strength and workability compared to Portland cement (PC) rubberised concrete as observed by Bala *et al.* (2014) The above observation indicates that cement and aggregates replacement should be maintained at a certain percentage in order to achieve better compressive strength properties considering different rubber aggregates sizes.

Porwal and Dwidedi, (2015) showed that the replacement of coarse aggregates with 20mm waste tyre aggregates up 30%, and replacement of PC with fly ash up to 20% with 10% incremental, slight improvement of compressive strength was observed with addition of flyash in to mix. Reddy *et al.*, (2017) also observed that, 80% of PC and 80% of fly ash with 5% replacement of natural aggregates with waste scrap tyre aggregates, the compressive strength progressively increased up to the level of the control mix of PC and natural course aggregates.

From the literature, it is clear that compressive strength is highly affected by bond strength. Therefore, with an increase in rubber content, bond strength decreases significantly, due to polar behaviour of rubber that tend to repulse water and attract air and reduces bond between paste and aggregates (Bravo and Brito, 2012). However, with addition of flyash to rubberised concrete bond strength slightly impoves compared to mix without any fly ash. Hence, it can be infered that fly ash addition improve adhesion between cement paste aggregates (Bala *et al.* 2014). It is essential to note that, strength enhancement depends on the percentage replacement for both rubber and fly ash.

Silica Fume

Replacing coarse aggregate with rubber aggregates and PC with silica fume, compressive strength moderately decreases considering different w/c ratios. Nevertheless the increase in coarse aggregate replacement together with an increase in cement replacement, compressive strength slightly improves, due to the fact that silica fume increases concrete density which ultimately enhances compressive strength (Guneyisi et al., 2004). Similar results were observed by Gesoglu and Guneyisi (2007), due to ultrafine characteristics of silica fume, rubberised concrete with silica fume performs better than concrete without silica fume considering different w/c.

It is evident that silica fume enhances the compressive strength of concrete depending on the replacement percentage of silica fume and rubber aggregates. However, Kumar et al., (2014) observed contradictory results, where the replacement of fine aggregates with 10% of rubber powder and PC replaced with 15% silica fume, reduced compressive strength by 34%. It can be allied to the weak bond between the cement paste and tyre aggregates.

Onuaguluchi and Panesar (2014), used pre-coated crumb rubber aggregates with 3 μm lime powder solution and replaced PC with 11% of silica fume. From their results, silica fume replacement of 5% and 10% with crumb rubber aggregates improved compressive strength by 29% and 14% respectively, when compared to the control mix. This indicates that the pre-coating of rubber aggregates improves adhesion rubber aggregates, as a result of densification of the cement paste, resulting in the improvement of bond between rubber aggregates and cement paste perimeter due to the filler effect of pozzolanic reaction products of the silica fume.

Furthermore, Gupta et al., (2016) validated Guneyisi et al., (2004) study that blending cement with silica fume improves compressive strength depending on different w/c ratios and different types of rubber aggregates (see Figure 2). As it can be observed from Figure 2 that with w/c ratio of 0.35 and 10% of cement replacement by silica fume, concrete performs better. Hence it is evident that silica fume addition improves properties of concrete. Hence it is evident that the addition of silica fume improves properties of concrete regardless of different w/c ratios used, however depends on the replacement level.

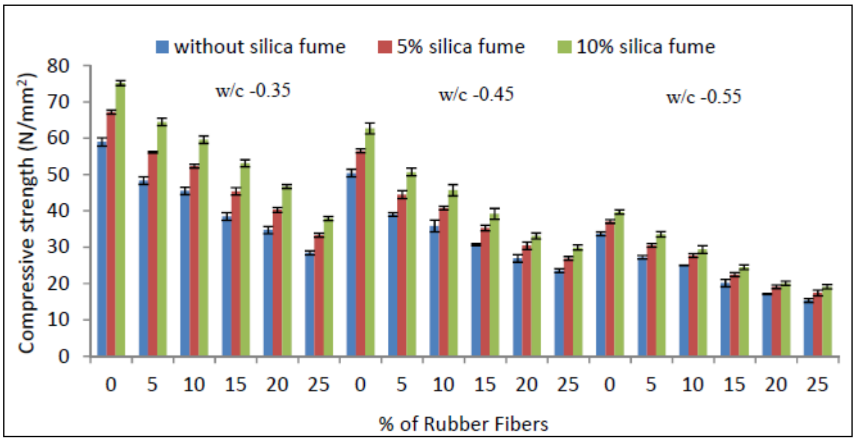

Figure 2: 28 days compressive strength of rubber fiber concrete (Gupta et al., 2016)

Fly ash-based geopolymer binder

Park *et al.*, (2015) studied the impact of sodium silicate to sodium hydroxide on class C fly ash based geopolymer concrete incorporating fine crumb rubber (1 mm or 2 mm), 14M of NaOH, curing at 30°C temperature and 70% humidity. Test results from Table 1 below shows that the compressive strength of rubberised concrete increased with increase in Na2SiO3/NaOH ratio. Additionally, setting time also increased with sodium silicate and sodium silicate/sodium hydroxide. Also, It can be observed that with 20% replacement, compressive strength of mix – 2 with high sodium silicate has high strength compared to mix – 1, Hence compressive strength increases with an increase in sodium silicate to sodium hydroxide ratio.

Table 1: Compressive strength and setting time (Park *et al.,* 2015)

Mixture	Rubber % (Vol.)	Na2SiO3 kg/m3	NaOH kg/m3	Na2SiO3 /NaOH	Comp.strength MPa	Setting time (min)
Mix - 1	0	42	84	0.5	30.8	4
Mix - 2	20	42	84	0.5	25.9	4
Mix - 11	0	84	42	2.0	38.2	10
Mix - 12	20	84	42	2.0	33.5	9

Similarly, Park *et al.,* (2016), replaced fine aggregates by 5 – 20% of crumb rubber aggregates and incorporated fly ash with different CaO content (14.14, 9.42 and 1.29%). NaOH with molarity of 8M and 14M; sodium silicate/sodium hydroxide ratio of 0.5 and 2 were adopt for the study. High compressive strength was recorded with sodium silicate/sodium hydroxide ratio of 2 and CaO 14.14% and NaOH molarity of 14M with 20% fine aggregates replacement. However, with an increase in rubber content replacement regardless of other parameters, compressive strength declined significantly. Similar results were also obtained by Azmi et al., (2016), where compressive strength declined with increase in rubber aggregates content, regardless of other parameters.

4. DURABILITY PROPERTIES OF WASTE TYRE RUBBER AGGREGATE CONCRETE WITH CEMENT EXTENDERS

Silica Fume

Pre-coating of crumb rubber aggregates with 3 μm lime powder solution and PC replaced with 11.2% Silica fume showed decrease in water absorption by 4.0 - 4.5% and porosity by 9.1 – 9.8% (Onuaguluchi and Panesar 2014). Comparably, water absorption and water permeability on samples with 10% of silica fume and 15% of rubber content, shows lower water absorption and permeability when compared to the concrete without any silica fume replacement and 15% rubber content. The above improvement in the durability properties can be attributed to the formation of a denser microstructure because of the incorporation of silica fume.

Furthermore, 10% of silica fume in rubberised concrete with low w/c ratio and prolonged moisture curing, reduces chloride penetration (Gesoglu and Guneyisi, 2007). With 6% and up to 20% replacement of Portland cement and fine aggregates respectively with silica fume and crumb rubber respectively. It was observed that up to 7.5% water absorption, sulphate attack reduced .This is due to impervious properties of rubber aggregates and the reduction of calcium hydroxide (Singh and Patel, 2017). However, above 7.5% water absorption, sulphate attack increased due to lack of internal packing of the concrete (Thomas *et al.*, 2015).

Flyash

According to Azevedo *et al.,* (2012) study, with an increase in fly ash and rubber content, water absorption increased as compared to the control mix. This also can be attributed to air content in rubberised concrete which tends to great path for water and air through concrete. The high content of fly ash in concrete shows resistance to acid attack than the control mixes, these can be attributed to the non-reactiveness of crumb rubber aggregates.

Fly ash-based geopolymer binder

Yahya et al., 2018 studied the effect of seawater in fly ash based geopolymer concrete infilled with motorcycle scrap tyre of 0.5 cm to 1 cm, replaced at 5, 10, 15 and 20%. Sodium silicate/sodium hydroxide ratio of 2 and 2.5, sodium hydroxide molarity of 12. From their results, they observed that all sample gained weight when exposed to seawater, due to a varied mixture between the crumb rubber and geopolymer paste and size of rubber, and hence water penetrated through it which consequently increased the porosity and decreased concrete strength.

5. CONCLUSION AND RECOMMENDATIONS FOR FUTURE STUDY

There is a limited study on the impact of different cement extenders and geopolymer binders in waste tyre rubber aggregates concrete in the South African construction industry. Generally, the literature demonstrates great potential for their use in waste tyre rubber aggregates concrete in South Africa and other developing countries. Therefore, some of the findings are discussed below;

- Above 5% of rubber aggregates, mechanical properties (compressive strength, flexural strength and tensile strength) and durability (water absorption, sorptivity and air permeability) decline with increase in rubber content, due to lack of bond and air content between the rubber aggregates and cement matrix, which creats path for both air and water. But improvements were noted with the addition of silica fume and fly ash (due to their fineness properties which fill the pores between the rubber aggregates), depending on particles sizes and w/c ratios.

- Rubber aggregates, improves acid attack and sulphate attack due to non-reactive properties. However, with the addition of silica fume and fly ash resistance increases, depending on replacement level of rubber aggregate, their particles sizes and w/c ratios adopted.

- In general with high w/c ratio, workability of concrete improves, but mechanical properties are affected negatively due to high water content which lead to poor packaging of rubber aggregates in the mix. On the other hand, most of the researchers found that with the addition of silica fume and fly ash workability declines, while compressive strength and porosity, as well as permeability, improves. However, workability cab=n be recovered with the addition of superplasticizers.

- There is a minimal study on geopolymer binders on waste tyre rubber aggregate concrete. However, from the reviewed literature, it is conclusive that by indroducing fly ash-based geopolymer binder in rubberised concrete, there is less strength reduction compared to cement extenders, which indicates improvement on concrete mechanical properties.

- From the reviewed literature, there is limited work on, how different geopolymer binders (fly ash, silica fume, GGBFS, GGBFS-Silica fume, GGBFS-fly ash, fly ash-silica fume based) performs with rubber aggregates on the mechanical and durability properties of concrete. Therefore, it is important to experimentally investigate the impact of different geopolymer binders considering different percentage replacement, aggregates size, w/c, molarity, sodium silicate/sodium hydroxide ratios, CaO content and different curing temperatures.

6. ACKNOWLEDGEMENTS

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Strategies for the Utilization of Non-Traditional Cost Estimation Models in the Construction Industry of Ghana

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ABSTRACT AND KEYWORDS

Purpose of this Paper:

Construction cost estimation in Ghana has faced criticism of not achieving accurate budgets for construction projects amidst the concept of cost modelling in the process of gaining foot in the construction industry. Hence this study presents the strategies that would enhance the utilization of non-traditional cost estimation models in the Ghanaian construction industry.

Design/Methodology/approach

To achieve this, a quantitative survey research design (structured questionnaire development) was adopted and utilized to elicit data from quantity surveyors both in public and private consulting firms in the Greater Accra and Ashanti regions of Ghana.

Findings

The results revealed that improvement of data management in firms, introduction of cost modelling development in higher learning institutions among other strategies were very key to aid in the utilization of cost estimation models in the construction industry.

Research limitations/Implications (if applicable)

Due to nearness in proximity of respondents, the survey was conducted in only two regions out of the ten regions in Ghana. Hence the implications made from this study should be considered suggestive.

Practical Implications

The findings of this study may be beneficial to construction professionals who are in pursuit of innovative ways of tackling inaccuracies and errors battling construction cost estimation in Ghana.

Direction for future research

A future research could be carried out to examine the possibility of teaching cost estimation modelling development in higher institutions in Ghana.

Keywords; Strategies, non-traditional cost models, construction estimation.

1. INTRODUCTION

Construction cost estimation is an important element that should be monitored at the preliminary phase of construction projects. The purpose of this development is to produce an estimate of the possible cost of a future construction project before the preparation of comprehensive design proposals and contract particulars are prepared (Skitmore, 1988). Potential clients prefer having knowledge on the cost of their proposed project through a guesstimate at the initial stages of the project to manage and estimate their projected financial obligation. This presents an information of his financial obligation prior to detailed design information.

Especially for construction projects, preliminary cost evaluation is an essential section of the project delivery plan thus allowing clients to be able to carry out a comprehensive assessment on the feasibility of his proposed project. After establishing the preliminary cost, a key test is performed on the assumptions using progressively specific cost evaluation practices which agrees with further development of design and construction details. Information on site conditions and proposed solutions are addressed at this stage. Ferry and Brandon (1991) posits that, among the two basic sources of construction cost estimates include the owner-designer thus the request from the client vis-à-vis the design proposal; which can also occur between organizations and the competing market. By this, clients basically are the primary originators of building project cost due to the demand for the project's cost details and their ability to pay.

Construction cost estimation involves the determination of the cost of a proposed project. It is also hooked on the interactions between the design variables and the decision for alternative means of embarking on the project and methods of undertaking the project (Ibrahim, 2003). Researchers have acknowledged innumerable groups of estimation basically based on their observation. Skitmore (1990) grouped methods of estimation into three basic types thus

(a) approximate estimates; this type is generally applied to evaluate the volume of work associated with the project before detailed designed is prepared. It can also be achieved with least preparation of design and associated data. It however follows that a sound intellectual guess, decision and knowledge on similar projects is needed to adopt this technique;

(b) Preliminary or definitive estimate; these estimates are prepared to access the comparative cost of alternative design to compare alternate schemes in economic studies which demands the preparation of designs and drawings. However, without obtaining much information and reasonable quantities of data, the accuracy of the estimates can probably be lowered; and

(c) Detailed estimation which projects the final assessment of the cost of the proposed project. To prepare a good estimate, information is retrieved from provisional plans, specification and bill of quantities.

A further research by Seeley (1996) classified the methods of estimation according to its purpose which includes; one-purpose, two-purpose, one-purpose preliminary, one-purpose later-stage, initial conservative cost estimates and post-initial conservative cost estimates. Principally the classifications established by Seeley (1996) promulgated that guestimate prepared for the client provides a clear view of his cost commitment on a proposed project. The application of non-traditional estimation techniques covers all stages of the construction process with the availability of good data. This paper commences with a review of the non-traditional cost modelling process. Description of the research method followed. The Survey results are illustrated and discussed and lastly presented are the conclusion and recommendations.

2. NON –TRADITIONAL COST MODELS

Since 1950's, there has been immense research with the aim of understanding the relationship between the parameters relating to the design and the cost of the building and to come up with models to be able to forecast the cost of buildings. Cost modelling can therefore be termed as the formation of a system defined with all those variables having an influence on cost (Holm et al., 2005). Based on the historical development, cost models are grouped into three. The first-group models started from practical elements of construction-oriented cost planning approach at the end of 1950's and was comprehensively practised until the end of 1960's. The second-group models also started from the regression analysis in the mid-1970's (McCaffer, 1975). Touran and Wiser (1992) opined that the third-generation models that were used in the 1980's were generally grounded on Monte Carlo simulation techniques propounded by Monte Carlo. Studies have revealed that the model pertaining to cost are generally characterized into deterministic and probabilistic modelling techniques. The first modelling technique presumes that the values can be allocated with any form of variables and can be accurately estimated. Additionally, probabilistic models' techniques can be utilised even if some variables are uncertain. Notwithstanding, cost modelling techniques can also be grouped based on their characteristics. By considering cost estimation in a broader perspective, the traditional cost estimation models are calculated based on quantities and characteristics of available cost data. The second model to be considered is the non-traditional model; this technique establishes the application of innovative techniques and practices in the preparation of cost estimates (Akintoye & Fitzgerald, 2000; Mann, 1992; McCaffer et al., 1984; O'Brien, 1994; Newton, 1991). The level of knowledge on the types of cost models however facilitates the adoption of a kind of cost model technique for cost estimation (O'Brien, 1994).

2.1 Stages involved in developing a cost estimation model.

The model establishes the approximation of realities and the predictions that emanates from the approximation. The equation being utilized is the statistical model. Statistical models include multiple regression models and causal models.

The steps illustrated in the Figure 1 below depict the stages in the statistical modelling process;

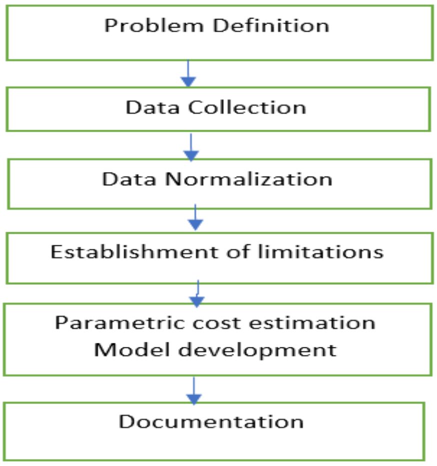

Fig 1. Statistical Cost Estimating Process. (Adapted from Black, 1984)

The best approach according to Black (1984) is to identify what the situation is thus the problem definition. It deals with determining the aim and areas of the study. Data collection comes next, thus historical data are very important in parametric estimation (Rose 1982). Data collection is a very important stage because without enough data, estimation will be inaccurate. The third step in the process is normalization of the data. Establishment of model limitations is fourth step of the statistical cost estimating procedure. Since the model is usually developed from an inadequate data set, its validity is dependent on the ranges of variables used in the model (Orczyk and Chang, 1990). Rose (1982) affirmed that the interpolation and extrapolation must accurately be done, and the range used to estimate the validity of cost must also be known. For that matter Orczyk and Chang (1990) concord that the extrapolation must be done beyond the range which will produce undoubted results. Step five is the statistical cost estimating modelling. This technique estimates relationship in the cost estimation models by using calculated models or graphs. Hegazy and Ayed (1998) argued that, traditional cost estimating relationships are developed by applying regression analysis to historical project cost information. The regression analysis technique establishes the prevailing connection that exist amongst the parameters and the cost, and the scientific equation of the modelling technique (Black, 1984; Orczyk and Chang, 1990). However, in recent times, countless experiments have been conducted using artificial neural network (ANN) technique as substitution to statistical methods of coming up with parametric cost estimating model (Hegazy and Ayed 1998). The final step deals with the documentation of the processes for model development that supports the proper implementation process (Black, 1984).

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2.2 The Practice of Modern Estimation

Ashworth and Skitmore (1983) emphasized on the need of attaching great importance to any estimation method employed when forecasting cost. Estimating the cost of projects is largely dependent on various factors (Chua et al., 1999; Akintoye, 2000; and Enhassi et al., 2009). A study by (Cheng and Wu 2005; Lowe et al., 2006; Marzok et al., 2008) on traditional methods of estimation explained that the importance of an estimation model is to estimate cost of projects depicting alternatives to the current approach and reduce uncertainty to the best minimum level. At the design phase of a project, the cost of the construction projects can be determined using various modelling techniques. Ashworth and Perera (2015) in his submission on cost modelling techniques emphasized on traditional building cost estimation strategies which have ended up ineffective in time due to the complexity and volume of works undertaking in recent times. Again, the traditional system of cost estimating has been substituted with computer-based systems which are simpler, saves time and more accurate. According to the industry players, since computer based estimating models depend extensively on database from past projects, information for its development has significantly improved cost estimation process in the industry.

2.3 The impact of Non-traditional Cost Estimation Modelling Techniques.

The utilization of newer estimation models is paramount due to the quest of projects clients demand for preliminary cost estimates of proposed projects. At the design stage, the financial proposal of a project can be obtained through scientific cost models with available information from past projects. Ashworth and Perera (2015) opined that the use of non-traditional methods is in ascendancy due to the introduction and rise in the complexity and sizes of construction projects and the demand of cost estimates devoid of errors. Further research by Ashworth and Perera (2015) postulates that the traditional methods of cost estimates has been replaced with non-traditional estimation techniques that are modest, periodic, time saving and accurate. However, accomplishing the goal of obtaining a more reliable and accurate cost estimation has turned to be a difficult task to perform due to the absence of historical cost data (Ashworth and Perera, 2015). Since computer based estimating models depend extensively on database from past project information for its development (Ashworth and Perera, 2015; Kim et al., 2005) it is of utmost importance to deal with the issue of data storage in the construction industry critically. Even so, the techniques in non-traditional cost estimation has significantly improved cost estimation process in the industry.

3. RESEARCH METHOD

A structured questionnaire survey adopted from Agyekum et al., (2018) was conducted among construction and consulting firms in the Ashanti and Greater Accra regions of Ghana. Such a survey was suitable for considering the scaled opinions on cost modelling implementation strategies. Formulation of the questionnaire was preceded by a literature review on non-traditional cost modelling and the strategies for successful utilization. Practicing professionals were identified with the aid of the Quantity Surveyor's directory of Ghana Institution of Surveyors (GhIS). The survey was achieved through personal delivery of hard copies of the questionnaires to quantity surveying professionals. Data collected were analyzed using relative important index (RII) and factor analysis (FA) with the aid of International Business Machines Statistical Package for Social Sciences (IBM SPSS) version 23.0. Respondents were asked to rank their opinions on cost modelling utilization strategies on a five-point Likert scale (from 1 – not significant to 5 – very significant). Prior to detailed examination of data retrieved, pre-test in the form of data reliability was performed. Reliability is therefore measured in the range of 0 to 1 with 0 representing no reliability (probability of failure is 1) and 1 representing high reliability (probability of failure is 0). Cronbach's alpha coefficient (α) was used. The calculated α value was 0.824, indicating that the 8 variables are internally consistent and highly reliable.

3.1 Profile of the respondents

A total population of 88 target respondents were identified using purposive sampling technique and were served with survey questionnaires. Effectively, 79.5% response rate thus 70 responses was achieved. The high response rate can be attributed to the fact that questionnaires were administered personally to respondents and successive follow-ups thereafter. The survey presented respondents with 56.3% being Senior Quantity Surveyors and 43.7% representing Assistant Quantity Surveyor. According to the results, 32.4% of the respondents were MSc holders, 64.8% of the respondents representing the highest were BSc holders and the least represented of the population were HND representing 2.8%. Professional qualification of the respondents indicates that, majority of the population were Members of GhIS which had a percentage of 94.4% of respondents and 5.6% of respondents were Fellow members of the GhIS. Finally, 49.3% of respondents had between 5-10 years of working experience, 25.4% of respondents had between 11-20 years of working experience and 25.4% of the respondents had more than 20 years of working experience. From these results, it suggests that the data gathered was of good quality and this informs the credibility of the data collected from these professionals.

Table 3.1. Summary of strategies for the utilization of non-traditional cost estimates

Code	Cost model utilization strategies	Literature source
S1	Clarifying the perceptions about cost models	Agyekum et al., (2018)
S2	Organizing cost modelling workshops for quantity surveying professionals	Oberlender and Trost (2001); Wang and Wang (1996)
S3	Government Support	Department of defense (1999)
S4	Enhancement of publicity on cost modelling benefits	Bledsoe (1992), Smith et al. (2000)
S5	Introduction of cost modelling development in higher learning institutions	Department of Defense (1999)
S6	Key stakeholder involvement in the study and development of cost modelling	Ashworth and Perera (2015)
S7	Improvement of data management in firms	Kissi et al., (2017); Boussabaine et al., (1999); Skitmore (2001)
S8	Development of framework for cost modelling development	Department of defense (1999)

4. ANALYSIS OF SURVEY RESULTS AND DISCUSSIONS

Respondents were asked to rank in their opinion, how these eight identified strategies (Please refer to Table 3.1) for utilizing non-traditional cost estimation models from literature could facilitate the utilization of cost estimation models in the Ghanaian construction industry. Respondent was required to tick in relation to the rankings provided, where ***1= Disagree; 2= strongly Disagree; 3. Neutral; 4= Agree; 5= Strongly Agree.*** The data were analysed by ranking the strategies for utilizing non-traditional cost estimation models to show those which respondents deemed most essential to the least indispensable. The results gathered were the collective responds from Consulting and Construction firms. Based on the information collected, Relative Importance Indices (RII) of the respondents was computed to deduce their rankings. The analysis was further improved by using one-sample t-test to check the importance of the variables. The one sample t-test is usually used to know if a sample mean is considerably diverse from a hypothesized mean.

Table 4.1. Ranking of cost estimation modeling utilization strategies

Code	Strategies	(ΣW)	RII= ΣW/(5*N)	Rank
S1	Clarifying the perceptions about cost models	312	0.879	**6**
S2	Organizing cost modeling workshops for QS professionals	318	0.896	**5**
S3	Government support	263	0.741	**8**
S4	Enhancement of publicity on cost modeling benefits	321	0.904	**4**
S5	Introduction of cost modeling development in higher institutions	329	0.927	**3**
S6	Stakeholders involvement in the study of cost modeling	339	0.955	**2**
S7	Development of framework in cost modeling development	298	0.839	**7**
S8	Improvement of data management in firms.	341	0.961	**1**

Table 4.2. One-Sample Test for cost modelling utilization strategies

Code	Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference		
					Lower	Upper	Rank
S1	23.871	70	.000	1.39437	1.2779	1.5109	6
S2	24.984	70	.000	1.49296	1.3738	1.6121	5
S3	4.066	70	.000	.69014	.3516	1.0287	8
S4	25.220	70	.000	1.50704	1.3879	1.6262	4
S5	27.915	70	.000	1.61972	1.5040	1.7354	3
S6	30.899	70	.000	1.77465	1.6601	1.8892	2
S7	16.187	70	.000	1.21127	1.0620	1.3605	7
S8	37.910	70	.000	1.80282	1.7080	1.8977	1

Observation from Table 4.1 revealed that, 'Improvement of data management in firms' had RII value of 0.961 and ranked 1st. 'Involvement of key stakeholders in cost estimation modelling study' was ranked 2nd with RII value of 0.955. 'Introduction of cost estimation modelling development in higher institutions' was ranked 3rd with RII value of 0.927. The 4th ranked variable was 'Enhancement of publicity about cost estimation modelling benefits' with RII value of 0.904. 'Organize cost modelling workshops for QS professionals' was ranked 5th with RII value of 0.896. 'Clarifying the perceptions about cost models' was 6th ranked with RII value of 0.879. 'Development of framework for cost model utilization' and 'Government support' were ranked 7th and 8th with RII values of 0.839 and 0.741.

According to Table 4.1, the top five key strategies were generated after the mean score ranking test on the eight variables. These factors including; Improvement of data management in firms; Stakeholders involvement in the study of cost modeling; Introduction of cost modeling development in higher institutions; Enhancement of publicity on cost modeling benefits; and Introduction of cost modeling development in higher institutions are discussed below.

The first significant strategy ranked by the respondents was; Improvement of data management in firms. Cost modelling involves mathematical and algorithmic representation of cost for a proposed project; however, this representation of cost is largely dependent on historical cost data. It is therefore worth noting that, without a strong management strategy of data in firms, the quest for utilization of cost modelling techniques cannot be realised. Skitmore (2001) opined that the availability of accurate and relevant data for the development of cost modelling improves its utilization. Moreover, Oberlender and Trost (2001) and Boussabaine et al., (1999) also suggested that with the availability of historical data, cost models can be developed to help achieve value for money through the optimisation of cost.

According to Kissi et al. (2017) the Ghanaian construction industry lacks good historic data management to be used for early cost estimation and minimization of project risks. Unfortunately, the lack of available data inhibits the interest in developing cost models (Shehatto 2013). However, the improvement of data management among construction firms could give a different environment where there would be enough data for cost model development.

Involvement of key stakeholders in cost modelling studies ranked second by the respondents. Generally, the acceptance of a technique or method for a professional practice is widely engineered by the key members of the professional body. This means that if major stakeholders in the industry push for the introduction of new and best approach in solving estimation issues, there will be a way for the introduction of non-traditional techniques for cost estimation. A study by Ashworth and Skitmore (1983) suggested that the issue of accuracy in cost estimation is paramount because the success and failure of every construction project lies in the estimated budget obtained by the client. It therefore proposed that, stakeholders in the industry should adopt innovative techniques to provide accurate estimate for successful completion of construction projects. This is; however, a wakeup call on the stakeholders to stand for change to the old system of estimation. The findings of this research affirm to the findings of Ashworth confirming that if key stakeholders explored the outstanding benefits of cost modelling as revealed in this study and promote its study and development among members; estimation accuracy could be achieved.

The 3rd strategy ranked by the respondents was the introduction of cost modelling development in higher institutions. Respondents believe that the sophisticated and complicated nature of developing cost models requires the introduction of its studies at the academic level. This means, institutions that offer estimating oriented course should inculcate the study of cost model development in their curricula to aid in the introduction at the classroom level. This will equip the professionals before practicing, by so doing help eliminate the non-familiarisation and the lack of understanding to these techniques. A research by parametric cost estimation association (Department of defence ,1999) opined that model development introduced in the curricula of higher institutions has helped in its development. Undoubtfully, cost models in developed countries makes use of this strategy.

Enhancement of publicity about cost estimation modelling benefits ranked fourth by the respondents. Publicity for any product in effect achieves success for the product. Publicity in this content is making known the techniques and its utilization to the industry professionals. The publicity in effect will detail all aspect of the various techniques to aid in understanding of the techniques. Earlier discussion in this study however revealed the benefits of utilizing cost modelling techniques and hence the need to give it the necessary recognition. Bledsoe (1992) opined that the positive benefits of cost modelling demands a better way to communicate to the industry. The study by Smith et al., (2000) suggested that, if the positive effect is sold to the industry, it will maximize its appraisal. It is therefore believed that strong publicity in the Ghanaian construction industry will facilitate the utilization of cost models among cost estimation professionals.

The fifth strategy ranked by the respondents was Organization of cost modelling workshops for QS professionals. Apparently cost model development tends to be distinct in terms of the techniques adopted and the type of project (Oberlender and Trost, 2001) hence the need for workshops to train professionals on the use and development of these techniques. Consequently, the best avenue for evaluating needs and the challenges of critical tools and techniques before they are used can be embraced by the creation of workshops for professionals (Wang and Wang 1996). Organizing workshops according to the respondents would provide better understanding to the various available techniques for cost estimation model development.

5. CONCLUSION AND RECOMMENDATIONS

Currently, the state of cost estimation modelling utilization in Ghana is not satisfactory. As this was evident in the preliminary survey of the study, thus 10% of the 70 respondents indicated that their knowledge on non-traditional cost modelling techniques was inadequate whiles none of the respondents utilized any of the identified techniques. These low utilization levels call for concern. The utilization of cost estimation modelling in other countries like Hong Kong, UK, USA and Singapore has cultured enormous benefits such as the increased performance in cost estimation and reduction in costs overruns at all stages of projects. Hence this study sought to explore the significant strategies needed for the utilization of non-traditional cost estimation models in the construction industry of Ghana. Earlier in this study, the awareness of cost estimation modelling and its application in the

Ghanaian construction industry is low. In descending order of ranking, the significant strategies as indicated by all the respondents includes; improvement of data management in firms, involvement of key stakeholders in cost estimation modeling study, introduction of estimation model development in higher learning institutions, increased publicity on cost estimation model utilization and organized workshops for quantity surveying professionals. Practically, the findings of this study may be beneficial to construction professionals who are in quest of innovative ways to improve on their estimation techniques. Considering the empirical discussions in this paper, the strategies for utilizing cost estimation modelling in the construction industry of Ghana are compelling.

Some limitations need to be acknowledged. First, the concern of generalization is realized by the geographical location. Due to nearness in proximity of respondents, the survey was conducted in only two regions out of the ten regions in Ghana. Hence the implications made from this study should be considered suggestive. Future works on cost estimation modelling in Ghana can expand the survey to other regions to further validate the outcomes of cost estimation modelling implementation strategies. However, to enhance the development of cost models, the higher learning institutions in Ghana should embrace the inclusion of cost modelling development in their core curricula. Moreover, this will increase relevant knowledge on value for money issues among construction practitioners.

A future research could be carried out to examine the possibility of teaching cost estimation model development at higher institutions in Ghana. Also, it would be highly remarkable to investigate further into the organization of cost estimation modelling workshops for construction professionals as this will aid the implementation of cost estimation models in the construction industry of Ghana.

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The Detection of Underground Utilities with Non-Destructive Technology

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ABSTRACT AND KEYWORDS

Purpose of this paper
The use of non-destructive technologies (NDT's) for the detection of underground utilities during the construction process can reduce damage to existing services, and avoid substantial costs and time delays. The effectiveness of Ground Penetrating Radar (GPR), regarded as the most sophisticated, was therefore tested.

Methodology
An overview of available NDT's for the detection of underground services indicated that the response of GPR is sensitive to soil conditions. The soil properties that can limit the reliability of GPR were therefore investigated. Basic tests were also done to illustrate the practical problems associated with GPR when operating under different soil conditions.

Findings
Preliminary tests indicated that GPR performance can vary significantly under different soil conditions.

Research limitations
The study was restricted to three soil textures. Only soil particle size was considered, other physical properties were not taken into account.

Practical implications
GPR data should be treated with circumspection, as results can be misinterpreted if the variables controlling GPR response are not understood. Special attention should be given to maintaining reliable depth measurements under different soil conditions that typically occur in South Africa.

Value of paper
Recognition of the limitations of GPR will prevent unwarranted reliance on its accuracy and contribute to sustainable construction practices.

KEYWORDS: Underground Utility Detection, Non-destructive Technology (NDT), Ground Penetrating Radar (GPR).

INTRODUCTION

1.1. Background

Unintended damage to subsurface utilities during construction excavation is a major cause of disruption in electricity supply, telecommunication, water supply and other essential public services. Utility strikes are also a leading cause of hazardous liquid and natural gas accidents (Lester & Bernold, 2007). Services being struck is a longstanding problem globally that cost billions of dollars each year (Li et al., 2015).

There is an urgent need to develop a reliable method for obtaining utility location data, and to model the positional uncertainties to prevent utility strikes. Underground utility detection can reduce damage to existing services during excavation, and avoid substantial costs and time delays. There are several non-destructive technologies (NDT's) available for the detection of underground services. However, Ground Penetrating Radar (GPR) is currently seen as the preferred method due to the following advantages (Li et al., 2015): GPR can detect non-metallic objects, which is its key advantage over other NDT's; The depth of utilities can be estimated through processing methods such as wave speed estimation. It is challenging for other NDT's to estimate the target depth as they rely heavily on the judgment of equipment operators; GPR has a higher level of resolution than the other NDT's. The integration of GPR and GPS enables the system to achieve a high accuracy level in locating subsurface utilities in three dimensions.

GPR is a geophysical instrument with a diverse range of applications. Over the past four decades, GPR has been used effectively to help in constraining problems in various fields such as archaeology, environmental site characterisation, glaciology, hydrology, land mine detection, sedimentology, and structural geology (Baker et al., 2007). GPR has been widely used in locating underground services due to its advantages such as fast data acquisition, cost efficiency when mapping large areas and high-resolution imagery for improved interpretation (Jaw & Hashim, 2013).

1.2. Problem Formulation

Locational data for existing utilities is either scarce, unavailable or at best, unreliable (Jaw & Hashim, 2013; Costello et al., 2007). Utility strikes are attributed to two main problems: The absence of reliable information regarding the correct location of underground services, and the lack of an efficient way to communicate the uncertainties associated with locational data to stakeholders and field operators. Inaccurate data on the location of existing services leads to falsely instilled confidence, and can mislead equipment operators into unintended utility strikes (Li et al., 2015). There is a rising demand for accurate non-destructive mapping of underground services, especially in urban areas where the utility networks are becoming denser. GPR response should be evaluated in consideration of all the variables relating to the radar system, the objects and the underground (Sagnard et al., 2017). The accuracy of subsurface mapping using GPR has often been overlooked, due to a lack of understanding of the physical basis on which GPR operates; a lack of a standard methodology for data collection; and a lack of reliable accuracy assessments (Baker et al., 2007; Jaw & Hashim, 2013). In order to reduce the number of utility strikes, the accuracy and limitations of mapping underground services using NDT should be determined (Jaw & Hashim, 2013).

2. LITERATURE STUDY

2.1. Overview of Non-destructive Technologies

In typical utility detection technologies, energy is transmitted into the ground and the reflected energy from subsurface utilities is recorded. Processing of the recorded information produces data about the distribution of the physical properties associated with underground objects. The recorded data can be processed and interpreted to estimate the location of the subsurface utility. Available NDT's for underground utility detection are based on various geophysical theories, including Electromagnetic theory;

Energy transfer theory; Magnetic theory; Elastic wave theory; and Electrical resistivity theory (Jeong et al., 2003).

Project-specific restrictions such as space, noise and budget constraints often limit the use of NDT's to those based on acoustic emission, magnetic and electromagnetic methods (including GPR) (Jeong et al., 2003).

It should be noted that all the NDT's discussed below were not solely developed for the detection of underground services. Several of the NDT's such as Ground Penetrating Radar (GPR), Low Frequency Electromagnetic Fields (LFEM) and Electromagnetic (EM) methods are also applicable to soil analysis, condition assessment, etc. This section highlights the advantages and limitations; and focusses exclusively on the underground utility detection capabilities of the different NDT's.

2.1.1. Ground Penetrating Radar (GPR)

GPR is the most reliable NDT under suitable soil conditions. It has the highest level of accuracy and is the best technique for detecting non-metallic utilities (Li et al., 2015). Since GPR can detect metallic and non-metallic objects, all the capabilities of EM methods are also provided by GPR. However, EM methods are less expensive and more user-friendly for detecting electrical cables (University of Birmingham, 2010).

2.1.2. Electromagnetic (EM) Methods

Pipe and cable locators are the best EM method for utility detection. Modern pipe and cable locators come with a variety of applications that cover the majority of benefits provided by the other EM methods, such as terrain conductivity and metal detectors (Jeong et al., 2003). The key shortcoming of EM methods is its inability to detect non-metallic objects (Li et al., 2015).

2.1.3. Low Frequency Electromagnetic Fields (LFEM)

LFEM technology covers all the advantages of the traditional resistivity method (Cross, 2014), and is considered the most reliable alternative under soil conditions which makes GPR ineffective. The LFEM method is less susceptible to soil conditions, but is not considered a specialised utility detection technique. Data interpretation is complicated and the equipment comes in large units, making it difficult to survey confined spaces (Hao et al., 2012).

2.1.4. Magnetic Methods (Magnetometer)

Magnetometers are the only NDT investigated, that is not affected by soil conditions (Lord & Koerner, 1988). However, magnetic methods can only detect ferrous metals, and results are severely affected by above-ground external magnetic interferences (Jeong et al., 2003).

2.1.5. Acoustic Emission Methods (Vibro-Acoustics)

Acoustic emission methods normally apply acoustic vibrations onto the tar- get (Katz et al., 2011). Although not an accurate detection method, Vibro- Acoustics can be a good tracing technique when a transducer can be connected to the utility (Rana, 2011). Acoustic Emission methods are normally used as an alternative when GPR or EM techniques are ineffective (Jeong et al., 2003), as access to the utility is required which implies that the utility is already detected at a certain location.

2.1.6. Infrared Thermography

The principle of Infrared Thermography is based on the energy transfer theory (Hao et al., 2012). The method is not widely used for utility detection, due to the other available methods that are less expensive and more precise. Accurate depth measurements are not possible, and external factors such as changes in ambient temperature or wind can disrupt the imaging result (Jeong et al., 2003). However, infrared cameras can be very useful for site inspections, to provide an indication of the density of the service network, and the scope of the utility survey to be executed.

2.1.7. Air-Vacuum Excavation

Air-vacuum excavation works with the concurrent action of compressed air to loosen the soil, and vacuum extraction of the resulting debris. Hence, it is not a pure “non-destructive” technology, but it should not cause damage to utilities, and provides visual confirmation of the target (Rana, 2011). It pro- vides the highest level of accuracy and is a highly recommended tool to be used in conjunction with other NDT’s (Jeong et al., 2003). On its own, air-vacuum excavation would not be an effective detection technique, as the location of the utility and intended pilot hole would be unknown.

In summary, applying GPR and EM methods in combination is the most effective solution for the majority of underground survey conditions (Bernold et al., 2003). GPR is the most sophisticated NDT for locating underground services (Li et al., 2015). However, soil conditions can have a significant impact on the effectiveness of GPR (Baker et al., 2007).

2.2. The Impact of Soil Conditions on Ground Penetrating Radar

This section comprises a brief study to understand how soil conditions affect the reliability of GPR technology. The objectives of the section are to provide a basic overview of the functioning of GPR technology, and to highlight the properties of soil that can affect GPR results.

2.2.1. An Overview on Ground Penetrating Radar (GPR)

GPR is a near-surface geophysical imaging technique used for non-destructive subsurface geologic and engineering investigations (Martinez & Byrnes, 2001). GPR is used to “see through” the ground, either to establish the structure of the soil or to find buried objects such as utilities made of metal, plastic, concrete, etc. (University of Birmingham, 2010).

GPR is a reflection technique, which uses radio frequency (RF) electromagnetic (EM) waves to acquire underground data (Jeong et al., 2003). Whereas seismic response is a function of acoustic properties, GPR response is a function of EM properties (Martinez & Byrnes, 2001). When the transmitted RF waves encounter an underground target, it reflects back to the receiver antenna (Jaw & Hashim, 2013). In order to produce an identifiable reading of an underground target, a GPR profile must be acquired. A GPR profile is produced when the antenna is moved laterally over the ground surface. The radar element transmits and receives signals that are reflected from the subsurface objects. This results in the “profile” of the object to appear on the GPR monitor, which also allows for the depth estimation of the target (Jeong et al., 2003). Reflections entering the equipment are monitored at the receiver and are then transferred onto a computer screen in order to depict the graphic profiles formed by the reflection of the EM waves. Cylindrical objects such as pipes and cables will form the shape of a hyperbola on the GPR monitor (Sinha et al., 2007).

GPR utilises propagating EM waves that respond to changes in the EM properties of the subsurface (Baker et al., 2007). GPR can be used to detect metallic and non-metallic objects since the signals received are reflected from any variations in the following EM properties: Relative permittivity, magnetic permeability and electrical conductivity (Sinha et al., 2007).

2.2.2. Soil Properties affecting GPR Response

The principal variables of importance in GPR are primarily the EM soil properties of relative permittivity, electrical conductivity and magnetic permeability, which affect how EM waves propagate and reflect in the subsurface (Baker et al., 2007). The aforementioned EM variables are influenced by physical soil properties, such as saturation, mineralogy, porosity and soil texture. Time-propagation modelling of the effect of mineralogy, porosity and saturation indicates that saturation has the largest influence on relative permittivity, followed by mineralogy and porosity. GPR response can vary significantly with variations in these physical soil properties, which should be borne in mind when interpreting GPR data (Martinez & Byrnes, 2001).

The propagation velocity of EM waves is the primary controlling factor in the generation of reflections, and is determined by the relative permittivity contrast between the target and the background material. Although the propagation velocity of EM waves is reliant on relative permittivity; the attenuation of an EM wave is reliant on a material's electrical conductivity and magnetic permeability. However, magnetic permeability only becomes an important factor when operating in ferromagnetic soils (Baker et al., 2007). Signal attenuation is associated with the conductivity of the soil and the transmitted GPR frequency (attenuation increases significantly as frequency and conductivity increases) (Baker et al., 2007).

Relative permittivity is a vital parameter in GPR studies, as it controls the propagation velocity of an EM wave through materials, reflection coefficients at interfaces, and horizontal and vertical imaging resolution. Hence, knowing material relative permittivity values will assist in interpreting GPR data and in planning GPR surveys (Martinez & Byrnes, 2001). Results can be misinterpreted if the parameters controlling GPR response are not understood (Martinez & Byrnes, 2001). The critical variables that dictate how EM waves react to changes in subsurface EM properties should be considered when using GPR (Baker et al., 2007).

In summary, the relative permittivity, electrical conductivity, magnetic permeability and GPR frequency affect how EM waves propagate, reflect and attenuate in the subsurface (Martinez & Byrnes, 2001). Relative permittivity affects the propagation velocity of EM waves, which control the generation of reflections. The propagation velocity of an EM wave decreases as the relative permittivity of the soil increases (resulting in resolution constraints and reduced GPR penetration depth). Electrical conductivity, magnetic permeability and GPR frequency affect the attenuation of a propagating EM wave. An increase in any of these variables will increase GPR signal attenuation and reduce penetration depth (Baker et al., 2007).

3. MATERIAL AND METHODS

The effectiveness of GPR was tested under three different soil textures. Soil tests were retrieved for three different areas that were subject GPR surveys. The GPR results for the three areas were compared, while considering the soil textures applicable to each site.

Grain size is classified as clay if the particle diameter is less than 0.002mm, as silt if it is between 0.002mm and 0.06mm, and as sand if it is between 0.06mm and 2mm (Knappett & Craig, 2012). Soil texture refers to the relative proportions clay, silt, and sand particle sizes, irrespective of mineralogical or chemical composition of the material (May, 2008).

3.1. Testing purpose

The literature study revealed that soil conditions could have an impact on GPR response. The purpose of this section is not to quantify the impact or to accurately define the relevant soil characteristics; but rather to prove that an impact does exist, and to illustrate the practical problems associated with GPR when operating under different soil conditions.

3.2. Testing approach

If the GPR performance fluctuates over different sites, and the only variable that changed is the soil conditions (i.e. GPR equipment, transmitted EM frequency and operator remained constant); then it should be possible to prove that soil conditions do have an impact on GPR.

The approach is to demonstrate that the soil texture for three test sites are different, which will provide the proof that the overall soil conditions for the three sites are not the same (irrespective whether other physical or EM soil properties have changed).

Hydrometer Analysis was used as the main method to determine soil particle size and ultimately, soil texture. Sieve Analysis results were used to examine particle size distribution of larger grained material, and to distinguish soil from gravel (i.e. particle sizes less than 2mm comprises soil).

The laboratory tests (Civilab, 2014; 2016; 2017) used do not reveal data for the soil in isolation, but rather provide results for the entire sample tested (i.e. including gravel, which is not classified as soil). Since this section aims to prove that soil conditions have an impact on GPR performance, the researcher followed this methodology: The soil portion was isolated from the entire sample, by only considering particle sizes less than 2mm, hence, the gravel portion of each sample was excluded. The relative proportions clay, silt and sand were then expressed as a percentage of the soil portion of the total sample. These percentages were then used to classify the soil texture in terms of the USDA soil texture triangle (refer to figure 1) (USDA, 2018).

Figure 1. USDA Soil Texture Triangle

Figure 2. GPR Equipment

3.3. Testing equipment

Equipment used for GPR testing was the Leica DS-2000. The DS-2000 transmits two different EM waves (250MHz and 700MHz). The higher frequency EM waves allow for better resolution in detecting shallower objects. The lower frequency EM waves, allow for deeper penetration, but the imaging resolution is notably lower (refer to figure 2 for GPR testing equipment).

4. RESULTS

4.1. Test Site 1 - Montecasino Office Precinct

The site is situated in Magaliessig Extension 64, Johannesburg.

4.1.1. Test Site 1 - Soil Texture

Table 1: Soil texture data for Test Site 1 was extracted from Civilab (2014):

TABLE-1:		TEST SITE 1 - SOIL TEXTURE			
Sieve & Hydrometer Analysis - Total Sample			Soil Portion of Total Sample		
Gravel	% of Sample =	15%	Grain < 2mm	=	85%
Sand	% of Sample =	66%	Sand	% of Soil =	77,65%
Silt	% of Sample =	11%	Silt	% of Soil =	12,94%
Clay	% of Sample =	8%	Clay	% of Soil =	9,41%
USDA - SOIL TEXTURE CLASSIFICATION:				SANDY LOAM	

4.1.2. Test Site 1 - GPR Performance

Soil texture for the first test site was classified as Sandy Loam (refer to circle 1 on figure 1). GPR was effective under this soil texture, with accurate depth measurements. The GPR response was different, and better than that obtained at the other two test sites.

4.2. Test Site 2 - Sandton Gate Development

The site is situated in Glenadrienne, Sandton, Johannesburg.

4.2.1. Test Site 2 - Soil Texture

Table 2: Soil texture data for Test Site 2 was extracted from Civilab (2016):

TABLE-2:		TEST SITE 2 - SOIL TEXTURE			
Sieve & Hydrometer Analysis - Total Sample			Soil Portion of Total Sample		
Gravel	% of Sample =	19%	Grain < 2mm	=	81%
Sand	% of Sample =	29%	Sand	% of Soil =	35,80%
Silt	% of Sample =	28%	Silt	% of Soil =	34,57%
Clay	% of Sample =	24%	Clay	% of Soil =	29,63%
USDA - SOIL TEXTURE CLASSIFICATION:				CLAY LOAM	

4.2.2. Test Site 2 - GPR Performance

Soil texture for the second test site was classified as Clay Loam (refer to circle 2 on figure 1). GPR was reasonably effective under this soil texture, however, the GPR depth measurements were inaccurate and constantly shallower than the actual depths measured after exposing the services. The GPR response was different to that obtained at the other two test sites. GPR performance was not as good as the first site, but better than the third site.

4.3. Test Site 3 - Effluent Treatment Plant - Rustenburg

The site is situated on Brons Street, Rustenburg.

4.3.1. Test Site 3 - Soil Texture

Table 3: Soil texture data for Test Site 3 was extracted from Civilab (2017):

TABLE-3:		TEST SITE 3 - SOIL TEXTURE			
Sieve & Hydrometer Analysis - Total Sample			Soil Portion of Total Sample		
Gravel	% of Sample =	1%	Grain < 2mm	=	99%
Sand	% of Sample =	23%	Sand	% of Soil =	23,23%
Silt	% of Sample =	30%	Silt	% of Soil =	30,30%
Clay	% of Sample =	46%	Clay	% of Soil =	46,46%
USDA - SOIL TEXTURE CLASSIFICATION:				CLAY	

4.3.2. Test Site 3 - GPR Performance

Soil texture for the third test site was classified as Clay (refer to circle 3 on figure 1). GPR was totally ineffective under this soil texture, and failed to detect any services. The GPR equipment was unable to detect a 75mm diameter PVC pipe, installed as shallow as 345mm below NGL. The GPR response was different to that obtained at the other two sites, and of no use.

4.4. Test Results Summary & Discussion

The study was restricted to the three soil textures under which the GPR performance was tested. Only soil particle size was considered, other physical properties such as saturation, mineralogy and porosity, which could have influenced the test results were not taken into account. This is considered a significant research limitation, and reduces the relevance of the findings. Test results for the applicable soil textures can be summarised as follows:

GPR performed well under Sandy Loam with accurate depth measurements; GPR was reasonably effective under Clay Loam, however, depth measurements were inaccurate; GPR was ineffective under Clay.

Based on the above, the following tentative assumption can be made: GPR response weakens as the soil particle size decreases (from sand to clay).

As mentioned in section 3, the purpose for carrying out the tests was not to quantify the impact of soil conditions on GPR; but rather to demonstrate that an impact does exist, and to illustrate the practical problems associated with GPR when operating under different soil conditions. No scientific conclusions can be made based on statistical findings. However, the results demonstrated that the soil textures for the three sites were different, and therefore it can be said that the soil conditions as a whole must also be different. The testing also indicated that the GPR performance was different at each of the three sites. The same methodology was applied at all three sites, apart from the soil conditions; all other principle variables (equipment, frequency and operator) remained constant. As the GPR performance was different at all three sites, it can be concluded that soil conditions do have an impact on GPR response (at a practical level), as confirmed by the literature study.

5. CONCLUSIONS

The use of non-destructive methods can reduce damage caused to existing services during excavation. However, these methods can be unreliable, and the accuracy and limitations of the applicable NDT should be determined, while considering the relevant site circumstances.

Ground Penetrating Radar is the most sophisticated NDT for locating underground services. However, it was found that soil conditions can have a profound impact on the effectiveness of GPR.

Results can be misinterpreted if the variables affecting GPR response are not considered. GPR response is severely affected by variations in physical soil properties, such as soil texture, saturation and mineralogy. Therefore, these variables should be borne in mind when using GPR as a subsurface imaging technique.

Understanding the parameters that dictate how EM waves react to variations in EM properties of the soil are important; as GPR response is a function of the relationship between material EM properties and EM wave propagation.

GPR response can vary significantly under different soil conditions, hence, the physical and EM properties of soil should be considered when interpreting GPR data.

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The influence of procurement processes on cost performance of projects: Lessons from the energy utility

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ABSTRACT

Purpose of this paper

This paper reports on the findings of a study conducted to establish the influence of procurement processes towards cost performance of infrastructure projects implemented by the energy utility. Procurement methods used in projects have influence in cost performance and the study demonstrated different cost outcomes according to the procurement methods.

Methodology

The study was conducted using qualitative method. The data was collected in three different ways namely interviews, document review and observation. The data was analysed using content analysis and narrative analysis methods.

Findings

The findings indicated that various procurement and delivery methods result in different actual costs in projects. According to the literature and the empirical findings of the study, the traditional method was found to be cost effective compared to the design and build method.

Research limitations

The study focused on infrastructure projects implemented by the South African energy utility and the study looked into their processes and practices. The types of projects were limited to the 132 kV Feeder bay projects that are intended to build capacity for the transmission and distribution substations.

Practical implications

The higher costs incurred by the less cost-effective procurement method could have been used to invest on other projects. It is important to consider the cost effectiveness of procurement methods

before initiating infrastructure project in order to incur meaningful expenditure. The lessons learnt were shared within the three affected divisions of the energy utility with an intention to provoke reflections and implement improvements in their projects.

Keywords

Cost performance, Procurement method, Procurement processes.

1. Introduction

The problem of cost overruns in the construction industry is known to be a global phenomenon and it is widely attributed to the procurement practices, processes and methods (Creeddy, Skitmore and Wong, 2010). Procurement has a key role to play in the construction industry and it may not be possible to place contracts without procurement processes. According to Kahkonen and Porkka (2005), procurement and tendering methods are the determinants of actual costs of projects. The process of selecting consultants and contractors who will implement construction projects is as important as the management of project activities during construction and the outcomes are as good as the capability of the team.

This study established through involvement of various construction practitioners that procurement processes and the life of the project will influence the health of the project from initiation to close out. The risks of construction cost overruns are more associated with the processes used to procure various services in the projects. Procurement is a process that creates, manages and fulfills contracts (National Treasury, 2016:6). Procurement includes the processes required to acquire goods and services, to obtain project scope, from outside the performing organisation (Project Management Institute, 2012). According to Hancock and Algozzine (2007:14) Procurement describes the merging of activities undertaken by the client to obtain a building.

The study looked into the following procurement methods:

- Design and build method

According to the Construction Industry Development Board (CIDB, 2011:3), design and build method is an arrangement where the responsibility of executing the design and construction is placed into a single contractor on the basis of a predetermined lump sum. This method becomes costly due to the dependency of an external professional team by the client not only for planning and design but also supervision of construction activities.

- Traditional method

According to Nagy, Kiss and Hornyak (2015:12), traditional method separates design, bid and build. In the traditional procurement method, the design is completed by an appointed team prior the involvement of the contractor who is only responsible for construction and not the design unless specified for specific items of the project. Since the design information is fully completed before the contractors' bidding process, there is a higher degree of cost certainty in this method as it minimizes changes in the design and other unforeseen circumstances which might result into extension of time claims (Nagy et al,. 2015:12). However there is pressure to complete the design and this may also result in insufficient time to complete the design documentation prior to issuing tender documents and this may lead to higher degree of price uncertainty.

Hughes and Greenwood (2010) argued that tendering procedures can be very costly due to the effort that goes into them and that result to higher costs in construction projects. According to this study, procurement processes also involve tendering methods that are used to acquire various services and for this reason the study also looked at the following tendering methods:

According to Fylvberg (2012), the cost performance of infrastructure projects have more to do with how they were established, run and concluded in terms of procurement practices and cost management.

2. Problem statement

Given the observation conducted on similar scope infrastructure projects completed by the energy utility wherein the cost variances were higher, it became necessary to do a study with an intention to establish why similar scope projects would spend significantly different project costs. During the financial year 2015/16, three projects implementation divisions spent varying costs to implement construction projects of similar scope and this was ascribed to procurement processes (Eskom, 2016). The observation by the researcher motivated the study to establish factors leading to cost variances. According to Azis, Memon and Rahman (2012:10), poor cost performance in construction projects is a common problem worldwide resulting in significant amount of cost overruns. Given the scarcity of funding in construction projects, it has become necessary to explain every cent spent in projects especially that it is the taxpayer’s money (Hodge and Greve, 2009). As different as projects are in their nature; similar scope projects are not expected to have variances in costs which are significant without major changes of scope in implementation. The nature of projects that were used for this research were construction of 132kV Feeder Bays intended to feed high power consuming customers who apply for special supply such as mines, heavy factories and high production industries. The challenge established was that customers of the same product were paying different amounts and this was caused by lack of standardization of construction costs between group capitals, transmission and distribution division of the utility. As part of seeking improvement, it is necessary to establish the degree to which final costs reflect projected budgets at bid stage and further address reasons for cost variances where they are found to be prevalent (Flyvberg, 2012).

3. Research methods

This section explains the methods and techniques adopted to conduct the research. A research methodology refers to a systematic and logical process and steps that are followed in the research process in order to gather and analyse the research findings that answer the research questions (Saunders et al., 2016). A case study was used to conduct a study on energy utility projects and the angle of the study became exploratory because the case of cost variance analysis had not been explored before. Studies have been conducted on causes of construction cost overruns in South Africa (Baloyi and Bekker, 2011), cost and time overruns of projects in Malaysia (Endut, Akintoye and Kelly, 2010), significant factors causing cost overruns in Nigeria (Ameh, Soyingbe and Odusami, 2010) and cost overruns in Vietnam projects (Hoai and Lee, 2008) to mention but a few. There has not been much research and study focusing on cost variances analysis of similar scope projects.

3.1 Methodology

This study used the qualitative approach due to the need to look into the details. A qualitative research methodology focuses on gathering rich insights and deeper analysis (Creswell, 2013). The level of data used in a qualitative approach must be detailed and not focusing on numbers but facts. The gathering of people’s opinions through semi-structured questions facilitated through a qualitative research methodology allowed for richer insights as new issues on causes of cost overruns could be exposed from the phenomenon of the study. The study used a case study in order to collect existing practices and approached with the energy utility. The study was more practical and based on the existing projects. According to Baxter and Jack (2008:3), qualitative study methodology provides tools for researchers to study complex issues within their context. Table 1 below gives a distinction and justification for applying qualitative method in this study.

Table 1: Criteria for Qualitative and Quantitative research

Criteria	Qualitative	Quantitative
Conceptual	Concerned with understanding the phenomenon from the informant's perspective	Concerned with discovering facts about the phenomenon
	Assumes a dynamic and negotiated reality	Assumes a fixed and measurable reality
Methodological	Data are collected through participants' observation and interviews	Data are collected through measuring things
	Data are analysed by themes from description by informants	Data are analysed through numerical comparisons and statistical inferences
	Data are reported in the language of the informant	Data are reported through statistical analyses

3.2 Data Collection

The study collected data in various methods namely interviews, project documentation review and observation.

3.2.1 Interviews

The researcher conducted interviews with construction practitioners who were involved in the implementation of projects from three divisions from the energy utility. Three divisions were: Group Capital, Transmission and Distribution. 242 individuals were interviewed from the three divisions of the energy utility. The Transmission Division offered 85 individuals while Group Capital offered 108 individuals and the Distribution Division had 49 individuals who formed part of the interviews. This data gathering process allowed the interviewer to have an open discussion on specific issues concerning cost variances on similar scope projects. This research also had two field supervisors to control a possible element of biasness within the organization. Semi structured interview is possibly the most common qualitative data gathering method in research as it is relatively straightforward and organized (Adcock & Collier, 2001:529). The population of participants is indicated in Table 2 below:

Table 2: Case study target population in three project divisions

Role	Transmission	Group Capital	Distribution
General Managers: Projects	1	1	1
Portfolio Managers	4	7	3
Programme Managers	10	15	5
Project Managers	40	45	20
Engineers	10	15	5
Quantity Surveyors	10	15	5
Project Administrators	10	10	10
Total	**85**	**108**	**49**

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3.2.2 Documentation review

The study involved review of documentation used in projects. Ten documents were reviewed for each project and the number of interrogated projects was fifteen with five from each division. The documents were arranged according to ten knowledge areas of PMBOK In this research documents which were reviewed were including but not limited to contracts, minutes, site instructions, payments, compensation events and risk management plan. This method helped this research to receive more data concerning the management of projects and performance of costs. According to Hancock et al (2007:19), a wide range of written material produces qualitative information which can be particularly useful in trying to understand the phenomenon.

3.2.3 Observation

The other method used to collect data for this research was observation. Observation is a technique that can be used when data collected through other means are not enough to arrive to conclusions or are perhaps difficult to validate (Creswell, 2017). Observations help the researcher to judge the behavior of a phenomenon directly without making assumptions (Hancock et al, 2007:18). It was beneficial to use observation in various projects in order to be able to compare circumstances that led to inconsistency in cost performance. The researcher was part of the projects from initiation to close out phase.

4. Results

The results presented were based on the construction of 132 kV Feeder bay projects. The scope of the projects entailed civil engineering works, structural steelwork and installations of equipment is represented below in Table 3. The results were gathered from interviews, document review and observation and they were also supported by relevant literature. The arrangement of results is grouped into three divisions of the energy utility namely Group Capital, Transmission and Distribution.

Table 3: Scope of the typical 132kV Feeder Bay project

High level scope of 132kV Feeder Bay Construction			
High level description	Build, equip and commission 132kV Feeder Bay	Unit of measure	Quantity
The construction scope entails the following:			
Civil works	Excavation of equipment foundations.	Cubic Meters (M3)	15
	Construction of plinths for equipment.	Cubic Meters (M3)	15
	Installation of steelwork.	Ton	20
Equipment installation	Primary Plant		
	Circuit breakers	Number	3
	Current transformers	Number	3
	Voltage transformers	Number	3
	Isolators and,	Number	3
	Surge arrestors	Number	3
	Secondary Plant		
	Junction box	*Number*	1
	Protection scheme	Number	1
Stringing and cabling	Stringing of conductors	Meters	500
	Installation of cables	Meters	2000
Commissioning	Outage and commissioning	Number	1

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Projects' information is listed in Table 4 below. It indicates project implementation entity, contract sum, project durations and standard forms of contract used to govern the projects.

Table 4: Summary of project information captured for the study

Case Studies	Summary of basic projects information							
	Projects	Division	Duration (Years)	Contract Sum (R. M)	Location (Province)	Form of contract	Average duration (Years)	Average contract sum (R.M)
Case 1	A	GCD	5.50	12.2	Western cape	NEC3	5 Years	12
	B	GCD	4.80	13.2	Gauteng	NEC3		
	C	GCD	4.90	13.2	North West	NEC3		
	D	GCD	4.40	10.2	Mpumalanga	NEC3		
	E	GCD	5.30	11.3	Limpopo	NEC3		
Case 2	F	Tx.AME	3.70	8.5	Gauteng	NEC3	3.5 years	8.5
	G	Tx.AME	3.40	8.8	Gauteng	NEC3		
	H	Tx.AME	3.40	8.2	Limpopo	NEC3		
	I	Tx.AME	3.60	7.9	North West	NEC3		
	J	Tx.AME	3.50	8.7	Mpumalanga	NEC3		
Case 3	K	Dx	2.00	5.6	Northern Cape	NEC3	2 Years	5
	L	Dx	2.20	4.8	Limpopo	NEC3		
	M	Dx	2.30	5.3	Eastern Cape	NEC3		
	N	Dx	2.20	4.8	Gauteng	NEC3		
	0	Dx	2.10	5.1	North West	NEC3		

Legend	
GCD	Group Capital Division
Tx.AME	Transmission Asset Management Execution
Dx	Distribution
NEC3	New Engineering Contract

4.1 Results on procurement processes

The study found that the choice of procurement methods had impact towards cost performance of projects. The study is presented in cases and each presents the approach used by a business division of the energy utility. The divisions were three, namely Group Capital, Transmission and Distribution. Each of the division autonomous and run projects in their own preferred way with different management teams, processes and procedures.

4.1.1 Case 1: Group Capital Division: Design and build

The findings indicated that the Group Capital division of the utility utilized the design and build procurement method and by doing so, projects were in this case designed and constructed by one entity. This approach resulted to higher costs due to the amount of control that the appointed contractors had. In this approach, if monitoring is not strong, contractors tend to over-design and create compensation opportunities through scope changes and variations. The actual final costs of the projects executed by this division were higher compared to the other divisions and this was attributed to the procurement method. The division utilized selective tendering and this was done through establishing panels from which contractors gets selected without using the open tendering approach. Figure 1 below demonstrates the organizational structure of the design and build procurement method.

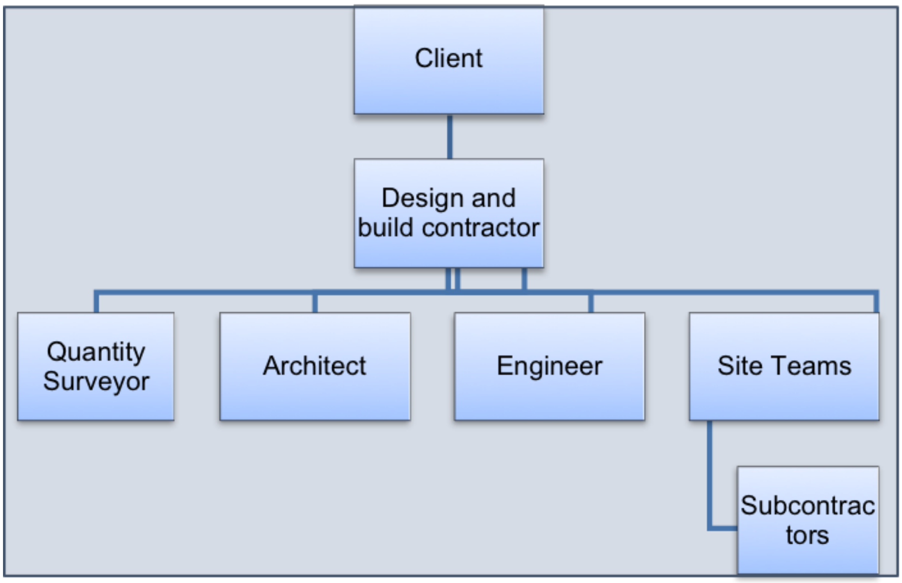

Figure 1: Organizational structure for the design and build method.

(Source: Takim, 2009)

4.1.2 Case 2: Transmission Division: Design and Build

The results revealed that this division also utilized design and build method. The projects of this division were constructed by a subsidiary construction arm of the energy utility which is given a right of refusal when it comes to awarding of contracts. Both the responsibility to design and to construct was apportioned to the contractor. The findings indicated that the costs of the projects were higher than the estimated and allocated budgets.

4.1.3 Case 3: Distribution Division: Traditional method

The findings indicated that the distribution division of the energy utility utilized the traditional procurement method. There was a clear separation between design phase and construction phase. The responsibility of designs remained with the client whom in this case was the energy utility and the construction was handled by the appointed contractor. The findings indicated that the distribution division realized cost savings as compared to the other projects departments within the energy utility and according to the interviewed project team members; this was more ascribed to the use of a traditional procurement method. Figure 2 below indicates the organizational structure of the traditional procurement method.

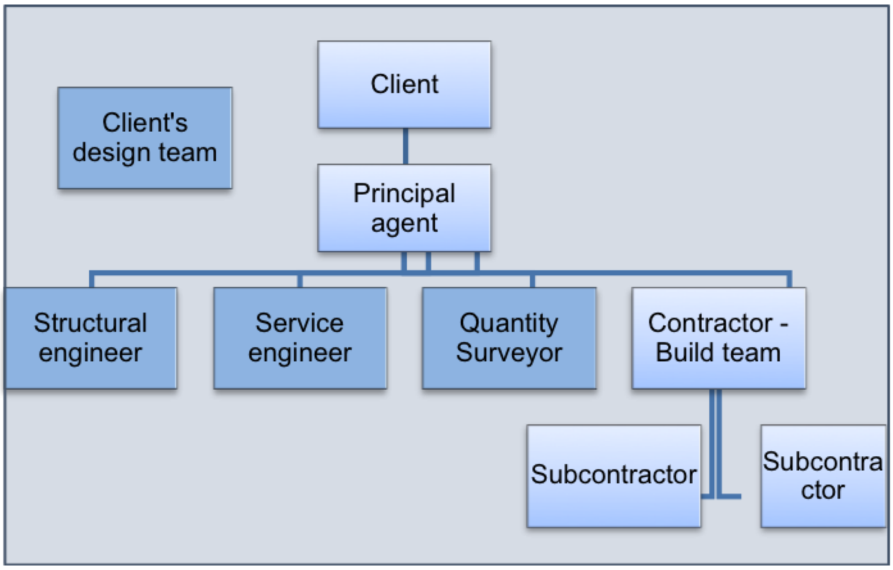

Figure 2: Organizational structure for the Traditional procurement method

(Source: Nagy, Kiss & Hornyak, 2015:12)

5 Discussions

The study argued that the reasons for cost savings which were realized in Distribution Division were primarily due the use of traditional method of procurement as opposed to design and build which seemed to have resulted to higher costs. It was further presented that the traditional method brought about clear separation of design and construction phase and the clarity of roles became a benefit to the project. The Group Capital and Transmission division who applied design and build method handed over more responsibility to the contractor and lost control of scope variations which resulted to higher costs than the planned expenditure. According to Nagy, Kiss and Hornyak (2015), when using the traditional procurement method, the design is completed by an appointed professional team prior the involvement of the building contractor and this brings certainty on the quality of designs.

On the design and build method, Seng and Yusof (2006:1) highlighted that the main characteristic of design and build is its provisioning of a single point of responsibility, fixed time and budget, good communication and risk allocation. Chinyio (2011:4) argued that the use of design and build tend to create unnecessary opportunities of extension and variations of scope by the contractor who is implementing both design and construction since he becomes a player and a referee. It has been seen in this study that there were more variations in the case where design and build method was applied while traditional method brought about a greater sense of control with regard to the changes of scope. All the changes had to undergo the change management procedures which discouraged the contractors to implement opportune changes due to intense approval that are required prior implementation.

6. Conclusion

The study focused on investigating the impact of procurement processes on cost performance. The results indicated that the traditional method saved costs for the distribution division as applied. The cost savings were attributed to clear separation of design and construction phase as there were no continuous design activities during construction. The scope was frozen and there was no flexibility for many variations as a result. The traditional method ensured that both design and construction phases get done by specialists on various aspects and such minimized risk of poor quality. Each of the two phases were given a specific duration and did not have to take place in parallel as opposed to design and construct where design amendments would have continued while construction is going on. The study then recommended that the other two divisions look into the possibility of adopting the traditional method which was used by distribution. The recommendation was considering the importance of consistency within the utility. The cost variances as a result of different procurement methods are represented below:

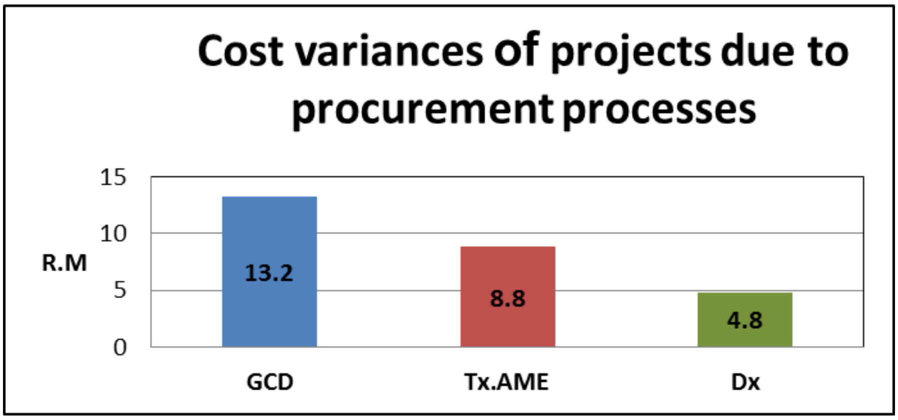

Figure 3: Cost variances of similar scope projects

7. Areas of further research

The study on the influence of procurement methods towards cost performance may require further research into cost performances of infrastructure projects implemented by different organizations applying different procurement methods.

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The Role and Effectiveness of Selected Construction PMO's in Botswana

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Abstract and Keywords

Project management (PM) has been adopted by both public and private organisations in two stages. The first stage, related to the acquisition of the competence by individuals in an organisation. These have used skills in an ad-hoc and disparate manner to solve PM related problems. However, in the past decade, most organizations, including some in Botswana, have moved to a second level, which is a more coordinated and sophisticated in the use of project management, the project management offices (PMO).The use of PMO centralizes the PM competences in one unit which then supports, facilitates or delivers projects in an organisation. Conceptually, PMOs are supposed to provide an efficient and effective platform for supporting the delivery of projects. While the adaptation of PMOs is a novel idea, anecdotal information gathered by the researcher, especially in Botswana, indicate that organizations have not put in place a system for measuring their performance. Though three PMOs have been studied so far, the results have indicated that the studied PMOs are not effective in a number of areas chief among them is the guidance or participation in the strategic selection of projects and assessment of quality of services delivered by projects. Focus discussions held with PMO team members also revealed that the dialogue was the first time that they thought seriously about measuring their performance.

1 Introduction

Project management offices (PMOs) are units with full time personnel that provide and/or support managerial, administrative, training, consulting and technical services for projects in organizations (Kwak and Xiao, 2000). The establishment of PMOs has been on the increase world-wide (PMI, 2017). This is due to their perceived advantages of supporting and/or directly managing projects through shared resources, competences and standardization of methodologies, tools and techniques and harnessing lessons learned. Wells (1999) further noted that establishing and operating a PMO in an organisation can provide benefits which include: standardization and portability of tools and techniques; predictable and repeatable use of project management tools and techniques; facilitation of the use of project management to become a core competency; growing staff professionalism in project management; more productive and skilful project teams; improved image through external recognition for overall organizational performance; profitability improvements. Other scholarly sources (e.g. PMI, 2012; Kwak and Dai, 2000; Kutsch, *et al*., 2015),) add benefits such as: reduction of failed projects; delivery of projects within budget; improvement of productivity; delivery of projects on or ahead of schedule and increase of cost savings.

The proliferation of PMOs has also led to a number of studies that have investigated various aspects pertaining to PMOs. These include factors that lead to the establishment of PMO (Bates, 1998); benefits that accrue from establishing and operating PMOs (e.g. Wells 1999); how PMOs should be positioned in an organisation for effective governance (e.g. Knutson,1998; Dinsmore, 2000;Hobbs and Aubry, 2008; Desouza and Evaristo, 2006); role of PMOs in assisting project teams (Fleming and Koppelman,1998); role, mandate, functions and the scope of services that PMOs perform (e.g. Hobbs and Aubry, 2008; Whitten, 2000; Block and Frame, 1998; and Bates 1998); the level of maturity of PMOs (Hill, 2004); and the key factors that may lead to achieving the long-term vision of PMOs (Block, 1999).

While there has been a strong argument for operating PMOs due to the benefits they provide, some studies have painted a gloomy picture of their value in organisations. Project failures have led scholars to study the success rate of PMOs and even their life expectance (Bolles and Hubbard, 2007). The PM solution (2014) study indicated PMO implementation failure rate was over 50%. In addition, the Standish

Group (2015) observed that only a third of all projects implemented by PMOs were successfully completed on time and on budget. Resulting from these failures Needs (2014) noted that stakeholders do not see much value from PMOs to the extent that 68% of stakeholders surveyed perceived their PMOs to be more bureaucratic than value generators. On life expectancy, Stanleigh (2006) noted that half of the PMOs close within three years, a finding corroborated by PM Solution (2014) which observed that since 2008, one in two PMOs implemented failed. According to Needs (2014), the overriding issue fuelling these perceptions is that in many organizations, there is a wide gap between what the PMOs deliver and what the business expects. The position taken in this article is that it is not perhaps the mere existence of the PMOs that is the problem but it is the way they are operated. Improving this aspect could yield better results that improve perceptions about PMOs. Block and Frame (1998) and Whitten (2000) provided three major reasons for the unfavourable views. First, PMOs are sometimes viewed as simply an expensive and unnecessary overhead for the organisation. Second and related to the first, inability to justify return on investment in a PMO. Third, PMOs are viewed as another added layer of bureaucracy that is bound to slow down business and consume resources.

In line with the global trend various organisations in Botswana, both in the public and private sector embraced the idea of organically growing PMOs or establishing them on the on-set. Despite the movement in this direction the project delivery landscape has not provided satisfactory results. A study by Ssegawa *et al.* (2013) noted that of the projects sampled during their investigation, only 8% met both time and cost requirements. Local reports (e.g. Ramadibu, 2010; Republic of Botswana, 2017) continue to indicate project delivery challenges in form of escalated costs, massive time overruns, poor quality infrastructure and questionable award of tenders, especially in the public sector which incidentally forms over 65% of the total value of tenders of the sector (Ssegawa, 2013).

Based on that background this article reports findings of a preliminary study, whose objectives were to investigate the (i) role that PMOs play and (ii) their level of effectiveness in pursuing that role. The rest of the article is divided into four sections. The next section reviews literature relating to the benefits, typologies and role/functions and services of PMOs. The third section describes the approach used to achieve the research objectives followed by a discussion of the findings of the study. The paper ends with a conclusion.

2 PMOS in Botswana

Like anywhere in the world (e.g. see Unger, Gemunden and Aubry, 2012; Ibbs and Kwak 2000; Whitten 2000; Bolles 2002; and Murphy 1997), in Botswana PMOs are known by different names that include, project office, project implementation unit, project office, project support office and recently project management centre of excellence. Furthermore, PMOs operate at various levels and sizes and hence perform different roles. Some have grown organically while others have been deliberately set up based on the contemporary PMO philosophy. Project management in central government departments and local authorities operate on a platform akin to PMOs. These include, for example, Departments of Engineering and Building Services (DBES), Roads, Water and Sanitation and Technical Services (at Ministry of Local Government); Engineers Corps (in Botswana Defence Force). Similarly all Departments of Architecture and Buildings and Roads in Local Authorities operate on some kind of PMO platform. However, in recent times, the Government has realised the need to formalise these units into PMO, for example, a PMO was established in 2004 in the Ministry of Minerals and Water Resources (X-pert group, 2009) and another tender was floated in 2017 for the Ministry of Transport and Communications (Republic of Botswana, 2017). A number of state owned enterprises (SOE) have established or are in the process of establishing PMOs including, for example, Botswana Power Corporation (BPC) and Botswana Housing Corporation (BHC). Private organisations also run PMO with the most notable Debswana headquarters (at its head office and the two mines of Jwaneng and Orapa). This synopsis briefly indicates the level of operation of PMOs in Botswana and the possible extent of the scope of the final research study of which this preliminary forms part of.

3 Literature Review

Project work has continued to dominate organizations since it was first conceived in the 1950s (Marchewka, 2015). Organizations have increased the use of projects beyond the traditional engineering sector because of the need to respond to customer requirements in a prompt and focused manner (Gray and Larson, 2014). In addition, projects offer a mechanism for ring fence resources and assign a single point of responsibility to foster greater focus, efficiency and accountability. Over the decades, there has been a movement away from focusing on individual project management competence to a centralised project management regime in form of a PMO (Hill, 2004; Lullen and Sylvia 1999). Why? The answer lies in the benefits claimed to accrue from establishing and operating PMOs.

3.1 Benefits of PMOs

PMOs provide a variety of project management services on a wider scale which, if effective, lead to superior and sustained project delivery. Over time this culminates into project management knowledge that facilitates superior performance of an organisation as illustrated in Figure 1. PMOs can perform several functions and services that may include: provision of consulting and mentoring services in proposal development; project planning, monitoring of implementation and reporting of progress and performance; developing and advocating for standards and method to leverage best practices; ensuring that members of the organization speak the same project management language; enhancing individual skills through training and encouraging certification of project management professionals; helping organisations identify and staff its projects with appropriate project management skills; developing a centralised historical archive for all types of project documents; providing project risk assessments; performing post-project evaluation services; and play a high-tech project support role by enabling virtual project offices.

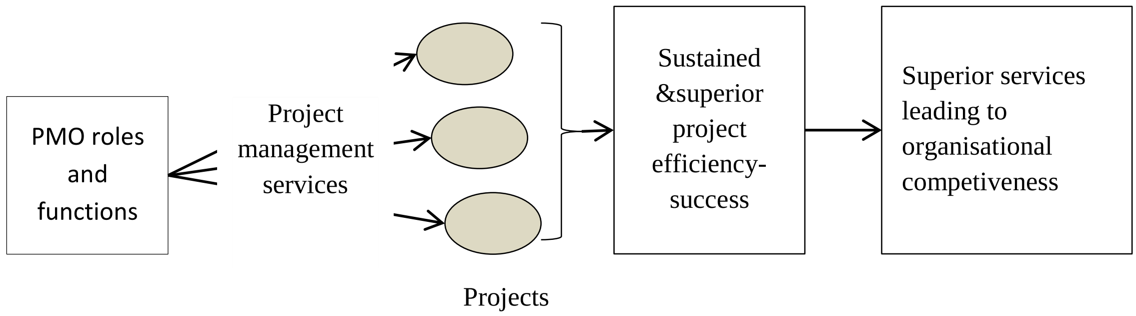

Figure 1: The Benefits of operating PMOs

In addition to the above, Bolles (2002) identifies four key functional elements. First is the a*uthorisation* of inputs to facilitate organisations in aligning its resources with its strategic objectives. PMO therefore, identifies, and prioritises projects and thereby providing means of advancing its levels of project management maturity. Second, the development of *standard* tools, templates and methodologies to be applied to all projects within an organisation. Third is the provision of *education and training* to all concerned with respect to project management within an organisation. This facilitates a cultural change to implement the authority and standard structures. Lastly is the provision of project *readiness* to proceed through the required methodologies and including an evaluative process that harnesses lessons learnt for improvement for future project delivery. Therefore, operating PMO has been viewed as a key approach towards improving overall efficiency and effectiveness in project and service delivery. Based on these premises PMOs have been evolving in size and sophistication, offering organisation a variety of services. The next sections briefly discuss the typologies that describe PMOs with a view to identifying the roles, functions and services they may offer.

3.2 Typologies of PMOs

Typologies classify PMOs with a view of creating an understanding their role and function in organisations. According to Tasic (2014) a typology is a system for classifying entities into groups according to how they are similar. Monteiro, Santos and Varajao (2016) noted typologies are a simplification and a reduction of the complexities of organizational reality but are nevertheless useful and necessary to support both research and practice. Unfortunately, there is no agreement on the exact number of typologies of PMOs. The PMI (2013) survey, for example, identified five PMO typologies while the work of Monteiro *et al*. (2016), yielded twelve. In this article we selected two typologies, because of their practicality in relating to organisational work and are briefly described in the next sections.

3.2.1 Implement-support typology

The simplest typology is one of support-implement projects. A PMO with an implementation role undertakes the direct delivery of projects, for example, it may be involved in the planning, executing and closure processes. A supporting PMO on the other hand will provide training/mentorship of project teams and standardisation of project management processes. Of course, in reality most PMOs are hybrid in nature in that they perform both roles, of supporting and implementing, with a varied degree.

3.2.2 Strategic-tactical-operational typology

Desouza and Evaristo (2006) noted that PMOs may have strategic, tactical and operational (STO) roles. At an operational level, a PMO provides support or implements projects, ensuring professionalism and excellence in applying widely accepted project management principles and practices to each project (Hill, 2004). At a tactical level, a PMO provides the service provided at operation level but adds more value through coordination of multi-project and management of cross-project dependencies. This may include resource integration across projects and ensuring that project management principles and practices are adhered to. At a strategic level, PMO involves all aspects of an operational and tactical PMO. It is further equipped with the authority to prioritize projects in relation to corporate objectives and strategies and advise senior management on the viability of project investments (Desouza and Evaristo, 2006). It may carry out the operational and tactical roles.

The PMI (2013) noted that in reality the STO typology may be fined tuned into four categories. A PMO may be *project-specific* where they provide project-related services to a temporary entity established to support a specific project. Secondly, the PMO can be a unit configured for the organization, division or department, that provides enabling processes to continuously support management of projects work throughout the organization (e.g. as found in organizations in IT, government, manufacturing or programmes). These are the most dominant type of PMOs in most organisations.

The PMI (2013) report further noted that a PMO may evolve into a *centre of excellence PMOs* which provides the organization with methodologies, standards, and tools to enable project managers to deliver projects successfully; ensures organizational success through good practices, tools, and processes. In this way, the CE PMO act as a central point of contact for project management in the organization. Lastly, it may be *enterprise PMO,* the highest-level of PMO which is responsible for aligning projects and programs to corporate strategy; establishing and ensuring appropriate enterprise governance, and performing portfolio management functions to ensure alignment with strategy and benefits (e.g. these could be found in government, manufacturing, and energy organizations).

3.3 Role, functions and services provided by PMOs

The brief discussion above indicates that typologies facilitate identifying what PMOs do in organisation. The authors defined roles as the major areas spanned by PMOs which may be based on the STO typology. It was further observed that in each role PMO perform specific functions which culminate in providing various services, for example, under strategic role, PMO could perform or participate in the strategic planning and portfolio management functions. The list of functions and services of PMO is not exhaustive as it depends on its size and the strategic intent of the organisation (Whitten, 2000; Block and Frame, 1998; and Bates 1998). The authors synthesised literature and identified the various functions and services that a PMO may perform (to avoid duplication they are indicated in Table 3 in Section 5).

4 Methodology

The case study research strategy as well as a multi-method data collection approach (Denscombe, 2007) was used to achieve the research objectives. Before each of them is described, a brief description of the PMO landscape is provided.

4.1 The PMOs case studies

The study being preliminary in nature, three PMOs were studied (it is expected that at the end of the full study eleven PMOs will be studied). The selection was based on convenient sampling i.e. on the basis of the first three PMOs to agree to participate in the study. The profiles of each PMO are given in Table 1(a)-(f). As Table 1 (a) indicates PMO1 is a government department, PMO2 is part of a local authority and PMO3 is part of a state owned enterprise (SOE).

Table 1(b) –(c) indicates that in terms of age, PMO2 is the oldest as it was established 15 years ago but in the 2018/19 financial year it handled a smaller project budget of P350.1 million. On the other hand PMO1 was established 10 years ago but its budget was the largest, at P800.5 million, in the 2018/19 financial year. Table 1 (d) indicates that all the PMOs handled building projects, which were a combination of new developments and maintenance. Table 1 (e) further indicates that in all PMOs majority of staff have short-term project management training while others are qualified project managers. Lastly, Table 1(f) indicates that majority personnel had less than five years of working experience in the PMOs

Table 1(a) – (e): The profile of PMOs which participated in the study

Attributes (background)		PMO_1	PMO_2	PMO_3
a)	Domicile	Department	Local Authority	SOE
b)	Age (years)	10	15	6
c)	Budget (2018/19) –BWP' million	800.5	350.1	600.9
d)	No of projects (2018/19)	11	14	13
	Type	*Building*	*Building*	*Building*
	New	*Y*	*Y*	*Y*
	Maintenance	*Y*	*Y*	*Y*
e)	No of staff with (some had two types of training)			
	PM certification (6 moths to 24 months)	*6*	*4*	*8*
	Short-term training (one week-<6 months)	*21*	*17*	*11*
f)	Staff with experience of 5 years or more			
	Number (total 22)	9	7	6
	Ratio	45%	40%	47%

4.2 Data collection and analysis

In order to obtain an in-depth understanding of the role and effectiveness of construction PMOs in the three selected organization several data collecting methods were used to obtain triangulated findings. The methods included document review, questionnaire, face-to-face interviews and focus discussions. A detailed review of project and related documents used by PMOs was conducted throughout the data collection period to understand and verify the issues relating to the study objectives, for example, a PMO written mandate; PMO correspondences; project process templates, minutes of meetings and various project reports.

A questionnaire, with both closed and open-ended-questions, was administered to a total of 22 personnel who had experience of five years and above from all PMOs (see Table 1 (f)). It was felt that the selected sample had the experience (over five years) to provide deep and useful insights to the issues under investigation. The questionnaire sought to obtain views of the respondents on role and effectiveness of PMOs. It consisted of three sections, with first requesting the profiles of respondents and the projects worked on. The other two sections probed the respondents whether the PMO provided or participated in a particular service and level of effectiveness at which the service was provided, if they provided it using the rubric indicated in Table 2. If a service did not exist respondents would indicate a zero (0). If a service existed, they would rate its effectiveness from ineffective (1) to highly effective (5). During the analysis an average rating was computed (column 2 of Table 2), and described according to rating label (column 3 and 4 of Table 2).

Table 2: Rubrics for measuring the effectiveness of service provided by a PMO

Respondent's Rating	Computed Average Rating	Rating Label	Description of effectiveness
5	4.5-5.0	Highly effective	Service is fully functional with no weaknesses
4	3.5-4.4	Effective	Service is functional with a few weaknesses
3	2.5-3.4	Somehow effective	Service is functional with a number of weaknesses
2	1.5-2.4	Almost ineffective	Service is functional with so many major weaknesses
1	0.5-1.4	Ineffective	Service exists but is almost dysfunctional
0	0.0-0.4	Non-existent	Service does not exist or is not carried out by PMO

As a follow-up to the questionnaire, three interviews were conducted with the respective PMO managers to seek clarity on certain aspects and hence obtain a deeper understanding of the role each PMOs plays in the organisation and their perceived effectiveness. Each interview lasted between thirty to forty minutes. To get an overall understanding and a sort of balanced view of the role played by the PMOs (Morgan and Krueger, 1993), three focus group discussions (FGDs)were conducted, consisting of five members each from each PMO (those who had five years' experience with the PMO). Each FGD lasted fifty to sixty minutes. The interviews and FGD were guided by a protocol (Krueger, 1998) which was constructed from an analysis of the gaps identified from results obtained from the questionnaire.

5 Results and Discussion of Findings

This section discusses the findings obtained from the study starting with the services offered by the PMOs in the three organisations.

5.1 Existence of services offered by PMO

Table 3 summarises results from an investigation of the nature of roles, functions and services performed by the three PMOs. The assessment by the selected respondents was conducted based on the rubric given in Table 2 (in section 3.2). Table 3 shows that PMO3 performs all STO (strategic, tactical and operational) roles identified in literature. However, PMO1 and PMO2 do not perform the strategic role and hence do not carry out the strategic planning and portfolio management functions as scores for the services are all below 0.50 (see shaded areas) e.g. environmental scanning and opportunity analysis is 0.20 and 0.40 for PMO1 and PMO2, respectively. Both PMOs (PMO1 and PMO2) are focused on the tactical and operational roles.

This should be understood in the context of the way government ministries and local authorities are structured as compared to a self-contained state owned enterprise (SOE) which houses PMO3. One of the PMO managers (PMO1) explained the reason behind the discrepancy of roles between PMO1/PMO2 and PMO3 by noting:

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"In government, for example, design and construction of building is sort of divorced from the entire project service as it comes later. The need is identified at either technical or political level. A service to satisfy this need is then conceived. It is the duty of the economic planner, who is not part of a PMO, to translate the conceived idea (service) into a project memorandum (or business case). If it is a health post, it may require, for example, human resource, transport, stock of drugs, equipment, furniture and building space. If the service requires a building element, the economic planner may consult the PMO, for things like estimation of space capacity, cost and construction duration or even location. The construction PMO will only come in later to develop the design and construction aspect of the project service when the entire project has been approved".

The explanation contrasted with that of project manager of PMO3 when she observed that:

"Our PMO participates in almost all processes and activities of the project life-cycle i.e. from initiation, planning, execution and closure of a project -in fact sometime we are requested to provide after-project closure services like measurement of the service level. We are essentially an implementing PMO but we do the work in conjunction with other internal and external stakeholders".

Table 3: Roles, functions and services performed by the selected PMOs

Source: Salameh (2014); Bolles (2002); Millhollan (2009), Salameh (2014); Daptiv (2012).

<table>
<tr><th rowspan="2">Role (STO typology)</th><th rowspan="2">Function</th><th rowspan="2">Services</th><th colspan="4">Perceived level of effectiveness of PMO services (none(0) –excellent (5))</th><th colspan="2">Overall</th></tr>
<tr><th>PMO1</th><th>PMO2</th><th>PMO3</th><th>All PMOs</th><th>All functions</th><th>All roles</th></tr>
<tr><td rowspan="6">Strategic</td><td rowspan="2">Strategic planning</td><td>Environmental scanning and opportunity analysis.</td><td>0.20</td><td>0.40</td><td>1.10</td><td>0.57</td><td rowspan="2">0.62</td><td rowspan="6">1.22</td></tr>
<tr><td>Formulation of strategic business goals</td><td>0.20</td><td>0.50</td><td>1.30</td><td>0.67</td></tr>
<tr><td rowspan="4">Portfolio management</td><td>Development and scoping of portfolios</td><td>0.25</td><td>0.34</td><td>2.20</td><td>1.27</td><td rowspan="4">1.82</td></tr>
<tr><td>Initiation of programmes and projects- Investment analysis(business case development and feasibility analysis)</td><td>0.30</td><td>0.39</td><td>2.10</td><td>1.26</td></tr>
<tr><td>Project prioritization, strategic alignment, risk management and resource management allocation</td><td>0.40</td><td>0.20</td><td>2.10</td><td>1.50</td></tr>
<tr><td>Portfolio reporting, benefits realization tracking and reporting.</td><td>0.20</td><td>0.10</td><td>3.10</td><td>2.70</td></tr>
<tr><td rowspan="13">Tactical</td><td>Project support</td><td>Provision of project management policies, standards, methodologies and processes</td><td>3.80</td><td>3.90</td><td>4.10</td><td>3.93</td><td>3.93</td><td rowspan="13">2.98</td></tr>
<tr><td rowspan="2">Capacity and career management</td><td>Recruitment of project personnel</td><td>3.00</td><td>3.10</td><td>4.20</td><td>3.43</td><td rowspan="2">3.97</td></tr>
<tr><td>Provision of training, skills development and certifications; career paths and development</td><td>4.10</td><td>4.50</td><td>4.90</td><td>4.50</td></tr>
<tr><td rowspan="3">Governance and Performance Management</td><td>Provision of project performance reporting and information dissemination</td><td>4.40</td><td>4.10</td><td>4.50</td><td>4.33</td><td rowspan="3">2.82</td></tr>
<tr><td>PMO performance management</td><td>0.23</td><td>0.34</td><td>1.40</td><td>0.66</td></tr>
<tr><td>Issue escalation and scope change management</td><td>3.10</td><td>3.20</td><td>4.10</td><td>3.47</td></tr>
<tr><td rowspan="2">Change management</td><td>Management of internal stakeholder interests</td><td>4.50</td><td>4.40</td><td>4.50</td><td>4.47</td><td rowspan="2">4.02</td></tr>
<tr><td>Management of external stakeholder interests</td><td>3.20</td><td>3.40</td><td>4.10</td><td>3.57</td></tr>
<tr><td rowspan="2">Knowledge management</td><td>Managing evaluations</td><td>2.30</td><td>2.40</td><td>4.10</td><td>2.93</td><td rowspan="2">2.40</td></tr>
<tr><td>Managing lessons learned</td><td>1.10</td><td>1.40</td><td>3.10</td><td>2.53</td></tr>
<tr><td rowspan="2">Service Management</td><td>Measurement of customer satisfaction</td><td>0.11</td><td>0.12</td><td>1.80</td><td>0.68</td><td rowspan="2">0.74</td></tr>
<tr><td>Measurement of the service level</td><td>0.09</td><td>0.10</td><td>2.20</td><td>0.80</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="3">Operational</td><td rowspan="3">Project delivery management</td><td>Detailed planning</td><td>3.80</td><td>3.60</td><td>4.30</td><td>3.90</td><td rowspan="3">3.80</td><td rowspan="3">3.80</td></tr>
<tr><td>Executing, monitoring and control</td><td>3.50</td><td>3.00</td><td>4.10</td><td>3.53</td></tr>
<tr><td>Closing projects</td><td>3.90</td><td>3.60</td><td>4.40</td><td>3.97</td></tr>
</table>

5.2 Effectiveness of the role and functions performed by PMOs

Judging from the results in Table 3 (last column), all PMOs were more active is pursuing operational and tactical roles. At operational level, they are considered effective since the average score was 3.80 (out of 5). However, PMO3 seems to be more effective than the rest with scores of above 4.0 in project delivery management. This was corroborated with project documents that were provided to the authors for review. As noted earlier (see Table 1(d)) PMO3 undertook 13 projects in the financial year 2018/19, 10 of them were completed within the stipulated time, 8 of them were completed within budget. This contrasted with PMO2 which had many challenges which culminated in many projects missing their delivery deadlines and having escalated costs.

It would appear that all the PMOs are less effective in performing their tactical roles as they had an average score of 2.98. The worst function they performed was that of service management with a score of 0.74. This is understandable from the explanation in Section 5.1 that once PMO1 and PMO2 provide building space they divorce from the project. As example that one PMO manager gave when he noted that "*if it was a project to provide health service in a local authority, then the Department of Health Service which operates the service would be expected to carry out the assessment of the service level and customer satisfaction"*. Despite the overall low effectiveness in performing the tactical role all PMOs were quite effective in carrying out the functions of project support and capacity and career management with overall scores of 3.93 and 3.97, respectively. The results is in line with the PMI (2013) observation that project Support and control are most dominant services of PMOs to be found in most organisations.

Another observation from the results was that all the PMOs were ineffective at measuring their performance having obtained an overall average score of 0.66 (i.e. 0.23, 0.34 and 1.40 for PMO1, PMO2 and PMO3, respectively). Failure for any organisational unit to develop a mechanism for measuring their performance is bad practice. This is because without measurement, one cannot know how successful they are (Osborne and Gaebler, 1992). One of the PMO managers noted that "*we use the iron triangle as a proxy form measuring their performance"*. However, during one of the focus group discussion "*it became clear that the iron triangle measures symptoms of the underlying causes of poor delivery performance"*. Performance measurement should go beyond the iron triangle (project efficiency) and encompass other dimensions such as project success (Caccamese and Bragantini, 2012).

6 Conclusion

The paper sought to assess the roles played by three selected PMOs and their effectiveness. This was as a result of a realisation by the authors that in the last decade most government departments have centralised the delivery of projects, by establishing PMOs, with a view to achieving improved outcomes. On the other hand anecdotal information clearly indicated that project delivery was not improving. Despite the limitations mentioned earlier of studying three PMOs, the study has indicated that they are not very effective in a number of areas. Most notably they do not participate in many of the strategic processes of organisations where projects are conceived and initiated. The PMOs also hardly participate in the post project activities, which for example, would enable them assess the level functionality of the service created by a project. Focus discussions were held with PMO team members also revealed that the dialogue was the first time that they thought about a number of issues, for example, measuring the performance of the PMO. However, there was exuberance in ensuring that in the future they will ensure the services provided by theirs PMOs will be clearly defined, the expected results stipulated including how the level of their achievement will be measured.

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Using Alternative Construction Method to Alleviate the Backlog of School Buildings in the Eastern Cape

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ABSTRACT AND KEYWORDS

Purpose: The inability of the South African government to eradicate the school building backlog has become a major issue as some schools are still using dilapidated facilities. The Department of Education estimated that it would take 17 years and the cost of R52 billion to alleviate the backlog of school infrastructure. This study investigated whether the government can make use of Alternative Construction Methods (ACM) to address the backlog of school buildings in the Eastern Cape.

Research Design: The research instrument used in the survey questionnaire made of both tick box questions, which were personally delivered to 50 stakeholders involved in school building construction in Port Elizabeth, South Africa of which 38 responded. Other sources of data included archival records on school infrastructural delivery.

Research Limitation/Implications: Survey questionnaires were distributed to only Stakeholders in the school building construction in Port Elizabeth and therefore the result may not be applicable to other provinces.

Findings: The findings indicate that Alternative Construction Method (ACM) is more economical than Conventional Construction Method (CCM) in terms of time and cost. However, in terms of quality, it is not guaranteed as compared to the CCM. Thus, the ACM cannot be used to replace CCM but can be used as a supplement to reduce the backlog in school building infrastructure.

Practical Implications: This research has come up with measures that if followed by the South African Government would help to utilise the ACM concept to supplement the CCM to help reduce the backlog of school buildings being experienced currently. The study also provides recommendations to all stakeholders involved in the school infrastructure delivery.

Conference Theme: Infrastructure Design and Delivery challenges

Key Words: Alternative Construction Method (ACM), Backlog, Conventional Construction Method (CCM), Department of Basic Education, School Building Infrastructure

1. INTRODUCTION

Since the existence of South African democracy in 1994, the education system in South Africa has changed from Bantu Education Act 49 of 1953 to the Department of Education (DoE) as per South African constitution section 29 of 1996 which clearly states that “every South African citizen has a right to basic education” (South African Bill of Rights, 1996). According to the Government Gazette for Education and Training of 1995, the South African government mandated to implement education and training policies that will benefit all and sundry. The government must institute policies that will make the way of the vision of making learning and cultural practices accessible to everyone, and also build a fair and equitable system that will provide good quality education to all.

Nxesi (2015) suggests that regardless of the achievements made since 1994 the infrastructure backlog is still a major concern to several rural communities and these backlogs indicate that not all people of South Africa have benefitted from the democratic government. The backlog in the school infrastructure building limits people of South Africa from experiencing improvement of their lives and integrity (Etheridge, 2018). Pefole (2017), the director of school infrastructure at Eastern Cape DoE estimated the backlog of school infrastructure in the Eastern Cape at R52 billion and it needs R6 billion for 17 years to address the issue of the infrastructure backlog. Provincial Education MEC Mandla Makupula reported that 17 schools have no access to water, electricity or sanitation, 13 schools were constructed with mud and zinc, and some of the schools did not even appear on the list of upgraded school infrastructure (Eastern Cape DoE, 2016). Hendrik (2017) conducted a visit to 60 schools of which, 46 schools were found to have a minimum of one unsuitable building structure and mind-bogglingly, 42 schools were found to have no access to clean water. While all schools he visited had some sanitation problems, 5 schools were found to have no working toilets, and only 15 schools had flush toilets.

Pefole (2017) stated that the Accelerated School Infrastructure Delivery Initiative (ASIDI) has earmarked R2.5 billion for the school infrastructure development, but ASIDI encountered problems in the previous financial year which inhibited delivery. Pefole (2017) further stated that the department was grossly underfunded, while service providers used it as a “cash cow”, as a result, the cost of building a school is very high. According to Pefole (2017), the backlog in school infrastructure buildings is as a result of a high cost of school infrastructure. Smith (2010) suggests that Alternative Construction Methods (ACM) provides safer and faster construction process due to factory production and site assembly operations, which also reduces construction site costs for the labour component, reduces waste and environmental pollution. It is important to consider the entire production chain of a product before concluding or suggesting about its efficiency, it would be misleading, therefore, to suggest that ACM is cost-effective and faster than Conventional Construction Method (CCM) based on on-site operations only.

The Association of South African Quantity Surveyors (ASAQS) (2017) opines that alternative methods of construction is normally more expensive than traditional methods and may not be as aesthetically pleasing. The former president of ASAQS Bert van den Heever (2017) suggests that alternative building methods come with a concealed price tag that may have an impact on the quality. The former president of ASAQS in a business conference (2017) further explains that South Africa has experienced some opposition to alternative methods of construction as most of these alternative construction methods have focused on the manufacturing of alternative walling and roofing systems. These phenomena they believe is as a result of the appealing nature of these two elements when looking at a building. However, as Van den Heever (2017) suggests, attempting to save money on walling through the use of alternative building methods is sometimes a futile undertaking as walling cost is normally less than 10% of the total project cost.

According to the National Assembly (2013), Independent Development Trust and the Department of Public Works have completed schools using ACM but Cronin (2013) indicated that it is very important to consider that ACM must be able to create jobs for the people and to develop emerging contractors. Cronin (2013) further suggests that the important task is to alleviate the backlog and that the view of the ACM is a temporal structure that is set to be used for classrooms for black South Africans while white South Africans enjoys the comfort of brick and mortar classrooms, and that ACM will never work in South African school building programmes. This study, therefore, investigated if the innovative ways of construction can be used to address the mistakes of the past within a short duration considering that the traditional ways have a huge backlog which needs R6 billion a year for the next 17 years as suggested by Pefole (2017).

2.1 Changes and challenges of DoE since 1994

According to Chipkin (2012) generally, the supporters of educational restructuring support changes in the schooling system but proposes that these changes should, first of all, occur in the classroom and must reflect on the day-to-day experiences of learners. Thus, leaving the schools on their own, deprived of the backing of other interested parties will be a futile exercise in the restructuring process. Chipkin (2012) further suggests that altering the schooling system must do primarily with realigning relationships at the stakeholder levels, but within the South African context, it has been contended that restructuring the schooling system antecedents on an education system that was traumatised by years of apartheid rule, where relationships between communities and schools, parents and teachers, pupils and principals, principals, and officials have been polarized (McLennan, 1997).

According to Hamann and Tuinder (2012), the DoE was tasked to address the instructive imbalances of the politically-sanctioned racial segregation government, however, this task could not be achieved completely without correcting the school infrastructure building issue, hence the introduction of uniform norms and standards. According to the Bill of Rights 29(1)(a) and (b) (1996), all citizens have a right to basic education and to further education and this enforces the government to make sure that education is accessible equally to all people of South Africa. According to the Eastern Cape DoE annual report in 2005, there were over 572 mud structures which were unsafe for schools in the Eastern Cape province only and it is estimated that more than 14 000 schools and 661 386 learners had inappropriate classrooms and 271 638 learners had no access to ablution facilities.

According to norms and standard, the department targeted to build 14 000 classrooms, 57 000 ablution facilities at a cost of R5.5 billion. The building of these classrooms and ablution facilities and other support space such as resource centres, computer labs and science labs were estimated to cost R15.87 billion between 2005 and 2014. This estimate included repairs and renovations to structures that required to be upgraded to the levels set out by the norms and standards (EC DoE Annual Report 2005). According to Damba-Hendrik (2016), there were challenges in the introduction of saving measures to overcome the overdraft which indicated that meeting targets will be impossible, late 2004 there was a need for national intervention to address the backlog in school infrastructure building in the Eastern Cape. As indicated by Damba-Hendrik (2016), the overspending on personnel ate into the funds for infrastructure development as the infrastructure funds were used to pay salaries.

According to the report of the Auditor General on the DoE (2011), the infrastructure planning staff should be mandated to the tasks of planning, monitoring, and communication. The Department of Public Works (DPW) is the main implementing agent for all state-owned properties and the planning and building of school infrastructure projects. To implement these tasks, the DPW appoints implementing agents such as Independent Development Trust (IDT), COEGA Development Corporation and Imvula Trust. But the Department of Education is still responsible for planning and monitoring of the implementing agents.

The Eastern Cape DoE planning process includes the district works inspectors who are mandated to visit the schools in need of infrastructure and report back to the head office to make planning commitments and it still works inspector's responsibility to report back to the schools on the progress of building their schools. However, there was still a shortage of works inspectors in the province and those who were employed had limited capacity and knowledge to execute their mandate (EC DoE Portfolio committee 2004).

Damba-Hendrik (2016) indicated that the shortage of works inspectors in the districts affected the ability of the Eastern Cape DoE to monitor and communicate the progress on sites, the schools were not aware of the Department's infrastructure plans and school principals were not aware of contractors who should be on-site and that made it impossible for the school principals to inform the DoE when contractors were not on site. Sidimba (2016) suggests that the saving mechanisms have affected the progress in appointing in house construction professional with the ability to plan and implement the works needed on the schools and that led to some school building projects being on hold. Sidimba (2016) therefore opines that funds for recruiting and keeping these construction professionals within the department must be budgeted for and that would help the Eastern Cape DoE to achieve its infrastructure plans and reflecting realistic timeframes for delivery.

2.2 Accelerated school infrastructure delivery initiatives (ASIDI)

ASIDI is the School Infrastructure Backlog Grant which was set up to eradicate inappropriate schools, provision of basic water, sanitation and electricity to the schools. DBE Annual Report (2011) indicates that the DBE started procurement of implementing agents for the ASIDI Programme in February 2011 but Finance Ministry directed that the Development Bank of South Africa (DBSA) should be used as the Implementing Agent for infrastructure development. And the memorandum of agreement was finalised on the 6th July 2011 between DBE and DBSA. Table 1 indicates targets for ASIDI Programme since its inception in 2011 and completed projects in terms on School Building Projects, Water Projects, Sanitation Projects and Electrical Installation Projects up until the 2017/2018 Financial year.

Table 1: Department of the basic Education progress report on the school infrastructure delivery

Infrastructure			**Years**						**Total**
		2011 - 2012	2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2016	2016 - 2017	2017 - 2018	
School buildings	Target	49	51	41	40	118	64	120	**483**
	Completed		49	4	53	51	16	32	**205**
Water projects	Target	321	500			192	132		**1145**
	Completed		226	6	149	224	10	70	**685**
Sanitation projects	Target	262	453				224		**939**
	Completed			226	169	21	9	61	**486**
Electrical Installation	Target	152	692				88		**932**
	Completed			150	142	14	0	66	**372**

Source: DBE Annual Report (2017)

On all four basic infrastructure needs on schools, the ASIDI Programme did not meet its targets as only 42% of School building projects, 59% of Water projects 52% of Sanitation Project only 52% and 40% Electrical installation projects were achieved. According to Fengu (2016), the challenges that faced the ASIDI Programme range from contractors exceeding contract periods to over budgets, due to the project manager's inability to manage the projects properly. Fengu (2016) also claims that there are no recovery plans requested by the project managers which should be a corrective measure that could be used to remedy delays on construction sites. Fengu (2016) again claims that the School Building projects are awarded to tenderers using an incorrect tendering point system which is not in line with the preferential procurement policy framework.

Ndleleni (2016) posits that DBE underspent Education Infrastructure Grant (EIG) and that led to a reduction of funds allocated to the grant by the National Treasury Department and this was as a result of poor administration and lack of focussed project implementation by the DBE. According to Dwane (2017), the National Treasury reported that in the 2016/17 first quarter DBE spent 19% of the R 929 million projection on the EIG. The noteworthy concern is that the National Treasury has attributed the drowsy spending of ASIDI to poor execution by implementing agents. Dwane (2017) further suggests that there must be a method set up to hold each one of those who are not doing their work accountable and necessary disciplinary measures taken against them.

2.3 Alternative construction methods

Haselau (2013) suggests ACM as an alternative way of construction must be cost-effective, short duration and of good quality. The ADM can be in different forms as indicated in Figure 1. De Lange (2008) suggests a Moladi Housing Technology where plastic prefabricated panels are used as formwork, light concrete is poured in-between the panels to make a wall and plastic formwork are stripped after 15 hours. De Lange (2008) further claims that the conventional method (brick and mortar) is 50% more expensive than this method. The Speedwall Building Technology, on the other hand, is where prefabricated panels are assembled on the site to form walls and openings for doors and windows prefabricated. The panels are spray plastered with a mixture of concrete sand to form a complete wall. This technology does not require deep foundations, is 12 times faster to erect compared to brick and mortar, cheaper and low maintenance cost (Speedwall Building System, 2018)

There is also a building constructed using Hydraform Interlocking Blocks System. According to Hydroform (2018), this system makes use of a mixture of soil and cement compressed mechanically to form the building blocks that are joined together when building a wall. This system has limited mortar which reduces the cost of the wall, this system is estimated to be 30% cheaper than the conventional method (Hydroform, 2018). The Light Steel Frame can also be sued as an alternative building method.

According to UFCC (2018) in this method, prefabricated structured steel panels are finished with fibre cement cladding and light concrete fill in between the cladding and plastered finish.

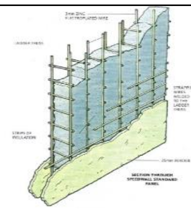
Moladi Housing Technology	Speedwall Building Technology	Hydraform Interlocking Blocks System	Light Steel Frame
			
Source: Moladi Building Website (2018)	Source: Speedwall Building Website (2018)	Hydraform Website (2018)	Source: UFCC (2018)

Figure 1: Types of ACM technologies

According to UFCC (2018), Reuben Ntuli Secondary School located in Eastern Cape was constructed using light steel framing and fibre cement cladding. Haselau (2013) concludes that ACM should be used where cost time and quality is to be considered but due to the variety of available ACMs, it is difficult to choose which method to use considering that they all have advantages and disadvantages.

2.4 Advantages and disadvantages of ACM

According to Barnard (2017), ACM is faster than conventional construction, low water uses on-site considering the current state of the water crisis in South Africa and that the cost transportation and time used to assemble making it more economical when building with this method. ACM is also believed to provide an added advantage to the environment and economically since they can be reused and lightweight buildings, for example, can be easily modified and renovated (Barnard, 2017). South African Frame homes (2018) further supports Barnard (2017) view regarding the advantages of ACM as most of them are non-combustible and do not shrink in reaction to humidity and has the highest strength-to-weight ratio of any building material. South African Frame homes (2018) detail that the use of bolts in light steel frames resist wind better than nails, the site is more likely to be clean compared to conventional construction thus improves health and safety on the site and reduces construction duration. In support of the view Barnard, Kulkarni (2017) concludes that the use of Light Steel Frame construction needs to be considered in the construction industry and also the universities should consider including modules with alternative construction innovations because it is environmentally friendly.

Lyons (2009) on the other hand gives a bad side of ACM for example, steel frames as being less energy-efficient and that makes it conducive to heat and that can have a negative effect on walls and insulation agents that are reactive to high temperatures. Considering that ACM is a new method of contraction, there are few contractors who can be able to build using ACMs (Lyons, 2009). Hartdegen (2018) also concludes that ACM is appealing for building improvements, in any event, it would have been thought so given the backlog in school infrastructure building and the way that it will take a decent number of years to finish them, the questions is why there are no tenders that are regular for these ACMs? Hartdegen (2018) answers that question by highlighting that there is no standard expert information for preparation of Bills of Quantities (BoQ) for ACM compared to CCM where there are many bricklayers who can work in one site, similarly as there are a number of plasterers, tilers, painters who can complete a sensible activity, especially in the event that they are entirely managed.

2.5 Alternative construction in school buildings

The ACM in School Building was discussed in detail in the National Assembly Committee on School Building Programme with DPW and IDT in 2013. According to the National Assembly Committee minutes (2013), the DPW proposed less professional consultant's fees by enhancing operational productivity, guarantee the utilization of standard plans and give a provisional bill of quantities. Makupula (2013) indicates that the analysis done after the utilization of ACMs and CCM on construction cost and cost per square meter for the two methods showed savings in that of ACM. Makupula (2013) opines that the average cost per school using ACM was around R9.2 million and R692 514 for each classroom whilst that of CCM was around R14.5 million and R1.08 million for each classroom.

Cronin (2013) in his attempt to find out about the impact of the use of ACMs on employment opportunities and improving the emerging contractors revealed that the life expectancy of schools constructed with ACMs was just around 30 years as against a life expectancy of 100 to 200 years for CCM schools. Wakaba (2013) characterizes ACMs to be the utilization of materials for the building which were not conventional and also ACMs are Agrément SA-certified and are penalized frameworks. Wakaba (2013) therefore indicates that the utilization of ACMs should be based on their design and energy efficiency advantages. The advantages emerging from the utilization of ACMs and in addition the confinements of ACMs were likewise clarified by Wakaba, (2013) which include:

- Life cycle cost of the ACMs had not been verified under local conditions;
- The design of schools must consider the type of ACMs;
- The once-off use of ACMs in an area restricts the advantages of aptitudes exchange and the chance of use of procured skills; and
- More support work is still needed to advance social acknowledgment although it was certain that ACM can be used for the school building.

According to the minutes of the National Assembly Committee on School Building Programme with DPW and IDT in 2013 some members of the committee were happy with the ACM concept, but were concerned that ACM will take away job opportunities for Grade 1 emerging contractors and that ACM will only benefit big companies and contractors from Gauteng province only and recommended that ACM can be used on a few schools. Cronin (2013) indicates that it is cheerful to observe the Committee pushing for rising emerging contractors as it was the need for the government to guarantee the improvement of the developing contractors, but that was not the principal need on the point of the day, the main need was to address the backlog in school infrastructure building. Cronin (2013) therefore indicates that priority must be given to the crisis in rural schools more especially in the Eastern Cape.

Odhiambo (2013) suggests that the focus must be on the maintenance plan and the necessity of the ACM building. Agrement SA was part of the team that did assessment and testing for the durability of ACM as part of the evaluation process (Odhiambo, 2013). The concern that the products had not been tested locally, should, therefore, be erased as the products had been tested in a laboratory. It could, however, be argued that testing them in a laboratory was testing them in a controlled environment, but many of these products had been tested overseas for several years (Odhiambo, 2013). Odhiambo (2013) further proposes that in terms of maintenance, the process should start from the construction, during the construction, the contractor together with the school governing body and the project steering committee must identify people to work with the construction team who will be left behind to be maintenance managers.

3. RESEARCH METHODOLOGY

Rahman (2012) suggests that both qualitative and quantitative are used to confirm research findings by combining different perceptions that will represent the status quo of the research question. In this study, a quantitative research approach was adopted. Ryzin (2011) concludes that in quantitative research, the collection of data includes instruments that produce quantitative measurements such as arithmetic data which represents the opinion of the participant. Castro (2010) suggests that this approach uses arithmetic data that can be interpreted to practical information, unlike Qualitative approach, lager sampling is used for this approach.

Castro (2010) also indicate that Quantitative data collection approach is structured and includes surveys, interviews, and observation. Castro (2010) further suggests that this approach has advantages such as an inclusive explanation of experience and deep structured analysis is possible considering that it captures data that cannot be analysed by measurement scale. Kothari (2004) suggests that research instruments are tools that can be used to gather data for research. Barbour (2008) indicate that these tools can be referred to as reading published information, interviews, questionnaires, and general observations. The data collection instrument used were survey questionnaires for the empirical study and published readings for the literature review. The data collected through structured questionnaires were used to gain opinions and views of the participants that are involved in School Building Programmes and Construction Industry. Questionnaires were the same for all participants. The survey questionnaires were randomly distributed to 50 construction industry professionals made up quantity surveyors, engineers, project managers and contractors of which 38 of them responded.

Kothari (2004) suggests that the collection of data by questionnaires is the most commonly used method in most of the academic survey because it is less costly, and the participants answer freely without the influence of the researcher, participants have enough time to think about their answers to the questions on the questionnaire. Kothari (2004) states the disadvantage of this method as having high non-responsive rate and the propensity of giving answers that are unclear depending on the structure of the questionnaire. The collected data analysis was analysed using excel analytical tools to group responses according to their similarities and magnitude. Data was then presented using table and graphs. The features of the respondents are as follows;

3.1 Respondents educational background

Out of 38 respondents, 71.05% of respondents have a Degree, 18.42% of the respondents have National Diploma whilst 7.89% of them have Honour's Degree and 2.63% have Matric certificate.

3.2 Nature of the respondent's occupation

Figure 4.4 shows the occupation of the respondents. From figure 4.4 out of 38 respondents, 57.89% respondents are quantity surveyors followed by 13.16% respondents are engineers whilst 10.53% project managers and contractors and only 7.89% are project managers.

3.3 Working Experience of respondents

Regard the working experience, out of 38 respondents, 55.26% of the respondents have 11 to 20 years of working experience, 23.68% of the respondents have 6 to 10 years of working experience, 15.79% have more than 21 years of working experience whilst those between 1 to 5 years working experience are 5.26%.

3.4 Respondents experience in the school building

Out of 38 respondents, 50% of the respondents have 11 to 20 years of experience in school building projects, 34% of them have 6 to 10 years of experience in school building projects, 11% of them have 1 to 5 years of experience in school building projects and 5% of them have above 21 years of experience in school building projects.

3.5 Knowledge level about Alternative Construction (ACM) concept.

Sixty-one percent (61%) of the respondents responded they have work with ACM, 18% of the respondents have basic knowledge, 11% of them indicated that they have expert knowledge on ACM, 11% of them responded that they know about ACM and 0% respond they do not know about ACM. This indicates that all the respondents contacted have some level of knowledge about ACM.

4. FINDINGS AND DISCUSSIONS

4.1 Duration of the project planning stage of school building projects

The in order to know the views of the respondents on how long it takes to complete the planning stage of the school building projects, respondents were asked to rate the duration of the school project planning phase. The result is shown in Figure 2. Fifty-three percent (53%) of the respondents are of the view that the time frame used for the planning phase of the school building project is fair, 34% of the respondents, however, has a contrary view and suggested that it takes too much time to plan for the school project. Eleven percent (11%) on the hand indicated that it takes less time to complete the planning phase of the school project whilst 3% did not respond.

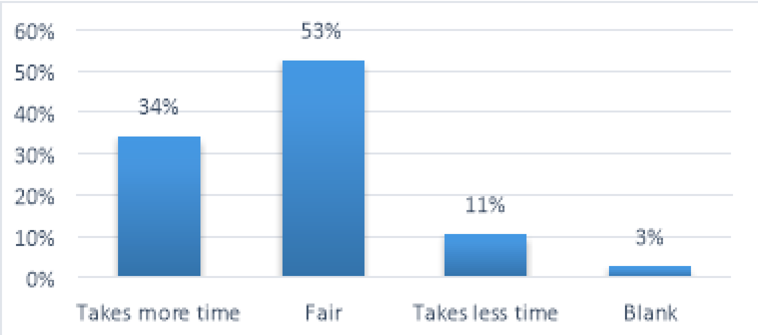


Figure 2: Duration of the project planning stage of school building projects

4.2 Duration of the construction stage of school building projects

Once again respondents were asked to express their views on how long it takes to complete the construction stage of the school building projects, respondents were asked to rate the duration of school project planning phase. This question was asked because the construction duration of school building projects can have an impact on the backlog of school projects.

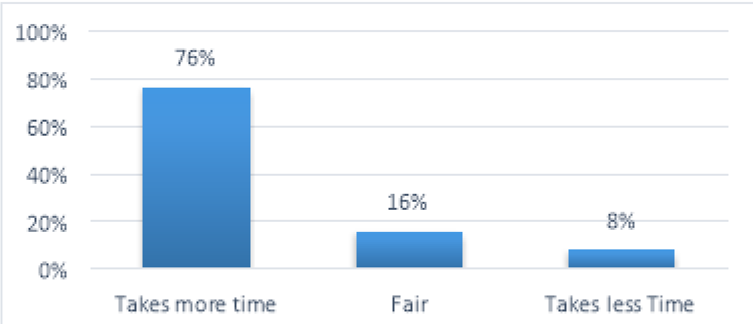


Figure 3: Duration of the construction stage of school building projects

Seventy-six percent (76%) of the respondents are of the view that it takes too long to complete the construction phase of the school building projects, 16% of the respondents, however, suggested that the duration for the construction phase is fair whilst 8% indicated that it takes less time to complete the construction phase of the school projects. The result is shown in Figure 3.

4.3 Causes of the backlog in the school building

This question was asked in order to know views of the respondents regarding the culprit responsible for the school infrastructure backlog. Out of 38 respondents, 57% respondents blamed the Department of Basic Education (DBE) being responsible for the backlog, 29% of the respondents rather put the responsibility on the implementing agents whilst 9% indicated that DBE and implementing agents are responsible. DBE and contractors were blamed by 3% of the respondents. The other 2% of the respondents did not respond. Figure 4 shows the respondent's reasons for the backlog in the school building.

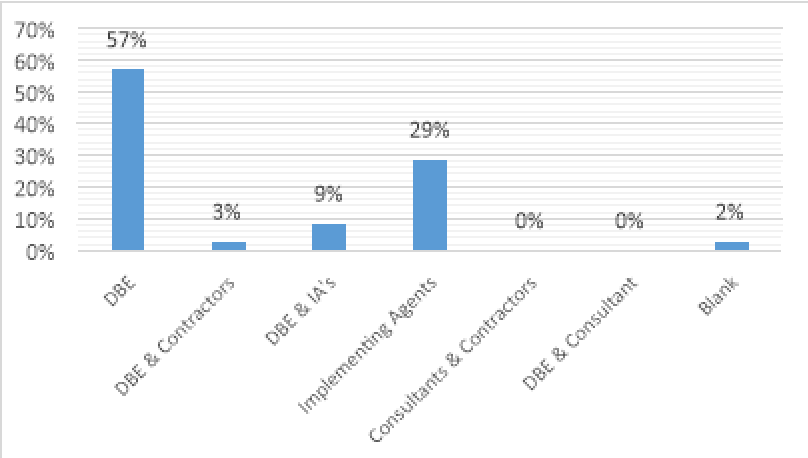


Figure 4: Causes of the backlog in the school building

It is therefore clear from the findings that, the majority of the respondents are of the view that the education infrastructure implementers are themselves causing the backlog of school buildings. This finding is very strange as both DBE and the implementing agents are tasked to ensure school infrastructures are initiated, implemented and finished on time.

4.4 Replacing Conventional Construction with Alternative Construction Method

Another objective of the study was to find out whether CCM can be replaced by ACM in providing school building infrastructure, ACM is perceived to be faster and cost-effective. Respondents were therefore asked to express their opinion on whether ACM cab is used to replace CCM in school building infrastructure development. The result is shown in Figure 5.

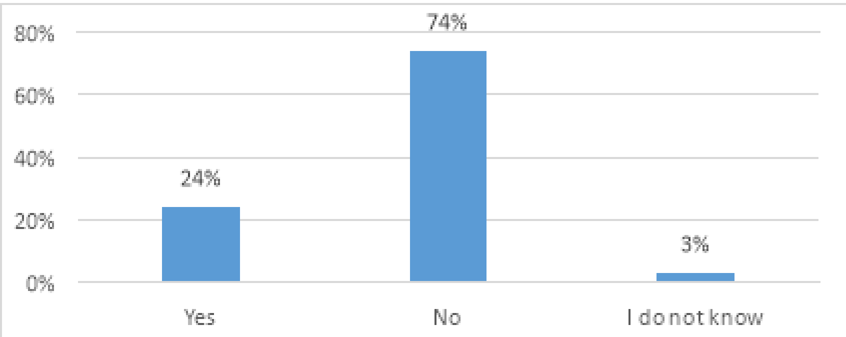


Figure 5: Replacing Conventional Construction with Alternative Construction Method

The result indicates that the majority of the respondents (74%) do not believe that ACM can be used to replace CCM in providing school buildings, 24% of the respondents on the other are of the view that ACM can be used to replace CCM whilst 3% of the respondents indicated no opinion as to whether ACM can replace CCM or not. The result indicates that even though ACM is faster and cost-effective, construction stakeholders still see CCM as the best construction method when it comes to school buildings perhaps as a result of their durability and maintenance friendliness.

4.5 ACM's ability to help alleviate the backlog in School Building in the Eastern Cape

In a follow-up question to the question in section 4.4, respondents were asked to rate their view on whether ACM can help alleviate the backlog in the school building in the Eastern Cape. In response to this question, 74% of the respondents indicated that they fully agreed that ACM can help alleviate the backlog in the school building in the Eastern Cape whilst 26% of the respondents disagreed that ACM can help alleviate the backlog in the school building in the Eastern Cape. The result is shown in Figure 6.

This result also indicates that although the majority (74%) of the respondents do not believe that ACM can be used to replace CCM for school building projects, they believe that ACM can be used as an appendage to ease the school building backlog.

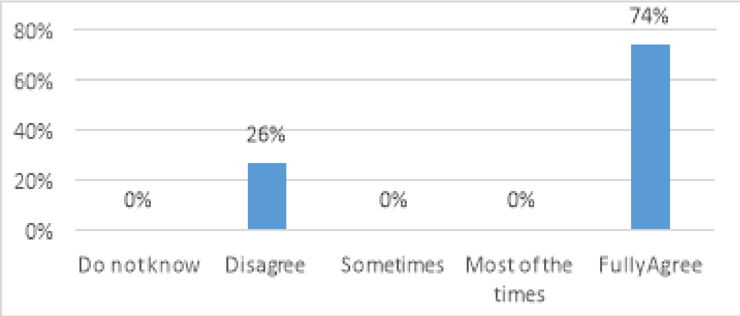


Figure 6: ACM helping to alleviate the backlog in School Building in the Eastern Cape

5. CONCLUSIONS AND RECOMMENDATIONS

There is indeed a backlog in school building infrastructure in the Eastern Cape. The study has revealed that DBE is the culprit in causing the backlog due to the longer time they take to plan and construct these projects. The planning and construction durations given by the DBE and Implementing Agents are the reasons why the currently used construction methods are not reducing the backlog. ACMs are believed to be faster and cheaper than CCMs, however, ACMs cannot be used to replace the CCM in alleviating the school buildings, but can only be used as a back up to reduce the school infrastructure building in the Eastern Cape.

It, therefore, recommended that DBE and implementing agents should re-examine the project time duration from the inception to completion in order to fast-track project implementation to help alleviate the school infrastructure backlog currently being experienced in the Eastern Cape. DBE, DoE and other school infrastructure implementing agents can make use of ACM as a temporary measure to alleviate the school infrastructure backlogs whilst instituting plans to make use of CCM to resolve the backlog problem permanently. Project consultants need to consider training their staff on the design requirements of all ACM Concepts that are available and recommend them to the government when designing school buildings.

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Analysis of risks factors in informal construction sector in Tanzania

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ABSTRACT
Purpose and objective
Operations in informal construction sector are exposed to a risky environment, thus the need for identification of risks to minimize the negative consequence of threats. Risk identification has been highly recognized in order to reduce the likelihood of risk events occurring to enable the decision maker moving towards a risk- neutral decision making point. This study aims at identifying risks in informal construction sector in Tanzania.

Design and research limitation
The study involved construction workers in informal sector in Dar es Salaam and Mwanza in Tanzania. Dar es Salaam and Mwanza are among big cities in Tanzania having more informal construction workers. Workers were purposively selected. Out of 1,000 questionnaires distributed 849 questionnaires were fairly filled equating to 84.9%, while non-participatory observation was employed for qualitative data. The collected data was cleaned, coded, entered into IBM SPSS version 20 and analysed using descriptive statistics mainly frequencies and descriptive. This was followed by calculation of Relative Frequency Index (RFI).

Findings
The study established that; lack of safety gears, difficulties in finding new job, delayed payment, lack of welfare facilities and poor financial base were the top five risk factors in the informal construction sector.

Practical implications
This study provides insights on risk factors and implies that although workers on formal construction sector face similar risks, the informal construction workers are more vulnerable to risks due to the nature of their settings.

Original or value of the paper
This paper offers insightful risk factors that impede informal construction sector in successful operation of projects activities in Tanzania. The identified risk factors are great impediments for implementing projects and that when identified and handled could minimize the occurrence and effect in the construction industry. The study is relevant and lies within the sustainable construction and environment as well the construction industry transformation and development.

Key words; Risk factors, informal construction sector, risk management and Tanzania.

1. INTRODUCTION

Risk management processes generally include three core processes, namely risk identification, risk estimation and risk response planning and execution. Analysis of steps outlined by various authors reveals their congruence with different levels of detailing. The complexity of risk management depends to a major extent on factors such as the size of the organization, the workplace situations within the organization, and the nature, complexity, and significance of the risks to which the organization is exposed (Klemetti, 2006). However, it has been argued that, it is critical that risks be assessed at every stage of construction activities and that the input of key stakeholders and project participants is sought (Carter and Chinyio, 2010). It should be noted that, risks affect operations of the construction industry in both its formal and informal settings. These risks are in the categories of natural, economic, technical, health and safety, and socio-demographic risks. These were identified in a number of risk management related studies (Finnerty, 1996; Mills, 2001; Miller & Lessard, 2001; Baloi and Price, 2012). In the event of risk manifestation, identification as a process has to be done or adopted in order to minimise or eliminate the consequences of risk regardless of its setting.

Different methods and strategies have been used in different stages of risk management process. Risk identification is the first stage of risk management whereby identification is aimed at determining potential risks associated with any given assignment/ activity to be performed by an individual or organization (Klemetti 2006). Methods such as brainstorming, expert opinion, structured interviews, questionnaires, checklists, historical data, previous experience, testing and modelling and evaluation of other projects have been used in hazard identification (AbouRizk , 2003; Smith *et al*, 2006; Cater and Chinyio, 2010). Risk analysis is based on how many people are exposed to each hazard and for how long. Thus, the probability and severity of harm that can be caused by a hazard is considered. The process of risk analysis relies on an individual's collective judgment in assessing the magnitude of the risks considered, which often uses risk identification terms of low, medium or high risk (Smith *et al,* 2006; Phoya et al., 2018). Likewise matrix of both qualitative and quantitative has been used to compare risk levels for different events and to set priorities for taking action. The greater the magnitude of risk, the greater the efforts that should be made to control it and the greater the urgency to control the risk and take action (AbouRizk, 2003; Smith *et al*, 2006; Cater and Chinyio, 2010).

Taking into consideration that the informal construction is growing and there is strong relationship between formal and informal construction sector (Phoya et al., 2018) informal construction should be given special attention due to the nature of its settings. Methods for Identification of risk have been traditionally guided by standards documents and guidelines such as frameworks and other formal systems or documents. It is clear however that if identification of the risks is to encompass of both formal and informal setting then the existing standards and guidelines are inadequate, since they are mainly targeted to formal setting. While there is substantial number of studies on risk management in construction sector, these studies focus on formal construction with little attention being given to informal construction sector. As results little is known about the types of risks faced by individuals and enterprises in the informal construction sector. This study therefore aims to identify risk factors in informal construction sector.

Even though there are extensive risk management in construction sector (Ahadzie *et al.,* 2008; Famakin *et al.,* 2012; Tabish and Jha, 2011; Zwikael, 2009), Cohen and Palmer, 2004; Cullen, 2008; Elyse, 2007; Finnerty, 1996; Klemetti, 2006; Malekela, 2008; Miller and Lessard, 2001, Mills, 2001; Tang, *et al*, 2007; Kikwasi, 2012; Chileshe and Kikwasi, 2014; Sospeter and Kikwasi, 2015), there is a paucity of empirical studies that identify risks and its magnitude in developing countries. In Tanzanian context, few studies have been done (Malekela, 2008, Kikwasi, 2012, Chileshe and Kikwasi, 2014, Mikapagaro, 2015; Phoya et al, 2018). Moreover, the majority of the studies focused on formal construction sectors with little attention given to informal construction sector. Likewise, policy attention appears to be constrained by lack of knowledge on risk identification and its magnitude in the informal construction sector. Even some authors (Phoya et al, 2018) have suggested for further study on methods for selection of risk response strategy and risk identification is necessary. Therefore, there is a growing need for specific studies on risk identification in the informal construction sector especially within Sub Saharan Africa (SSA) including Tanzania. The results of this study are intended to make theoretical and practical (in terms of policy) contribution.

2. LITERATURE REVIEW

2.1 Types and nature of risks in construction activities

Nature of the risk in construction activities can be perceived in two ways. Firstly, the nature of the risks based on their sources, types and classifications. In this case various types of risks are identified and classified into various categories depending on their sources. Cohen and Palmer (2004) identify sources of construction risks to include changes in project scope and requirements; design errors and omissions; inadequately defined roles and responsibilities; insufficient skilled staff; force majeure; and new technology. Baloi & Price (2012) categorizes construction risks as technical, social, construction, economic, legal, financial, natural, commercial, logistics, and political. Similarly, Mills (2001) lists three most important risks to include: weather, productivity of labour and plant and quality of material. Other researchers such as Finnerty (1996) and Miller and Lessard (2001) have categorized same risks in addition to demand, supply, regulatory, operational, completion and sovereign. All risks categorized and other resulting from stated sources need to be well known to the project team so that they can be properly managed to enable smooth achievement of project objectives. Secondly, the nature of the risks is based on the risk gravity. In this case, risks are identified and analyzed based on the likelihood of occurrence and magnitude of the impact (Mikapagaro, 2015). The nature of risks can also be perceived in the context where the event occurs, be it in formal or informal construction sector. For example in the informal sector, building owner enters informal arrangement with a skilled labourer who organizes other labourers. Sometimes the labourers may disappear without completing a project or may build without adhering to specifications. This is regarded as risk.

2.2 Informal construction sector

Informal construction sector lies on the concept of informal economy. Informal economy is the diversified set of economic activities, enterprises, and *workers* that are *not* regulated or *protected* by the state (ILO, 2013). It consists of economic activities that occur outside of formal institutional boundaries but which remain within informal institutional boundaries for large segments of society (Ishfaq *et al.,* 2017). The concept of informal sector or informal economy first came into use in a study of urban labor markets in Ghana which was conducted by International Labour Organization (ILO) in early 1970s. The term was used as a way of describing the dualistic economic structure of developing countries that involved both main-stream formal economy and an un-official economy. During that period, the informal economy was viewed as marginal, weak and stagnant concept and the expectation was for it to disappear in developing countries once such countries achieved sufficient levels of economic or industrial growth.

On the contrary, the informal sector has continued to persist and be robust in some countries to date Tanzania included. In a nutshell, informal sector is seen like a temporary phenomenon but it is still growing, contributing to economy also is an apprenticeship to emerging entrepreneurs. It is estimated that 30% of output and 70% of workers in developing countries are to some degree operating in informal economy (ILO, 2013). The informal economy is estimated to account for 42% of Gross Domestic Product (GDP) in sub-Saharan Africa (SSA), and specifically 34% of the national economy in Tanzania (Economic and Social Research Foundation (ESRF, 2011). According to the International Labour Organization (ILO) (2013), the informal economy comprises half to three quarters of all non-agricultural employment in developing countries. Although informal sector is always viewed as a hindrance to development by denying government direct tax revenue, emerging entrepreneurs use it as a test bed for their enterprises and therefore an important platform for new enterprise creation for developed and developing countries. In view of this, the informal economy has remained a useful concept to activists, policymakers and researchers since a large share of employment and income is outside the regulated formal economy (Chen, 2007).

2.3 Contribution of the informal construction sector to the economy

The informal construction sector plays a great role in the development of the construction industry and the economy with regard to employment creation, income generation, poverty alleviation and supply of houses in both formal and informal urban areas (URT, 2003). Consequently, it supplies building materials and labour to the formal sector through sub-contracting arrangements. On the other hand, the formal sector depends on the output of the informal construction sector. For example, they use building materials and sublet contract to labours from informal sector. This dependency contributes to the promotion of the informal construction sector. As a result, the informal construction sector has a growing necessity in the context of the overall national economic policies and with regard to the effective performance of the construction industry.

ILO report of 2002 define the informal construction sector as workers who are employed on a casual or temporary basis without any proper form of contract, as well as those who work for themselves (entrepreneurs) either alone or in small groups in construction related activities. The terms and condition of employment are not regulated in any way and hence the workers have no protection against dismissal and no social protection against sickness, old age or incapacity to work. Basing on this research, informal construction workers refers to a small, unregistered enterprise and individual, unprotected workers operating within building construction sector, which includes building materials but excludes civil engineering.

In most developing countries, especially in Africa, it has been noted that the informal construction sector has been growing rapidly. The pace has been fast, especially during depressed economic times when building owners often start with simple structures to provide basic shelter and then improve the structure as time and finance permits. For example, in Tanzania the total contribution of construction industry has increased from 0.8% in 2000 to 9% in 2011. Its contribution to GDP rose from 5% to 8% during the same period (ILO, 2013). While employment in road works and mining construction activities is largely formal, it is informal in the housing sector, save for large corporate construction projects. Residential construction activities are regularly done informally, and substantial sub-contracting of informal contractors occurs in formally contracted projects.

2.3 Risk assessment methods

Methods for identifying and analyzing risks have been broadly studied. For example, risk analysis techniques and methods of identifying risks are similar and are categorized as qualitative and quantitative. However, there are some varying opinions on this categorization as shown in Table 1. Furthermore, some of the techniques used in risk identification are also used in risk analysis. Techniques which are used in identification of risks and categorized as qualitative as well as quantitative include: expert judgment, FMECA (failure mode and effect criticality analysis), HRA (human reliability assessment), interviews, risk probability and impact assessment, risk ranking/risk index. Similarly, techniques which are for both identification and analysis of the response include: Brainstorming, CCA (cause consequence analysis), change analysis, checklist, expert judgment, FMECA, interviews, HRA and SWOT (strengths, weaknesses, opportunities and threats).

Table 1: Qualitative and quantitative risk analysis techniques.

S/N	Author	Qualitative	Quantitative
1	De Marco & Thaheem (2014)	Brainstorming, checklist, hazard review, change analysis and HRA, interviews, CCA, PHA (preliminary hazard analysis)	Decision tree, expected monetary value, expert judgment, FMECA, fuzzy logic, SWOT, ABC analysis, risk ranking/risk index
2	PMI (2013 & Chinenye et al., 2015)	Risk probability and impact assessment, probability and impact matrix, risk data quality assessment, risk categorization, risk urgency assessment and expert judgment	Interviewing, probability distributions, sensitivity analysis, expected monetary value analysis and expert judgment
3	APM, 2008 & (Cagliano et al., 2015)	Checklist, interviews and brainstorming	Sensitivity analysis, probabilistic analysis, influence diagram, decision tree, Monte Carlo Simulation, Breakeven Analysis, Scenario Analysis

In Table 1, the work of (Chinenye *et al*., 2015) has similar quantitative techniques to o APM (Association for Project Management, 2008) and qualitative techniques to PMI (Project Management Institute, 2013). A study by Cagliano *et al* (2015) identifies 31 project risk management techniques but for the purpose of this study only techniques for selection of risk response and categorized as qualitative or quantitative are included in the in Table 1. Other techniques for risk response classified by Cagliano et al (2015) are: FMEA (failure mode and effects analysis), HAZOP (hazard and operability), SWIFT analysis and what-if analysis. The selection of risk management response strategy must take into account the source of risk, and, size and complexity of the project. Baloi & Price (2012) analyzed probability theory, certainty factors, Dempster-Shaffer theory of evidence and fuzzy logic techniques and concludes that the nature of risks under consideration is determinant in the selection of modeling and analysis techniques. Webb et al. (2014) and De Marco & Thaheem (2014) argue that complex projects require more sophisticated risk analysis techniques and simpler and routine projects may benefit from relatively simpler analysis techniques, such as qualitative techniques.

3. METHODOLOGY

The research focused on the informal construction workers in the two urban centers in Tanzania namely Dar es Salaam and Mwanza. The focus was on urban areas due to the fact that the construction industry can ideally be better modeled in urban than in rural areas given that the scale and intensity of these activities is more in cities and towns than in rural areas. The two cities were selected as the study area because they are the top two urbanized regions in Tanzania (NBS, 2014). In these two regions the focus was informal workers which are involved in construction activities such as masonry, ceiling board fixing, carpentry, electrical installation, painting, architects, brick making, iron welding for door and window grills, plumbing, and floors finishing, material producers and suppliers. The study adopted mixed method whereby both quantitative and qualitative methods were used. According to Creswell and Clark (2007) and Creswell (2013) the researcher may adopt a combination of the qualitative and quantitative research methods in a single research design. They argue that qualitative approach may be used in conducting face-to–face interview or by observation with individuals from a target population and then test the tentative conclusion in a larger population through a survey research strategy. In a nutshell, mixed method involved collecting both numerical and textual information, either simultaneously or sequentially, so as to best understand research problems, with the final database representing both quantitative and qualitative information. To identify risk factors in informal construction sector, it required both text and numerical data. Survey method was employed for quantitative while non-participatory observation was employed for qualitative data.

The population of the study was difficult to determine, as a result it was agreed by authors that the sample size was 1,000 informal construction workers comprising of 700 and 300 from Dar es Salaam and Mwanza respectively. Due to the fact that informal sector is not regulated, selection of workers was done using both purposive and snow ball sampling. Questionnaires were prepared in English, translated Kiswahili to enable workers to understand and respond well to the questions. After translation, questionnaires were pre-tested to five informal construction workers in Dar es Salaam and recommended modifications were done to accommodate construction site language. Questionnaires were administered by researchers and research assistants on informal construction workers. Out of 1,000 questionnaires sent out, 900 were returned with 849 fairly filled questionnaires equivalent to 84.9%. A total of 31 risk factors in construction were extracted from literature. Respondents were asked to indicate the likelihood of occurrence of risks using 5-Likert scale i.e. 5=very frequent, 4=frequent, 3-average, 2-ralely and 1= none.

Data were coded, cleaned entered into IBM SPSS version 20, analysed using descriptive statistics. Descriptive statistics features used for analyzing data are frequencies and discriptives. Further analysis was done by calculating Relative Frequency Index (RFI). The Relative Frequency Index (RFI) is calculated as follows:

RFI = ΣW/AxN Where; W = weight given to each factor by respondents A = highest weight N = total number of respondents. The ranking method used in this research had been used in similar in several studies with some necessary changes (Sospeter & Kikwasi, 2015). Table 2 presents the nature of risk in informal construction from workers.

4. RESULTS

4.1 Nature of Risks in informal construction sites.

Table 2 presents assessment of risk factors in the informal construction sector. The results indicate that, lack of safety gears in informal construction was highest ranked with Relative Agreement Index equals to (72.8%) and mean value 3.64). Difficulties in finding new job was ranked as the 2nd risk factor with relative index of 72.2% and mean value of 3.61. Late payment and lack of health and lack of welfare facilities were ranked 3rd with relative index equal to 68.6% and mean value of 3.43. Poor financial base/low capital was ranked in 4th position with relative index of 66.8% and the mean value of 3.34. The 5th risk factor were low payments and manual handling with relative of 64.8% and mean of 3.24. The risk factors which were ranked least include Poor/non-performance, Weather and climate condition (heavy rain) or too sunny, Natural hazards (floods and fire), Poorly defined roles and responsibilities and Age. These factors had relative index below 45% and mean value below hypothesized mea (2.5) indicating that they are low impact.

Table 2: Nature of risk factors in informal construction; workers' perception

Risk category	Type of risk	N	Mean	RII (%)	Rank
Natural	1. Natural hazards (floods and fire)	788	1.98	39.6	24
	2. Weather and climate condition(heavy rain) or Sunny	788	1.98	39.6	24
Economics Factors	3. Low pay (wages/salary)	748	3.24	64.8	5
	4. Poor financial base/low capital	766	3.34	66.8	4
	5. Financial failure/ bankruptcy	742	2.99	59.8	8
	6. Non-payment	792	3.12	62.4	6
	7. Delayed payment	790	3.43	68.6	3
	8. Lack of enforceable contracts/poor contractual relation	736	2.92	58.4	9
	9. Price fluctuation (materials)	639	2.69	53.8	15
Health and safety Factors	10. Lack of safety gears	789	3.64	72.8	1
	11. Poor housekeeping	785	3.10	62.0	7
	12. Manual handling	748	3.24	64.8	5
	13. Lack of health and welfare facilities	790	3.43	68.6	3
	14. Theft/vandalism/ damage of materials, tools and equipment	756	2.71	54.2	13
	15. Poor security	758	2.74	54.8	11
Technical Factors	16. Inaccurate estimation of budget	717	2.71	54.2	12
	17. Inaccurate estimation of materials	709	2.62	52.4	16
	18. Poor workmanship	713	2.08	41.6	22
	19. Poor/non-performance	717	2.08	41.6	23
	20. Poor definition of project scope and requirements in terms of cost, time and quality	660	2.57	51.4	17
	21. Lack of /poor designs	639	2.69	53.8	14
	22. Poor analysis of site conditions	586	2.44	48.8	22
	23. Poorly defined roles and responsibilities	591	1.93	38.6	25
	24. Poor technology (tools and equipments)	717	2.67	53.4	15
Social-demographic factors	25. Shortage/unavailability of materials on site	749	2.56	51.2	18
	26. Shortage/unavailability of labour	748	2.23	44.6	21
	27. Shortage/unavailability of equipments	745	2.55	51.0	19
	28. Shortage/unavailability of power	723	2.76	55.2	10
	29. Family life	698	2.31	46.2	20
	30. Age	702	1.79	35.8	26
	31. Difficulties in New market/finding job	746	3.61	72.2	2

The Top Five risk factors in Informal Construction

Table 3 shows the top seven risk factors ranked up to 5th position and related groups from the total risk in informal construction. The results show that three of them are related to the health and safety risk, three also from economics/financial risk and one from social risk.

Table 3: Top five ranked risk factors in informal construction

	Risk factor	Risk category	Mean	RII(%)	Rank
1	Lack of safety gears	Health and safety risk	3.64	72.8	1
2	Difficulties in new market/finding job	Social risk	3.61	72.2	2
3	Lack of health and welfare facilities	Health and safety risk	3.43	68.6	3
4	Delayed payment	Economic risk	3.43	68.6	4
5	Poor financial base/low capital	Economic risk	3.34	66.8	5
6	Low pay (wages/salary)	Economic/financial risk	3.24	64.8	6
7	Manual handling	Health and safety risk	3.24	64.8	7

Findings from Observation

Figures 1 and 2 indicate some of the workers in informal construction working in hazardous situation. Through observation to some of the informal construction it was revealed that construction workers were working in hazardous situation without any protective safety gears. Manual handling was high and there were no any welfare facilities. The finding from observation corroborates the findings from survey as the health and safety risk factors are high in informal construction.

Figure 1 & 2: workers in informal construction working in hazardous situation.

5. DISCUSSION OF FINDINGS

The study reveals that workers in informal construction are exposed to harmful work practices without any safety protective equipment, compensation or insurance in case of accidents. They also have to bear responsibility themselves to nurse the aftermaths of the accidents. A more serious concern is the risk of injury that construction workers face, which can deprive them of a source of income if they sustain an injury. There is high repetitive working movement, carrying heavy load manually, awkward posture due to poor working tools and facilities for lifting and transportation. This finding is similar to the work of Sospeter & Kikwasi (2016) which found that workers in informal construction are challenging with health and safety issues. This study further reveals that there are no guidelines which guide how health and safety issues will be handles in informal construction sectors. The facts that health and safety is traditionally guided by standards documents and guidelines, it is clear that in the informal construction there are no formal contracts or guidelines which could be referred in case any adverse circumstances occur on construction sites. Likewise, legislating health and safety standards for the informal workplace has little relevance because most workers in this sector are either self-employed or work within small bands, with little additional resources to meet legislative demands. Policy frameworks, instead, need to focus on raising awareness, providing technical expertise in hazard control, providing resources to control hazards and providing medical expertise for medical surveillance, disease diagnosis and management. The state needs to direct public sector resources to address these strategies.

The study reveals that search for a market for their services and products as a high ranked risk factor with high Relative frequency). As social economic risk factor culminates other factors such as financial matter, job security poverty and even health and safety provision. The finding is similar with the work of Jason and Well (2010) they found that the biggest challenge facing informal workers in Tanzania was penetrating the market and search for customers. This finding collaborate the clients' view that it was also challenges for them to get the right "artisan" This imply that there is no platform where workers and clients meets in informal construction sector. This is contrary to the formal construction where all contractors are registered with classification and it is easier to get contractors from Contractors' Registration Board. In the informal sector, there is no place or organization where you can find clients or artisan. However, the study reveals that employment of most of the informal construction workers was based on social networks. Social networks play an important role in sustaining workers employed within the informal urban economy. The networks are a form of social capital to most of the informal workers since it assures employment opportunities (Thaheem, 2014). To address the foresaid challenge there is a need to create platform where clients and informal workers can meet. This could be through social networking among informal construction workers and clients as well. The idea of forming an umbrella association comprising the various groups of informal construction workers can enrich the social network and addressing all the issue related to employment and health and safety risk factors

Delay, non-payments and low payments are risk factors in informal construction sector. The study reveals that employment nature of the workers in informal construction was largely based on the relationship between the worker and the owner of the site or the foreman in charge of the site. Most of the workers had verbal agreements with the owners, that leaves the workers/foremen exposed to risks of depravation of legal redress in case of disagreement over terms of engagement, payment or injury at work. The lack of employment contract also indicates that workers are denied benefits that they can enjoy under labour legislation, for example, insurance or health cover. The finding collaborates with the research by Jason (2008), and Cagliano et al (2015) which found that work is "insecure, unsafe and unprotected". The lack of employment contracts means that workers are outside any labour legislation that can provide them with employment protection. Employment regulations or guidelines are important for addressing the challenges related to delay, low and nonpayment of the workers in informal construction sector.

This is study reveal that lack of capital or poor financial base as one of the high risk in informal construction sector. Poor financial base limit informal workers to expand and sustain their working environment. The finding is consistence with the study done by Famakin *et a*l. (2012). They found that informal construction workers were facing the challenge on access to finance and lack of access to finance constrain many workers operating informally. These workers face a further barrier such that their records are informal, and hence they cannot access formal banks for capital to finance their operations. Other factors that hamper effective contribution of the informal construction sector in the country-wide survey are: lack of adequate skills, lack of capital, prohibitive regulations, and insecure operating environment. The need for provision of loan with low interest rate in informal workers can improve the challenge of access to finance.

6. CONCLUSION AND RECOMMENDATIONS

Workers in informal construction sector face similar risks as those in the formal sector. However, workers in informal sector are more vulnerable in number of risk as risks in informal sector are aggravated by the nature of their settings. The informal sector is not regulated as a result its working environment is not well defined and this has culminated workers to be vulnerable to many risk factors. The analysis of 31 risk factors considered in a survey indicates that the most critical factors are: accident due to lack safety gears, not getting job at required time, low salaries, lack of welfare facilities, delay/non-payments, financial constrain/low capital and manual handling. To address the challenges, policy frameworks, instead, need to focus on raising awareness, providing technical expertise in hazard control, providing resources to control hazards and providing medical expertise for medical surveillance, disease diagnosis and management. The government needs to direct sector resources to address these critical risk factors.

Limitation and contribution of the study

This research has limited its scope to informal construction sector in Tanzania with a specific focus on identification of risk factors in projects hence the results are influenced by the project size, nature of activities, owner of the project, policy of the country. However, it is authors belief that developing countries of similar economic, socio-cultural and business set up could benefit as well as the risk factors are among variables that when identified and handled could contribute to the construction industry comparative advantage of which risk management belongs.

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Barriers of Sustainable Construction Practices in Nigeria

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ABSTRACT AND KEYWORDS

Purpose of this paper
In a bid to achieve sustainable construction through the adoption of sustainable construction practices in the Nigerian construction industry, this study assessed the barriers to the sustainable construction practices in Nigeria.

Design/methodology/approach
The study adopted a quantitative survey design with a questionnaire used to solicit information from construction managers, project managers and quantity surveyors within the 6 regions in Nigeria. Data analysis was done using percentage, and factor analysis. Cronbach's alpha test was also used to determine the reliability of the questionnaire used while Shapiro-Wilk normality test was used to determine the normality of the data gathered.

Findings
The study revealed that the major barriers to sustainable construction practices in the country are sustainability knowledge related, regulation and policy related, sustainable materials and technology related, and information and management related.

Value
This study contributes to the body of knowledge on sustainable construction in Nigeria where construction projects are still experiencing challenges of poor sustainable construction. The findings will help understand the critical barriers to avoid in the quest to attain sustainable construction.

Keywords – Construction, Factor Analysis, Nigeria, Sustainable construction, Sustainability,

1. INTRODUCTION

The Nigerian Construction Industry (NCI) has proven over time to be a major contributor to the country's socio-economic development through infrastructure delivery. Oke *et al.* (2018) described the industry as a motivator of Nigeria's economy. According to Saka and Lowe (2010) construction to the country's economic growth and development as it contributes significantly to the nations GDP and at the same time creates considerable employment. Despite this importance of the industry, it has been observed that it is impacting negatively on the environment. This is because the industry relies on natural resources within the environment for it to produce its products. Since most of these resources are non-renewable, significant harm is being done on the environment as land degradation, high energy consumption and pollution are becoming evident in most countries around the world (Baloi, 2003; Du Plessis, 2002). Based on this fact, the call for more sustainable construction (SC) practices has become obvious. This SC practice involves delivering construction projects in a more economic, social and environmentally responsive manner (Abidin, 2010; Akbiyikli *et al.*, 2009). This call has become important if the future generations ability to meet their needs using available natural resources is to be achieved (Brundtland Report, 1987).

To achieve SC, construction professionals must strive to deliver construction that encourages the preservation of the natural environment, promotes the social well-being of the occupants and provides reasonable economic stands for the investors (Aghimien and Awodele, 2018). Similarly, Miyatake (1996) has earlier suggested that for a sustainable built environment to be achieved, cyclic processes must be adopted. The use and reuse of materials, as well as the decrease in energy consumption and other natural resources, must be adopted. Based on this knowing, studies within developing countries have placed focus on perception, awareness and ways of improving adoption of SC (Al-Sanad, 2015; Abolore, 2012; Oke *et al*., 2019) challenges of adopting SC (Aigbavboa *et al.*, 2017; Ametepey *et al.*, 2015; Djokoto *et al.*, 2014) assessment of renewable energy, energy efficiency, and green buildings (Ahmed and Gidado, 2008; Isa *et al*., 2013), and materials and management tools in delivering SC (Oke *et al.*, 2015). Although few studies on the challenges facing SC in Nigeria abound (Aghimien *et al.,* 2018; Alabi, 2012; Davies and Davies, 2017), most focused on the specific type of projects or a specific state/region of the country. There is still a paucity of information on the key barriers facing SC practices in the Nigerian Construction Industry (NCI) as a whole. It is based on this knowledge that this study assessed the barriers of SC practices in Nigeria with a view towards preferring solutions needed to overcome these issues and attain SC in the country.

2. LITERATURE REVIEW

One notable issue affecting SC delivery in developing countries is the absence of historical data and exemplary projects on which construction professionals can build and learn from. Because of the low level of adoption of SC in most developing countries as observed from previous literature (Aigbavboa *et al.,* 2017; Aghimien *et al.*, 2018; Alabi 2012; Al-Sanad, 2015; Baron and Donath, 2016) getting historical data on SC projects. Ametepey *et al.*, (2015) observed that in Ghana this issue is severely hindering the attainment of SC. This can affect the level of knowledge and understanding of the concept of sustainability among construction participants in these developing countries. Opoku and Ahmed (2015) have earlier stated that public awareness and proper knowledge and understanding of sustainability are key to the successful promotion of SC practices. However, studies have shown that sustainability awareness and knowledge related factors as some of the major factors affecting SC in Kuwait, Ethiopia and Vietnam (Al-Sanad, 2015; Baron and Donath, 2016; Nguyen *et al.*, 2017). Thus, a poor understanding of the concept of SC in its holistic form can be a major barrier towards achieving SC.

Resistance to changes is also a crucial issue affecting SC within the construction industry. In most cases, the cultural background within an environment plays a significant role in the adoption of new ideas such as SC. Since the construction industry has operated in a style for a long period of time, adopting changes may prove difficult most especially when results are being achieved with the old style (Ametepey *et al.,* 2015; Djokoto *et al.*, 2014). This has affected the adoption of SC practices in developing countries like Ghana (Ametepey *et al.,* 2015), in Nigeria (Davies and Davies, 2017) and Palestine (Osaily, 2010). Therefore, Aghimien *et al.* (2018) submitted that if SC is to be achieved in most developing countries, the construction industry needs to jettison the traditional method of construction for a more innovative SC method.

Mousa (2015) noted that the construction industry is client-driven in nature and this adversely affects SC as most clients with insufficient knowledge prematurely eliminate any sustainable alternative that is not commonly used. Ogunkah and Yang (2013) also noted that in most cases the activities of the construction industry are determined by the client, and this may affect SC when clients fail to demand the use of SC materials for their projects. Similarly, SC cannot be achieved without top management support as their decision is crucial to the adoption or non-adoption of SC practices (Abisuga and Oyekanmi, 2014; Ametepey *et al.*, 2015). In terms of availability of SC materials, Shi *et al.* (2013) noted that SC materials are essential to the attainment of SC. However, their use has been hampered by the uncertainty of their performance. This tends to affect their availability within the local market, making it difficult to source SC material locally.

As a result of lack of readily available SC material within the local market and lack of understanding of the concept of SC, there is the likelihood of the misconception that SC practices and material may lead to high investment cost. Although some studies have claimed that the initial cost of implementing SC is high (Darko and Lowe, 2016), incorporating life-cycle costing during the assessment of the various costs and their implications will to a large extent show the beneficial attribute of SC on the long-term (Shi *et al*., 2013). Miranda and Marulanda (2001) submitted that one of the major challenges of SC in Peru is the idea that it will increase the cost of the project. A similar observation was made by Isa *et al.* (2013) in Malaysia and Zhang *et al.* (2011) in China. In agreement Ametepey *et al.* (2015) and Häkkinen and Belloni (2011) pointed out that there is a fear of higher investment costs for SC as compared to traditional building. Other factors such as perceived low status of SC materials (Hwang and Tan, 2012), absence of building codes and regulations hindering the adoption of SC (Hakkinen and Belloni, 2011), absence of government support (Aghimien *et al.*, 2018; Al-Sanad, 2015; Ametepey *et al.,* 2015; Osaily, 2010) are evident in the body of literature.

3. RESEARCH METHODOLOGY

This study set out to assess the barriers of SC practices in Nigeria through a survey approach with questionnaire used in harnessing quantitative data from construction managers, project managers and quantity surveyors in the country. These set of construction professionals were selected due to their role in the estimation and use of construction materials, as well as the management of construction projects. These professionals were gathered from the 6 regions in the country. Since the study cut across the entire country, an electronic questionnaire was adopted for easy sending and collection of feedback from respondents. Due to the difficulty in getting the contact details of some these professionals, snowball sampling was adopted. Atkinson and Flint (2001) have earlier stated that the snowball approach can be very helpful when there is a need to increase the sample size, as in the case of this current study. Following the approach adopted, the exact number of distributions cannot be determined, thus making the calculation of a total response rate impossible. However, a total of 70 professionals participated in the study.

The choice of a questionnaire survey was premised on the fact that the study hoped to solicit a response from respondents across the country as against the popular approach of picking a state or region to represent the entire country. The questionnaire survey is a simple survey approach which can cover a wider range of audience within a short period of time (Tan, 2011) hence its adoption in this study. Two sections were used in the questionnaire to harness information from the respondents. The first section gathered information on the background of the respondents, while the second harnessed information on the barriers SC practices in the country. The closed-ended questionnaire design was adopted, and respondents were asked to rate 20 identified barriers based on their level of severity using a 5-point Likert scale, with 5 being very severe, 4 severe, 3 moderate, 2 less severe and not severe.

In analysing the data gathered, the reliability of the research instrument was first determined using Cronbach alpha test with an alpha value of 0.948 derived for all assessed barriers. This shows that the instrument is highly reliable as the alpha value is closer to 1. The normality of the data gathered was also assessed using Shapiro-Wilk test. Ghasemi and Zahediasi (2012) suggested that Shapiro-Wilk normality test is most suitable for assessing the normality of data gathered from a sample size of less than 2000 as in the case of this study. Thus, using Shapiro-Wilk test the result revealed that the significant value of all the 20 assessed barriers is 0.000 which is less than the 0.05 required criteria for normality. This implies that the data gathered is non-parametric in nature, hence only non-parametric analysis can be conducted. Following many barriers identified from literature, there is the likelihood of some barriers leading to similar underlying effects. Based on this understanding Factor Analysis (FA) was conducted to reduce the large group of barriers into a smaller number of underlying grouped factors A similar approach was adopted by Kissi *et al.* (2018) in analysing the drivers militating against SC pricing in Ghana

4. FINDINGS AND DISCUSSIONS

4.1 Background Information

The result on the background information of respondents revealed that more Quantity Surveyors participated in the study (46%), this is followed by Construction managers and Project managers with 30% and 24% respectively. The result also shows that more response was gotten from respondents in the South-West and the North-Central regions of the country with 48.6% and 24.3% responses respectively. The South-South, North-West, South-East and North-East had a response rate of 11.4%, 10%, 4.3% and 1.4% respectively. Majority of the respondent (64.3%) work with for private organisation, with only 35.7% working with the government. The average years of working experience of the respondents are calculated as 8.6 years, while the highest academic qualification of the respondents is a master’s degree (47.1%). This is followed by a bachelor’s degree and postgraduate diploma with 31.4% and 11.4% respectively. The least academic qualifications are a higher national diploma, ordinary national diploma and PhD with 5.7%, 2.9% and 1.4% respectively.

4.2 Barriers to Sustainable Construction

In conducting FA, the suitability of the data was first determined by examining the sample size. According to Preacher and MacCullum (2002) and Zhao (2008) if the communalities for the assessed variables are high (≥ 0.6), and the expected factors to be extracted is small, less emphasis should be placed on the sample size. The result from the communalities generated revealed that all the assessed barriers had a communality of above 0.6 aside from the method of selecting SC materials which gave a communality of 0.529. Also, the number of variables being analysed was considered in determine FA suitable for the study. Between 20 to 50 variables are believed to be most suitable for FA to be conducted (Hair *et al.*, 1998). Following the communalities generated and the 20 variables assessed, it can be said the data gathered was suitable for FA. The factorability of the data gathered was also tested using Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity. A KMO value of 0.880 and a significant level of 0.000 for the Bartletts test was derived as seen in Table 1. Hair *et al.* (1998) and Stern (2010) has earlier suggested that KMO value should be greater than 0.7 if the sample size is adequate. Also, Pallant (2005) suggested that Bartlett's test of sphericity should be significant at $p < 0.05$ for FA to be considered appropriate. The result of the KMO and Bartletts test reveals that the data gathered is factorable using FA.

Table 1: KMO and Bartlett's Test for the barriers of SC

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.880
Bartlett's Test of Sphericity	Approx. Chi-Square	982.369
	df	190
	Sig.	0.000

Having satisfied the requirements for FA to be used, FA was conducted using principal component analysis (PCA) through varimax rotation. Result in Table 1 shows that 4 components were extracted with an eigenvalue greater than 1 using the factor loading of 0.50 as the cut-off point. The percentage for each of the components extracted includes component 1 with 50.5%, component 2 with 8.1%, component 3 with 5.5%, and component 4 with 5.2%. Thus, the final statistics of the PCA and the components extracted accounted for approximately 69.4% of the total cumulative variance. This fulfils the criterion of factors explaining at least 50% of the variation as stated by Stern (2010). Furthermore, Pallant (2005) suggested an evaluation of the scree plot when considering the specific components to retain. In analysing the scree plot, a change (or elbow) in the shape of the plot is identified and only components above this point are retained. Figure 1 shows that a change from the fourth component, hence, confirming that the four components are suitable for extraction. The 4 extracted components and the variables loading on them are shown in Table 2.

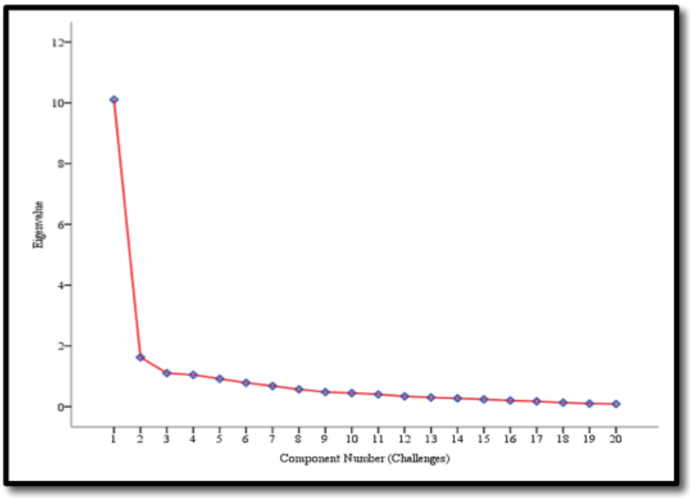

Figure 1: Scree Plot Result

4.3 Discussion of Extracted Factors

A. Sustainability Knowledge Related Factors

The first principal component with an eigenvalue greater than 1 has a very high factor loading of 50.5% which is well above the factor loading for the other three principal components put together. This implies that this component accounts for the most issue facing the SC practices in the country. The variables loading on this component are, clients fear high investment cost, inadequate knowledge and understanding of SC, low demand for sustainable products, construction industry's to resistance to change, method of selecting SC materials, lack of expert opinions on SC, and clients preference. Looking at the nature of these variables, this component was subsequently named "sustainability knowledge related factors".

Previous studies have shown that the concept of sustainability is still vague to most construction experts and stakeholders in developing countries (William and Dair, 2012). This has led to the resistance from construction participants, the fear of an increase in cost on the part of the clients which invariably affect their demand for the use of SC materials on their projects. This finding is in tandem with the submissions of Al-Sanad (2015), Baron and Donath (2016), and Nguyen *et al.* (2017) who noted that sustainability awareness and knowledge related factors are key hindrances to the attainment of sustainable construction in developing countries around the world. If this is to change, there is the need for more public awareness and proper enlightening of construction stakeholders as to the concept and inherent benefits of SC as observed by Opoku and Ahmed (2015) and Pitt *et al*., (2009).

B. Regulation and Policy related factors

The second principal components with an eigenvalue greater than 1 account for 8.1% of the total extracted factors with variables such as inadequate sustainable measurement tools, inadequate building codes and regulations on sustainability, inadequate government policies/support, and client worries in profitability loading on it. Considering the latent characteristics of these variables, this component was subsequently named "regulation and policy related factors". There is no gainsaying that without adequate sustainability measuring tool, SC projects will be almost unlikely as there will be no benchmark to use in determining sustainable projects. In the same vein, having building codes and regulations to promotes sustainable construction, as well as government supporting SC through creating and enforcing SC policies, is very important. The finding of this study further corroborates the submission of Hakkinen and Belloni (2011) that building codes and regulations hindering the adoption of SC. It is also in tandem with Al-Sanad (2015), Ametepey *et al.* (2015) and Osaily (2010) submission that government support is an important factor affecting SC Kuwait, Ghana, and Palestine.

C. Sustainable materials and Technology related factors

The third extracted component accounts for 5.5% of the total extracted factors with variables such as the perception that sustainable construction materials being of low status, the unreliability of suppliers, inadequate technology and technological process, and limited availability of sustainable materials. Considering the pronouncement of material and technology within these variables, this component was named "sustainable materials and technology related factors". The importance of SC materials in the delivery of SC projects has been reiterated in previous studies (Kissi *et al*., 2018; Shi *et al.*, 2013). The perception of SC materials being of low status has also been identified by Hwang and Tan (2012). Findings of this study in tandem with these submissions as the fact that SC materials such as the use of earth blocks for construction which is believed to be highly sustainable (Aghimien and Awodele, 2016), are perceived to have low status. This is adversely affecting the attainment of SC projects in Nigeria. The finding of this study also supports Abidin *et al.* (2003) submission that the use of technology to improve project process and construction methods can go a long way in attaining SC.

D. Information and Management related factor

The last extracted component with an eigenvalue greater than 1 account for only 5.2% of the total extracted factors. This component has variables such as limited access to relevant information and historical data, interest and commitment of top management, inadequate exemplary demonstration project, and level of integration of life cycle cost. This component was further named "information and management related factor". Without adequate information, the successful delivery of SC projects might not be attained. This is because, through modelling SC projects that have been achieved successfully in the past, a roadmap for the attainment of more sustainable projects can be created. Findings of this study further corroborate the submission of Ametepey *et al.*, (2015) that lack of information and exemplary demonstration projects can serve as hindrances to SC. Similarly, this finding further affirms Abisuga and Oyekanmi (2014) submission that the support of management within an organisation places a significant role in the adoption or non-adoption of SC practices within the organisation.

Table 2: Rotated component matrix for the barriers of SC practices

Barriers of SC Materials	Component 1	2	3	4
Clients fear of high investment cost	0.778			
Inadequate awareness and knowledge	0.714			
Low demand for sustainable products	0.703			
Industry's resistance to change	0.701			
Method of selecting SC material	0.693			
Lack of expert opinions on SC	0.636			
Clients preference	0.595			
Inadequate sustainable measurement tools		0.793		
Inadequate building codes and regulations		0.781		
Inadequate government policies/support		0.768		
Client worries on profitability		0.666		
Unstable prices of SC materials		0.498		
Perception that SC materials are of low status			0.729	
Unreliability of Suppliers			0.712	
Inadequate technology and technological process			0.677	
Limited availability of sustainable materials			0.588	
Limited access to relevant historical data				0.792
Lack of commitment of top management				0.688
Inadequate exemplar 'demonstration project				0.631
Level of integration of life cycle cost				0.548

5. CONCLUSION AND RECOMMENDATIONS

This assessed the barriers to SC practices in Nigeria through a quantitative survey. Based on the findings from data gathered from construction managers, project managers and quantity surveyors from across the 6 regions of the country, the following conclusion was drawn. The major barriers to SC practices in the country are sustainability knowledge related, regulation and policy related, sustainable materials and technology related, and information and management related. Therefore, to attain SC within the country, enlightening construction clients and other participants through seminars and workshops organised by construction professional bodies, on the concept of SC and the overall benefit of implementing SC concepts is important. This will help eliminate the client's fear of the high cost of construction and their idea of SC materials having low status. Similarly, through this enlightenment, the understanding of SC concept will increase among construction experts particularly in the aspect of available SC materials and technologies needed. Also, there is the need for the development of appropriate sustainability measurement tool and building codes and regulations that will help check the construction processes and ensure they are sustainable. Similarly, the government must be ready to champion the course of SC attainment through the creation and enforcing of SC policies in the country. There is also the need for support from top management and proper documentation of information on SC projects being conducted to have a means of reference when handling new SC projects.

This study contributes to the body of knowledge on SC in Nigeria where construction projects are still experiencing challenges of poor SC. The findings will help understand the critical barriers to avoid when trying to achieve SC. However, while this study contributes to knowledge, care must be taken in generalising its result as the study was conducted among only three sets of construction professionals in the country. Further study can be done with a wider range of construction stakeholders to get a much wider view of the topic and compare results.

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Industry 4.0 diffusion in the South African construction industry – Construction professionals' perspective

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ABSTRACT AND KEYWORDS

Purpose of this paper
The emergence of the fourth industrial revolution popularly called 'Industry 4.0' promises inventive solutions to age-old issues of delivering construction project successfully. Evidence of the use of the industry 4.0 features and the benefits thereof have been noted in other industries aside construction. This study, therefore, assessed the adoption of some features of this industrial revolution, and the benefits inherent in its proper adoption in the South African construction industry. This was done with a view to encourage the use of the array of technological features proposed by this industrial revolution to have better service delivery within the industry

Design/methodology/approach
The study adopted a quantitative survey design with questionnaire used to solicit information from construction professionals in Gauteng province. Data analysis was done using percentage, mean item score, and Kruskal-Wallis H-test. Cronbach's alpha test was also used to determine the reliability of the questionnaire used.

Findings
The findings revealed that the most adopted industry 4.0 features within the South African construction industry are the internet of things and cloud computing. However, Kruskal-Wallis H-test revealed a significant difference in the view of the different construction professionals about the rating of these two features. The study further revealed that the proper diffusion of these industry 4.0 features into the activities of the construction industry will give benefits such as; providing value for money, increasing work efficiency, reducing waste, better storage of design data and improved design management.

Research Limitation
The limitation of this study lies in the fact that to a single province within South Africa, thus, there is a need for further studies in other provinces within the country, to compare results.

Value
This study contributes to the body of knowledge by bringing to light the most used industry 4.0 feature within the South African construction industry, as well as the perceived benefits inherent in their usage.

Keywords - Construction 4.0, Digital technologies, Digitalisation, Fourth Industrial Revolution, Industry 4.0

1. INTRODUCTION

There have been four phases that have altered mankind's way of existence, referred to as industrial revolutions. First is the human's transitioning from being a hunter-gatherer society to agrarian society, and from then on to becoming an industrialised society. From the industrial transformation came the advancement in information, and this saw human society becoming more information-oriented with the use of information technologies (Ozlu, 2017). Currently, the fourth phase of the industrial revolution known as the Fourth Industrial Revolution or Industry 4.0 is upon us. Industry 4.0 is essentially the application of the combination of innovations such as; the Internet of Things (IoT), sensors, cloud computing, robotics in conjunction with Artificial Intelligence (AI) amongst others, for the production, distribution, and use of physical goods (Fuchs, 2018). The implementation of 4IR features is still in its early stages, and only a few concepts of the revolution have been adopted by the construction industry. The espousal of Industry 4.0's technologies and the application of its concepts will provide the construction industry with a competitive advantage over other industries (De Andrade Régio *et al*. 2016). De Andrade Régio *et al*. (2016) further stated that by the year 2020 the speed of change, both within society and the workplace, will occur at an exponential rate. Several workplaces such as factories, where pre-fabrication of building materials and/or components occurs, will become smart because of the innovative technologies of Industry 4.0, thus improving efficiency and productivity within the workplace, and maximising flexibility (Petrillo *et al*., 2018). Industry 4.0 aims to increase efficiency in using resources as well as to improve productivity also to achieve a high level of automation (Lu, 2017).

Understanding that Industry 4.0 is at its early stage and its adoption in the construction industry is only at a very minimal level especially in developing countries like South Africa (Aghimien *et al*., 2018b; Osunsanmi *et al*., 2018) where construction projects delivery is still adjudged as poor (Emuze and Smallwood, 2011), evaluating the current adoption of its features within the industry is deemed necessary. This is with the belief that knowing the Industry 4.0 feature that has been adopted and the ones that still need to be given thorough consideration will go a long way in improving construction project delivery using digital technologies and applications. It is based on this notion that this study assessed the current use of the technologies and applications offered by this current industrial revolution in the South African construction industry (SACI) as well as the perceived benefits of its diffusion with the service delivery of the industry. Subsequent parts of this paper include the review of existing literature, the methodology adopted for the study, the findings and the conclusion drawn from these findings.

2. LITERATURE REVIEW

2.1 Challenges of the Construction Industry

Despite the immense contribution of the construction industry to the growth of every nation as observed in past researches (Durdyev and Ismail, 2012; Windapo and Cattell, 2013), the industry around the world is not without its own problems. The South African construction industry, for example, is facing a challenging cycle with the index trading at 69%, which is lower than in 2009 when there was a global financial crisis. According to the Pwc report, 8 out of 9 construction companies endured a decrease in their market capitalization, and the total market capitalization for the construction industry decreased by 38% (Crampton, 2016). These problems are connected to several challenges facing the construction industry of which technological advancement in the delivery of services is one. According to Windapo and Cattell (2013), South Africa is behind in levels of technology compared to other developed countries. This tends to result in limiting the scope of the projects that companies can undertake, with the availability of material, equipment and personnel. The end-users are also resistant towards adapting into construction methods that are capable to develop adequately and in new advanced methods of building systems, mainly in the low-cost housing market, and the difficulty in balancing labour and technology. The government has also encouraged construction companies in employing more labour than acquiring technologies to increase the economic growth of the nation and to reduce the rate of poverty. With the advent of the 4IR, the construction industry stands a better chance of improving their service delivery through technological advancement that the 4IR offers (Aghimien *et al*., 2018b).

2.2 Overview of Industry 4.0 features and benefits

According to De Andrade Régio *et al.* (2016) and Ozlu (2017), the German-launched Industry 4.0 concept is an extension, which is building on the preceding third revolution of which was technology based. The industry 4.0 can be described as a new level of organisation which comprises of increased digitalisation and automation in the manufacturing environment and intends to create a digital value chain to facilitate the conveyance of information in the products and their environment and business partners (Oesterreich and Teuteberg, 2016; Vaidya, et al, 2018). One such concept of industry 4.0 is cloud computing which has gained mass traction in terms of its usage (Deloitte, 2016). This feature involves the process of storing files in the “cloud”. However, its widespread usage is dominated by cloud-based storage tools such as Dropbox and Google drive, rather than the use of cloud-based document management systems (Harris, 2016). Furthermore, Deloitte (2016) observed that the adoption by industries is relatively low compared to that by consumers, as cyber-crime is seen as a major barrier, hindering its full-scale adoption. Another key feature is the use of robotics in the delivery of services. Deloitte (2016) has also earlier noted that the use of robotics by most industries in Africa is still at the automated stage, following the migration into the third revolution, and not yet at the smart or artificial intelligence stage. This low level of adoption was further attributed to the costs of acquiring and using smart robots. Vaduva-Sahhanoglu *et al.* (2016) have noted that the use of robots in construction can increase construction efficiency, can bring satisfaction for stakeholders, protect the environment, and durability. Thus, the entire construction activity and the processes involved will result in high performance.

The internet also gives the opportunity for the overall system of the network which is linked to each other in the form of Internet of Things (IoT). Furthermore, IoT can also be the Internet of Everything (IoE) which consists of Internet of Service (IoS), Internet of Manufacturing Services (IoMs), Internet of People (IoP), an embedded system and Integration of Information and Communication Technology (IICT) (Celaschi, 2017). However, it has equally been observed that South Africa is still at a formative stage when it comes to the adoption of IoT applications. There is a foundation, but widespread adoption is lacking (Deloitte, 2016). According to McDonald (2017), the IoT for the construction industry includes equipment and worker monitoring via wearables, drone surveillance and different devices used for data collection. Wearable devices can be used to track workers by means of monitoring work locations, hazardous conditions when accessing unsafe surroundings and improve overall performance. Operation and maintenance needs can also be monitored by equipment sensors in real time beforehand to avoid costly breakdowns. Work progress to a specific location or an entire project over time can be tracked using drones. All IoT systems can maximize profits when applied correctly. According to Bogue (2018), drones play a crucial role within the construction industry, with an increasing number of usage on construction projects being experienced in the United Kingdom. Drones are equipped with cameras containing high resolution and other sensors. These drones can be used to survey sites before construction works start, monitoring of stockpile and inventory, monitor project progress, assessment of health and safety and detect possible hazards.

Another significant feature of the 4IR is Building Information Modelling whose implementation in the construction industry of developing countries has only been achieved at a minimal level (Ikediashi and Ogwueleka, 2017). Harris (2016) attributes this minimal usage to the costs involved, level of infrastructure available, and the lack of international recognised BIM courses in South Africa. The construction industry has a broad range of services available for use in BIM. The industry can use BIM for visualization, to create fabrication drawings, to reviews codes of best practice, cost estimating, construction sequencing, detect clashes in design, interference or collision, also do analysis on forensic and can be used for facilities management (Goldswain, 2016). According to Chimhundu (2015), the benefits of implementing BIM is that they provide improved design management by being able to detect design clashes on time. BIM also provides clients with better value for money, replacement of traditional methods of construction project delivery which are reckoned to be inefficient and mostly have cost overruns and delayed projects, and better storage of design data throughout the entire built asset's life cycle.

3. RESEARCH METHODOLOGY

This study assessed the benefits inherent in the diffusion if industry 4.0 features in the service delivery of the SACI. A survey approach was adopted, and quantitative data was gathered from construction professionals in Gauteng province. The study adopted the use of a questionnaire as the instrument for data collection due to its ability to cover a large range of respondents within a short period of time (Tan, 2011). The questionnaire used was designed in two sections with the first designed to harness information on the background of the respondents. The second section sought answers to the most used industry 4.0 feature and the perceived benefits of the use of these features in the delivery of construction services. A 5-point Likert scale was used measuring the variables in this section. A total of 60 construction professionals participated in the survey. In analysing the data gathered, information on the respondent's background was analysed using percentage, while the mean item score was used to rank in descending order the variables in section 2. Based on the different professional background of the respondents, Kruskal-Wallis H-Test was further employed in testing the significant difference in the view of the different professionals. Kruskal-Wallis H-Test was adopted based on its suitability in ascertaining the significant difference in the view of three or more group of respondents as observed by Pallant (2005). The reliability of the questionnaire was also tested using Cronbach's alpha test. Cronbach alpha gives a range of value of between 0 and 1, and the higher the value, the higher the degree of internal consistency. The Cronbach's alpha value of 0.762 and 0.809 was derived for both the level of usage of the identified industry 4.0 features and their perceived benefits. This shows that the instrument used was reliable since the degree of reliability of an instrument is more perfect as the value tends towards 1 (Moser and Kalton, 1999).

4. FINDINGS AND DISCUSSIONS

4.1 Background Information

Data analyses revealed that 55% of the construction professionals involved in the study were male while 45% were female. In terms of profession, more responses were gotten from Quantity Surveyors (50%). This is followed by Engineers, Construction managers and Architects with 24%, 18%, and 8% response rate respectively. For their academic qualification, 42% had a National Diploma, 33% had a Bachelor's degree, 20% had an Honours' degree, 3% had a Master's degree, and 2% had a Doctorate. Majority of the respondents (55%) have up to 5 years working experience within the construction industry while the remaining 45% have above 5 years of working experience. most of them (52%) work within a contracting firm, while 42% works for consulting firms, and 7% were government employees.

4.2 Industry 4.0 diffusion in construction service delivery

The result in Table 1 shows the construction professionals rating of some selected industry 4.0 features that are related to construction as they are being used in the SACI. The table also shows the chi-square value and the significant p-value derived from Kruskal-Wallis H-Test conducted. A look at the table shows that out of the 9 assessed features, only 2 have a mean value of above average of 3.0. This means that the level of usage of the remaining 7 features in the service delivery of the SACI is low. These 2 features are IoT and cloud computing. Kruskal-Wallis H-Test conducted shows that at 95% confidence level, there is no significant difference in the view of the various construction professionals about the level of usage of the 7 less used industry 4.0 features as a significant p-value of above 0.05 was derived. However, the story is different for the top 2 features as a significant p-value of below 0.05 was derived. This implies that construction professionals have a divergent view as to the usage of these two features.

With the continuous development in internet gadgets and use of same in day to day activities, it is not surprising to see construction professionals claiming that IoT and cloud computing are the highest industry 4.0 feature being used. However, IoT and cloud computing goes beyond just the use of the internet and saving documents on google drive. In fact, Deloitte (2016) has stated that in South Africa the complete adoption of IoT is still at a formative stage. There is a foundation, but widespread adoption is lacking. The low level of usage discovered for the other 7 features further confirms past submissions that the construction industry around the world is slow in the adoption of technological features that could be most beneficial to their service delivery (Aghimien *et al.,* 2018b; Castagnino *et al.*, 2016; Osunsanmi *et al*., 2018).

Table 1: Level of Industry 4.0 diffusion in construction service delivery

Features	Mean	Rank	Kruskal-Wallis Test Chi Sq.	Sig.
Internet of Things	3.95	1	11.039	0.026**
Cloud computing	3.42	2	10.577	0.032**
Big Data	2.93	3	2.994	0.559
Automation and Robotics	2.82	4	0.792	0.939
BIM	2.78	5	3.004	0.557
Additive Manufacturing	2.50	6	1.449	0.836
Simulation based tools (AR, VR, MR)	2.22	7	4.380	0.357
Aerial visuals (Drones)	2.10	8	1.615	0.806
Sensors / Laser scanners	2.00	9	4.471	0.346

Note: *AR = Augmented Reality, VR = Virtual Reality, MR = Mixed Reality,*
*** Significant at $p < 0.05$*

4.3 Benefits of Industry 4.0 diffusion in construction service delivery

In determining the benefits inherent in the use of industry 4.0 features within the SACI, some benefits were identified from the review of literature and respondents were asked to rate these benefits based on their level of agreement. The result in Table 2 shows the rating of these benefits as well as the chi-square value and the significant p-value derived from Kruskal-Wallis H-Test conducted. A look at the table shows that all the 12 assessed benefits have a mean value of above average of 3.0. This means that the respondents believe that to a considerable extent if industry 4.0 features are deployed into the service delivery of the SACI, the industry stands to enjoy the listed benefits in this study. Kruskal-Wallis H-Test conducted shows that at 95% confidence level, there is no significant difference in the view of the various construction professionals with regards to these listed benefits aside one (Improved design management, p-value = 0.001) wherein a significant p-value of less than 0.05 was derived. This result implies that while there is a converging view of the 11 benefits, the respondents had a divergent view about the use of industry 4.0 features being able to provide improved design management. This discrepancy in opinion about this benefit can be associated with the different professional backgrounds of the respondents for the study. While the architect, structural engineers, and construction management might see the possibility of these industry 4.0 features leading to an improved designing and management of same, the quantity surveyor might not.

On the overall the key benefits to be derived from the diffusion of industry 4.0 in the SACI are providing value for money (mean = 4.25, sig. = 0.675), increasing work efficiency (mean = 4.20, sig. = 0.260), reducing waste (mean = 4.17, sig. = 0.475), better storage of design data (mean = 4.12, sig. = 0.163) and improved design management (mean = 4.12, sig. = 0.001). This result is in line with Vaduva-Sahhanoglu *et al.* (2015) submission that the use of some industry 4.0 features such as robotics and automation increase construction efficiency and at the same time protect the environment by reducing wastage of natural resources used during construction. Furthermore, to Chimhundu (2016) has earlier noted that features such as BIM will give better design of construction projects and proper management of same during construction. The findings also support Hashim *et al.* [26] submission that the use of digital technologies which are associated with industry 4.0 will give better quality delivery, savings in cost, clients and participants satisfaction, as well as effective project delivery. Aghimien *et al*. (2018a), Chimhundu (2015), and Staub-French and Fischer (2017) also noted that with features such as BIM, lashes in design can be detected early thus, leading to eliminating of errors and rework from construction work and in turn achieving project within budget and attaining value for money.

Table 2: Benefits of Industry 4.0 diffusion in construction service delivery

Benefits	Mean	Rank	Kruskal-Wallis Test Chi Sq.	Sig.
Providing value for money	4.25	1	2.334	0.675
Increase work efficiency	4.20	2	5.280	0.260
Reduce wastage	4.17	3	3.522	0.475
Better storage of design data	4.12	4	6.536	0.163
Improved design management	4.12	4	18.962	0.001**
Easy monitoring of project progress	4.10	6	8.144	0.086
Maximising profits	4.10	6	2.152	0.708
Shorter construction time	3.93	8	4.130	0.389
Achieving a durable and strategic method of construction	3.87	9	5.117	0.276
Effective equipment and employee monitoring through wearables with IoT	3.85	10	6.051	0.195
Possible hazards detection using drones	3.83	11	4.164	0.384
Quality construction	3.83	11	7.836	0.098

*** Significant at $p < 0.05$*

5. CONCLUSION AND RECOMMENDATIONS

This study assessed the benefits inherent in the diffusion if industry 4.0 features in the service delivery of the SACI using quantitative data gathered from construction professionals in Gauteng province. Based on the analyses of the data gathered the study concludes that the most adopted industry 4.0 features in the SACI are the internet of things and cloud computing. However, there is a significant difference in the view of the different construction professionals about the rating of these two features. Furthermore, if industry 4.0 features are properly deployed in the service delivery of the SACI, the industry stands to benefit in areas as achieving value for money on construction projects, increase in work efficiency, reduction of waste, better storage of design data, and improved design management abound.

Although this study contributes to the body of knowledge by bringing to light the level of usage of some industry 4.0 feature within the SACI as well as the perceived benefits inherent in their usage, care must be taken in generalising the result of the study due to some identified limitations. The study was limited to a single province within the country, thus, there is a need for further studies in other provinces within the country, in order to compare results. There is also the need for further studies conducted with a much larger sample size than what is obtainable in this current study.

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Innovative environmentally sustainable concrete: Explaining the low uptake in UK construction Activities

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ABSTRACT AND KEYWORDS

Purpose of this paper

This study explores the reasons for the low uptake of innovated environmentally sustainable concrete by the UK construction industry. Despite the significant impact the manufacturing and use of concrete has on the natural environment on the one hand, and on the other, the commitment of the UK construction industry to the UK Government's carbon emissions target, it is of great concerns that innovated environmentally concrete is disregarded by the industry. Concrete is the second most used building material in the world; it is comprised of cement, sand, aggregates and water; all of which are critical to the ecosystem and the environmental media. The cement within concrete accounts for 8% of total global CO2 emissions whose atmospheric concentration induces unpredictable changes in global weather patterns euphemistically referred to as climate change, and with devastating consequences. Against this background, governments around the world have voluntarily established carbon reduction targets, and in the case of the United Kingdom, this target has been set at 80% to be achieved by 2050. To this end, various policy instruments have been introduced by the UK government to encourage households and businesses, which are deemed as critical partners in the delivery of set reduction target. This is why it is important to ascertain why innovated sustainable concrete is not widely used in UK construction despites the efforts of the government and the commitment of the construction industry to sustainable operations.

Design/methodology/approach
Apart from the critical literature review undertaken to appreciate and understand previous research efforts relating to product innovation generally, and in particular, innovation within the construction industry, a qualitative research methodology was adopted, given the desire for greater understanding of product innovation trends and challenges in the construction sector, albeit with particular focus on the low uptake of sustainable concrete. A semi-structured interview was conducted on construction professionals who have particular interests and expertise working in the UK concrete industry supply chain. The results were thematically coded using open-coding and analysed into factors that influence the uptake of new sustainable concrete.

Findings
The main factors established that explain the low uptake of innovated environmentally sustainable concrete in the UK construction industry include; cost, quality, practicality, testing and durability issues, risk avoidance, poor marketing and promotion, government policy, construction culture as well as lack of cohesion and collaboration in the concrete supply chain. Conclusions and recommendations were established based on these findings to encourage the uptake of innovated sustainable concrete in UK construction activities, and enable the UK government fulfill its reduction target for carbon emissions.

Research limitations/implications (if applicable)
The study is limited to concrete and the United Kingdom. The implication being other innovative environmentally sustainable building materials may also be encountering similar market penetration challenges as sustainable concretes. Similarly, this situation may not be unique to the United Kingdom in which case, meeting carbon emissions reduction targets set by many countries may prove more difficult

than would have been previously envisaged without critical attention being paid to the sustainability attributes to construction input supply chains.

Practical implications
This study provides insights to acute challenges facing environmentally sustainable construction materials in the market place and allows targeted interventions that will ensure innovations in construction materials are not stifled in the UK.

What is original/value of paper.
Findings and conclusions drawn from this study will not concentrate minds on how to better support construction product innovations, a necessary move that will assist global efforts in meeting carbon emissions targets.

Keywords: Concrete, Cement, Environment, Sustainability, Innovation, Supply-Chain

1. Introduction
Construction is an industry that has an enormous impact on the environment, given the huge consumption of raw materials and generation of wastes (Holton et al., 2008). The extraction and transportation of these raw materials invites significant alterations to the eco-system, as well as significant emissions of green-house gases into the environmental media (Khatib, 2016). Currently, the world is consuming these raw materials in a highly unsustainable manner. In the UK for example, 420 million tonnes of raw materials are consumed annually by the construction industry (Khatib, 2016).

Concrete, which is a mixture of cement, sand and water, is a versatile building material, and one of such materials whose production and consumption invite significant alterations to the natural environment (Watts, 2019), and the unsustainable methods of extraction employed often undermine the regenerative capacity of the natural environment. Cement is a critical material in the manufacture of concrete, this explains the interchangeable use of concrete and cement in the building material literature. Concrete features prominently in almost every form of construction, including buildings, roads, bridges, and other critical infrastructure and services, and annually, over 10 billion tons of concretes are manufactured globally (Meyer, 2009). In the process of concrete production, significant amounts of green-houses gases are released in addition to the environmental impact of other key material inputs – water and sands. Globally, cement production has increased 4-fold over 30 years, from 1 billion tonnes to over 4 billion tonnes, this is expected to increase annually by 500 million tonnes (Vidal, 2019), and already, cement accounts for 8% of the world's carbon dioxide emissions (Rodgers, 2019).

Generally, cement production ranks third behind transport and the energy sectors that contributes man-made or anthropogenic CO_2 emissions to the environmental media (Andrew, 2018). There are two crucial stages of cement production from where the bulk of CO_2 emissions derive: the first being at the stage where by-products of fossil fuels, mainly coal, are burnt to generate heat for driving the cement-making process; this is followed by the critical second stage where the thermal putrefaction of calcium carbonate takes place, leading to the production of cement 'clinker' (Watts, 2019). It is at this second stage that more than 50% of carbon emissions associated with cement production is released (Watts, 2019). According to Vidal (2019), every 1000kg of cement produced involves the release of 1000kg of CO_2 into the environmental media.

The continuing use of concrete is on the rise, this owes to its key attributes that start cost-effectiveness, fire resistance, and mechanical and high durability (Meyer, 2009). The implication of such rising demand for concrete is the associated carbon emissions, and unless effective measures are taken to decarbonise concrete production, global carbon emissions target will be difficult to achieve. It is on this stark reality that persuaded the UK concrete industry, which include concrete manufacturers, the aggregate industry, the ready-mixed industry, and the precast sectors together with other interrelated sectors to agree and commit to the Concrete Industry Sustainable Strategy (CISS) in 2008. This strategy was revised in 2012 with various sustainable commitments to be achieved by 2020.[1] In particular, it was expected that by 2020, the concrete industry would have achieved:

[1] Construction 2025: industrial strategy for construction – government and industry in partnership. https://www.gov.uk/government/publications/construction-2025-strategy.

- 90% decrease in wastes destined for landfill by 2020, taking 2008 as a baseline.
- 30% reduction in CO_2 emissions from concrete production by 2020, taking 1990, as a baseline.[2]
- Achieve 95% BES 6001 responsible sourcing certification standard by 2020
- 100% of relevant production sites with action plans for site stewardship and biodiversity

These developments followed from the UK Government's commitment to a general target of 80% reduction in CO_2 emissions (Zhao and Pan, 2015). Indeed, concrete manufacturers and allied sectors have adopted series of measures aimed at minimising emissions of greenhouse gases from their production and distribution activities.

2. Innovated Environmentally Sustainable Concrete

Huge efforts have gone into decarbonising concrete production (Holton, et al. 2008), this is reflected in Figure 1 which shows the amount of patents filed by the cement and concrete industry continues to outgrow other energy and natural resource intensive industries. The particular area of focus is in finding alternatives to 'Clinker', a by-product whose procession generates more than 50% of carbon emissions associated with cement and concrete production.

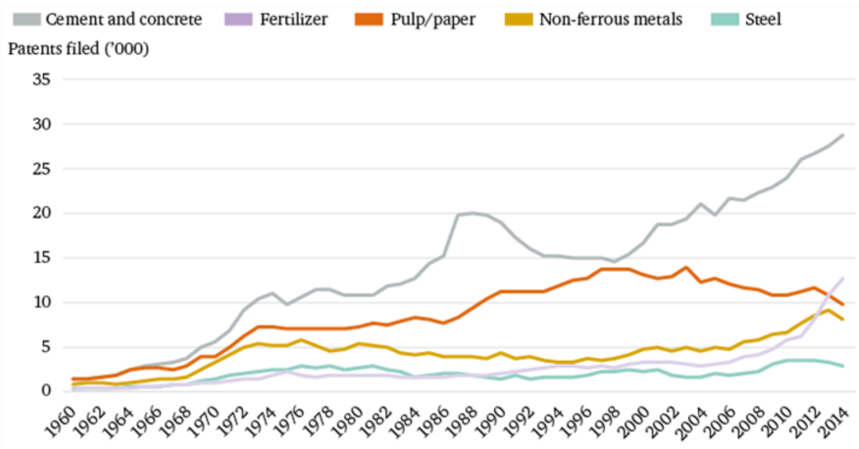

Figure 1: Innovation in Low-Carbon Cement and Concrete

Source: https://reader.chathamhouse.org/making-concrete-change-innovation-low-carbon-cement-and-concrete#

The manifestations of these innovations can be found in the increasing decarbonisation of cement production round the world. As Figure 2 indicates, the cement industry has witnessed the increased use of alternatives to clinker, including limestone calcined clay cement, or 'LC3', which are found to reduce CO_2 emissions associated with cement production by as much as 20% to 30%. In India, this method of cement production is being tested on a large scale, as the country sees it as a necessary strategy for achieving its carbon emissions target, and this is particularly given the expected exponential growth in cement consumption owing large scale infrastructure supply. Other materials have been innovated in place of clinker, these include slag and fly ash that has drastically reduced clinker input to cement manufacture by 50%. Overtime, 'Portland Cement' has been partially substituted by other cementitious materials, including ground granulated blast furnace slag (GGBS), and other admixture and additives. These innovations have not only allowed for reductions in carbon emissions, but also, it made it possible for concretes to be produced into different compressive strengths (Kusuma, et. al. 2015). Furthermore, recycled aggregates are also being used in concrete production, further decarbonising concretes production (Meyer, 2009).

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[2] Cement Industry Carbon 2050 Strategy (Mineral Products Association) http://cement.mineralproducts.org/current_issues/climate_change/carbon_strategy.php

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In the UK, the use of GGBS in concrete production is growing, and this owed mainly to numerous advantages adduced, including greater durability, increased strength, reduction in heat generation, resistance from sulphate attack, and lower greenhouse gas emissions (Kim et al., 2018). Indeed, it has been found that using GGBS instead of conventional aggregates facilitates annual reductions of 2.5 million tonnes of CO2 emissions (Tait and Cheung, 2016; Meyer, 2009). Furthermore, Hanson, a major UK ready-mix supplier of concrete indicates that it has been able to replace 70% of Portland cement (CEMI) in ready-mix concrete with sustainable alternatives resulting in significant reductions in CO2 emission reductions.[3]

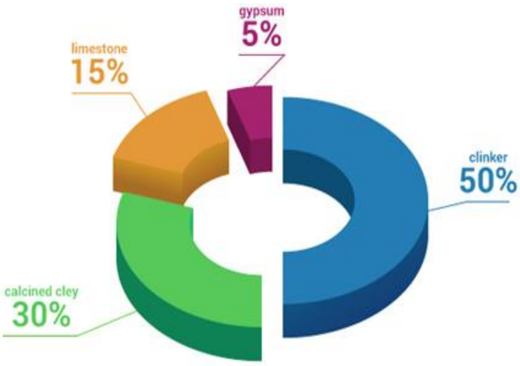

Figure 2: Innovation in Cement Production

Source: https://www.zkg.de/en/artikel/zkg.html

However, the efforts of concretes manufacturers at decarbonising have not been rewarded with increased demand for innovative sustainable concretes, as up-takes of these products have falling drastically below expectations. While various explanations have been abstracted from the challenges facing newly innovated products coming on to the construction markets (Reijonen and Croisel's, 2017; Hardie, 2010; Davis et al, 2016; Vidal, 2019), little study exists on the challenges facing concretes. (Ozorhon and Oral, 2017). Indeed, Vidal (2019) argues that the low-uptake of innovated sustainable concrete in the UK can be explained by looking at the challenges faced by new construction products face entering the market, including industry culture, attitude to risks, and concerns about quality and standards. Evidently, the scarcity of literature on the reasons for low-uptake of innovated sustainable concretes in the UK, despite the proven sustainability attributes, remains the motivation for this study. Understanding the reasons for such low demands for this products is a necessary prerequisite for targeted policies and strategy for decoupling increased production from CO2 emissions.

Several objectives are pursued in this study to enable the realisation of the aim of study. The first objective is to establish the effects of concrete production and use on the environment, and this provide context to the study. Secondly, to understand and analyse the characteristics of innovative sustainable. Thirdly, to establish the reasons for the low-demand for innovated sustainable concretes despite beneficial environmental attributes and particularly in regards to both commitments of the construction industry and the government to decarbonise the industry, and finally, to suggest appropriate policies and measures to accelerate the use of sustainable concrete in UK construction industry activities.

3. Research Methodology and Strategy

The research question that results from reviewing the literature and contextualising of the low-use of innovative and environmentally sustainable concrete in UK construction activities lend itself to the use of qualitative research methodology. This owes to the fact that it is the unique views and opinions of construction industry practitioners, evidenced by their experience and duration in the industry, that is sought to deepen our understandings of the challenges faced by sustainable concretes in the UK construction industry (Ritchie and Lewis, 2003). Thus, the qualitative research methodology is used in this study to enhance our knowledge and deepen the meaning that can be adduced to explain the low-uptake of sustainable concretes in UK construction activities (Ritchie and Lewis, 2003). The underpinning ontological and epistemological positions adopted for this study hinge on knowledge being seen as a social construct in which it is determined by culture, values, and specific conditions the researchers have encountered (Ritchie and Lewis, 2003). As such, the epistemological positioning of the authors is of

[3] https://www.hanson.co.uk/en/ready-mixed-concrete/sustainable-concrete

interpretivism, with the use of a qualitative research methodology to look at the factors that lead to low uptake in the use of new innovative sustainable concrete. According to Wildemuth (2016), knowledge gained from culture and values derive from research investigating 'why?' and 'how?'. The data obtained can be analysed using inductive reasoning to understand specific contexts, which in this case, is the low-uptake of innovative sustainable concrete in UK construction activities (Ritchie and Lewis, 2003).

The data were collected using a structured questionnaire in a cross-sectional survey with purposive or non-probability sampling technique. The purposive sampling strategy was chosen for reasons of costs and time constraints. The sample size of participants requires the right balance of numbers to provide depth and breadth to the research (Cleary, Horsfall and Hayter, 2014, Mason 2010). However, Mason (2010) observes also, that too many participants can lead to saturation; more participants do not necessarily result in more valuable information other than repetitive and redundant information (Mason, 2010). Sample sizes averaging between 20 and 30 participants are deemed adequate, and beyond which saturation begins to emerge (Mason, 2010), leading Atran et. al, (2005) to advise on a minimum of 10 interviewees.

The strength of this study, irrespective of the sample size, is the quality of interviewees that comprised an array of professionals within the industry. These include quantity surveyors, directors, engineers, construction manager, health and safety managers, technical and research staff to afford broad perspectives on the research. Furthermore, the construction industry experience of participants ranged from 4 to 45 years, with a collective industrial experience of 379 years, providing a significant wealth of practical knowledge and understanding of the UK concrete industry. This will also enhance validity and reliability of research results (Cleary, et al., 2014). As Table 1 shown in appendix 1 reveals, 21 interviewees with extensive knowledge of the UK construction industry were identified and interviewed. The interview questions are similarly presented in Table 2 in appendix 2.

4. Analysis of Results

Figure 3 is a summary of the interview responses in appendix 3, the responses have been grouped into eleven main themes explaining the low-uptake of innovated environmentally sustainable concretes, and these themes have been further disaggregated into sub-themes.

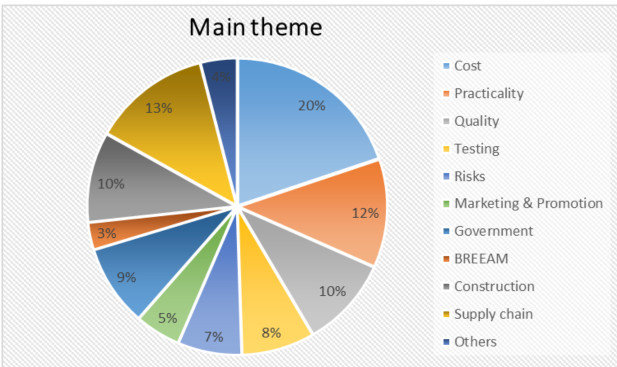

Figure 3: Summary of interview responses

The dominant reason given for the low up-take of sustainable concrete in the UK construction industry is the costs of the product, which clients are unable to accommodate. A disaggregate analysis of the origin of costs points to that of 'clinkers', which is considerably less than those of sustainable alternative inputs to concrete manufacturing, which are then reflected in final concretes prices. This seems to be the overwhelming views of industry practitioners, particularly the quantity surveyors who argued that clients are unfavourably disposed to bearing such costs. This finding coincides with those in the literature that sustainable alternatives to clinkers are relatively more expensive, and shown to the main reason that conventional concretes remain very popular with clients. In other words, sustainable concretes remain relatively uncompetitive in price, hence the difficulty in penetrating the market for concretes. The issue of cost was further probed where the environmental benefits and associated low running costs were pointed out to participants. The responses from respondents were instructive, the overwhelming view indicates that very few property developers take such a long-term view of investments; this they argued to be particularly the case, when such investments are likely to change hands after project completion. Other elements of costs relate to 'testing and trials' for durability and structural integrity - processes critical to establishing product quality.

Practical problems associated with production and manufacture was the second major theme raised by respondents. The low cement content or the total substitution of other sustainable alternatives for cement are deemed problematic, particularly the longer time it takes to for the concrete to set, causing delays and distorting completion time resulting in cost-overrun. In particularly, majority of the participants pointed to the practical problems associated with graphene given that, the supporting theoretical formulation often proves difficult to replicate during manufacturing. One of the participants went further to discuss the difficulty of dispersing graphene into concrete on a large scale, as concrete needs 1300L of water for an 8m3 wagon load of concrete. This poses the difficulty of dissolving and dispersing graphene evenly in the batching plant, which is then put into concretes and having to repeat the whole process again within minutes for the next load of required concretes. Participants also indicated the numerous tests associated with the use of new products, trials and mock-ups using new alternative concrete mixes have proved relatively expensive.

Additional costs identified include those associated with the use of innovative concretes, including those relating to high rework costs. One participant in particular, who had to revert to using conventional cement acknowledged the costs associated with using new innovative type of concrete with plastic fibres was enormous owing replacements of blocked pipes that resulted in extensive wastage of building materials.

Concerns about quality of innovated environmentally sustainable concretes was a major reoccurring theme during the interview. In particular, the strength and durability of sustainable concretes were advanced as main concerns. Participants of design and structural engineering background indicated their reluctance to specify newly innovated materials such as sustainable concretes without established evidence of durability over the physical life of the infrastructure concerned. They pointed to the limitations brought about by the fact that their public indemnity insurance does not account for the risk of specifying untried and untested materials. They argued erring against such caution will have adverse effects on business margins.

Another aspect of 'testing for durability' raised is absence of standardised testing regulations and procedures, as existing measures have continuously lagged behind the speed and rate of innovation in concrete manufacture, which in turn, heightens the risks associated with their use. One of the participants who is a sub-contractor holds the view that the cost associated with taking risks with newly innovated products is too much for clients to bear. In his opinion, there is need to build in a premium rate, at least, for the first couple of years to cover any such risks, otherwise clients may be unwilling to bear such risks. Shifting attitudes and perceptions to facilitate market penetration invites higher marketing and promotion costs. According to another respondent, lack of market penetration affects volume production without which unit cost remains 'sticky upwards', as economies of scale is forfeited, leaving sustainable concretes largely uncompetitive. However, some of the participants hold the view that it is only a matter time for a downward pressure on prices for sustainable concretes, pointing to wider availability of GGBS alternative, which was previously very scarce. This will allow increased production and allowing for relatively competitive price for standard concrete mix. Indeed, one of the participants hold the view that volume production and availability on the market is critical to sustainable concrete becoming widely used in UK construction.

The importance of practical knowledge about the performance and use of sustainable concrete is critical to market penetration, according to all the participants. Personal experience using innovated light weight concretes on site was tendered by some of the participants, the highlight of the discussion is the importance of training operatives such as sub-contractors on how to handle newly innovated concretes. In the particular example offered, trainings on how much water is required to ensure that the exact amount of water required to pump concretes is what is retained. He argued that the low-uptake of innovated building products generally, and sustainable concretes in particular owe to lack of sufficient knowledge about how to use the new products. This is said to be particularly the case with more complex mixes which are susceptible to moisture and other external conditions. According to majority of the participants, this has serious implications for occupational health and safety. The specialist health and safety participant highlighted the importance of having rigorous procedures in place to ensure new materials enhance rather than compromise health and safety on sites. The blockages that often accompany the use of innovated plastic fibre concrete have resulted in more manual handling of pipes to effect repairs.

Other issues considered important by participants relate to the necessary steps to ensure wider-uptake of innovative sustainable concrete, particularly the resistance to change by the construction. The culture of sticking with what you know and becoming risk-averse to modern construction techniques need to change. Examples were tendered where workers continue with conventional solutions to cracks in concretes instead of using the new self-healing concrete. Similarly, participants were unanimous on the role of the government in encouraging up-take of new products that add value to the environment and contributes towards the realisation of their carbon emission target. Also, the roles of professional bodies, construction product manufacturers and others such as BREEAM in disseminating and organising training programmes in support of newly innovated products were also emphasised.

5. Discussion of Findings

This study establishes the potential of reducing the impact of the built environment on the natural environment by focussing on the supply chain of construction materials. The case of concretes shows that substituting innovated environmentally sustainable concretes for conventional concretes can lead to reductions in carbon emissions, and by extension the built environment in general. There is urgency in adopting this strategy for the decarbonisation of the construction industry, and this owes to the versatility of concrete as a building material, the huge amount consumed in the process of maintaining existing infrastructure and services, and replication in areas of disamenities. Despite the environmental benefits, newly innovated construction inputs, such as sustainable concretes face several challenges coming on to the market. These challenges are in the main to do with concerns about quality and durability, and the attendant impacts on costs that construction industry clients are generally unwilling to bear.

Following the findings, it is crucially important to mitigate the risks associated with the use of innovated sustainable concretes, or indeed, other innovative sustainable products, through public indemnity insurance. The reason being that clients' insurance do not cover the risks of using newly innovated concretes that have not been sufficiently tested. Similarly, a standard Care Certification and level of testing is necessary to reassure the industry about quality and standards of newly innovated products coming on to the market. The point raised by one participant is instructive in that there was no BREEAM points allocated to structural frame until recently, which is why there has been no focus on sustainability and use of sustainable materials in designing structural frames. Also, the need for all stakeholders to communicate and work towards a common purpose in order to create the much need awareness about newly innovated products, such as sustainable concretes, is essential.

The role of the government in promoting the use of sustainable construction products is critical if these products are to successfully penetrate the market and compete with conventional construction products. This can be achieved through the use of command and control measures - regulations, statutory instruments, and economic incentives through taxations. Buildings and other infrastructure constructed from sustainable concretes could be exempted from property rates or offered tax rebates to the tune of carbon emissions saved. Alternatively, the unsustainable conventional concrete could be taxed to the tune of CO2 emissions associated with the facility – 'carbon tax'. This will facilitate market penetration and enhance competition in the market for concretes. Above all, the government could insist, as with the Building Information Model (BIM) initiative, that all public buildings and infrastructures should be constructed from sustainable concretes. Such a move will force the wider use of sustainable concretes, leading to increased production and downward pressure on unit price.

6. Conclusion

In conclusion, this study provides useful insights into the challenges facing innovative sustainable concretes in the market place. In particular, the factors responsible for the low demand for innovative and environmentally sustainable concrete in the UK construction industry have been critically analysed and possible solutions and strategy discussed. Furthermore, the study shows the importance of proactively decarbonising the construction industry by focussing on the supply chain of sustainable products; this will allow the nature of the challenges they face penetrating the market to be better understood for a much effective and targeted policies to be applied. Concrete is a vital building material that has witnessed phenomenal growth in demand, as demand for infrastructure and services rise to support increasing urbanisation and growth and development, more concrete will be demanded, which is the reason for seeking a more sustainable manufacturing process.

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Appendix 1

Profile of Interviewees

Participant	Type of company	Job Role	Years of Experience
1	Subcontractor	Engineer	30
2	Subcontractor	Quantity Surveyor	9
3	Main Contractor	Structures Manager	10
4	Subcontractor	Quantity Surveyor	5
5	Subcontractor	Health and Safety Manager	35
6	Subcontractor	Commercial Director	45
7	Subcontractor	Engineer	5
8	Subcontractor	Commercial Manager	13
9	Subcontractor	Construction Director	22
10	Subcontractor	Pre-construction Manager	18
11	Subcontractor	Concrete Technologist and Quality manager	15
12	Engineering Consultancy/ Designers	Director	23
13	Subcontractor	Construction Manager	34
14	Main Contractor	Civil Site Engineer	4
15	Subcontractor	Senior Engineer	11
16	Subcontractor	Commercial Manager	15
17	R & D Sustainable Cement Specialist	Research and Development Director	22
18	Concrete and cement Supplier	National Technical Manager	35
19	Structural engineering/ Architect	Associate Director	11
20	Client/ Property Investor/ Property Developer	Director of development	3
21	Client/ Property Developer	Quantity Surveyor	14

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Appendix 2

Table 1 Interview Questions

Nos. of Interviewees	**Questions**
1	What is your job title?
2	What type of company do you work for?
3	How many years of experience do you have in the industry?
4	Have you used, specified or supplied any innovative environmentally sustainable form of concrete or concrete-mix in the past?
4(a)	If yes to question 4, why did you do so, and what were associated advantages using it?
4(b)	If yes to question 4, what were the advantages associated with their use?
4(c)	If no to question 4, why?
5	What factors do you think about when choosing concrete types?
6	Here is a list of innovative types of concretes that research suggests are more environmentally sustainable than conventional concrete: a. Cement free b. Hempcrete c. Graphene d. Plastic concrete e. Self-healing concrete f. Geopolymer concrete g. Carrot and beetroot concrete
6(a)	Have you used or specified any of the concretes listed in 6 above?
6(b)	If yes to 6(a), why did you specify them and what were the advantages associated with their use?
6(c)	If yes to 6(a), what problems arose, if any?
7	If no to questions 4 and 6, can you explain why you have not considered using innovative environmentally sustainable concrete?
8	There is a low-uptake of innovative environmentally sustainable concrete in the UK construction industry. Why do you think this is the case generally?
9	Who normally makes the decision on the type of concrete to use in your organisation?
10	In your opinion, who is best placed to drive sustainability innovations in the concrete supply chain?
11	Is sustainability a factor you consider critical in the projects you are involved?
12	What do you think will encourage increased use of innovated environmental sustainable concrete in the UK construction industry?
13	Have you noticed any changes over the years with types of concrete used?
14	Do you see a role for the government in encouraging the use of innovated environmental sustainable concrete?
15	Any other points or issues you would like to raise?

Appendix 3 Table 3: Frequency of themes raised by interviewees

		Interviewee Participants																						
Main Themes	Sub-Themes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Sub-Theme Frequency	Main Theme Frequency
Cost	Material Cost																						19	36
	Market competition																						2	
	Volume																						3	
	Research testing and trialling costs																						3	
	Programme																						6	
Practicality	Production Issues																						3	22
	Workability of the material																						12	
	Practical knowledge of the material																						1	
	Safety																						2	
	Procurement and Availability																						7	
Quality	Quality																						2	18
	Strength																						7	
	Durability																						3	
	Aesthetics																						6	
Testing	Lack of Testing																						8	14
	Types of testing																						5	
	British Standards																						1	
Risk	General Risk																						4	12
	Insurance																						8	
Marketing and Promotion																							9	9
BREEAM																							5	5
Government																							17	17
Construction Culture	General Construction culture																						5	19
	Mainstream use and Precedence																						4	
	Change over time																						10	
Supply Chain responsibility and perspective	Client driven/ Client Perspective																						9	24
	Main Contractor Perspective																						2	
	Subcontractor Perspective																						4	
	Concrete Supplier Role																						1	
	Structural Engineering/ Designer perspective																						2	
	New sustainable concrete company perspective																						1	
	Supply Chain Collaboration																						5	
Other Sustainable approaches:	Concrete Wastage																						3	7
	Cross Laminated Timbre (CLT)																						2	
	Demolition																						2	

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Perceptibility of barriers and threats to successful and sustainable restoration of Heritage Buildings. *A perspective of UK's heritage practitioners.*

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ABSTRACT AND KEYWORDS

Purpose of this paper
The research set out to examine whether, among heritage practitioners, there is unanimity as well as notable discrepancies in what they perceive as the barriers and threats to the successful and sustainable restoration of heritage buildings.

Design/methodology/approach
The study collected data from 87 practitioners. These included professional building surveyors, conservation officers, designers, main heritage as well as specialist heritage subcontractors. This heterogeneous sample was subject to the same research instrument. The data generated was chiefly non-parametric.

Findings
Principally, the notable barriers explored are 'Prognosis–intervention barriers'. These are represented by a lack of knowledge about the principles of conservation and repair; followed by inconsistent repair standards. Even among the most dexterous heritage practitioners, the study noted a marked variation in the prognosis of structural failure as well as routine inconsistencies in the defects diagnosis methods. These challenges are contemporaneous within the sector as the likes of Historical England, (as custodians of Ancient Monuments) are continually seeking long term, and in some cases imminent interventional solutions. It is worrisome, however, to note that the custodians themselves are trapped in paralysis as the cycle between episodes of intervention become longer. The corollary is that, throughout the UK, most grade 1, grade II* and Ancient Monument structures are making the 'risk register': too many buildings, face the threat of being lost foreover.

Research limitations
The study concludes that a wider UK sample will be needed. This is because some of the applied technologies, preferred by practictioners, are not widely practised, especially in a sector where planning consent and wholesome depature from established principles, the local siginifcance attached to buildings are not only inimitable but demand solutions which are intagible and incomparable.

Practical implications
Within the heritage sector, the ongoing concerns about the slow rate of sustainable restoration merits considerable attention. Likewise, the challenges intrisic in the technical heritage doctrines such as

'reversibility' should in turn, be embraced as offering sustainable low carbon retrofit solutions. Indeed, by putting emphasis on the 'reversibility' ethos, a multi-perspective analysis unveils the fact that among practitioners, a sense of optimism is generally lacking. The study concludes that the sector lacks 'can-do' attitudes. As a result, it is diffuclt to innovate and to find solutions to the inexorable cycle of disrepair and the enormous restoration bill, currently estimated to run into several billions of Pound sterling. Sadly, locked-in with this, is the enormous high carbon foot print due to the ensuing restoration and repair activity.

Keywords: ***Low carbon restoration, reversibility, inexorable disrepair, risk register.***

1. INTRODUCTION

A heritage asset is defined as a 'shorthand' for any component of the historic environment. In the UK, the National Planning Policy Framework – NPPF defines a heritage as a 'building, monument, site, place, area of landscape identified as having a degree of significance meriting consideration in planning decisions, because of its heritage interests'. Given this wide ranging definition, this study only focuses on heirtage buildings. The siginficance of this is obvious in that in 2016, Oxford Economics (2016), on behalf of the Lottery Heritage Fund, presented its findings and articulated the role, relevance and part played by the heritage sector. It stated that:

'The role and impact of the heritage sector is considerable. Including direct, supply chain, and wage-expenditure effects, in 2015 the heritage tourism sector alone supported a £20.2 billion gross value added contribution to UK GDP and 386,000 jobs. That is £1 for every £93 of UK GDP in 2015, and one job for every 81 in the broader economy is a derivative of the heritage sector activity (Oxford Econimcs, p.35).

It is also noted from Historical England (2019) that the 'heritage at risk register' is increasing year in and year out. The corollay to this is the actual backglog of restoration action and the increase in the consequential cost of refurbishment and low-carbon retrofit activity. As the UK is already committed to the Tyoko agreement, and its own 2050 zero carbon emission target, the continued accumulation of the very desolute stock of heritage buildings in need of restoration activity, remain a long term challenge. In concert, these issues are prominently threats and salient barriers to the UK's comittment to the Climate Change Act (enacted in 2008).

Similar concerns have been raised by the official advisor to the UK's government on climate change - the Committee on Climate Change or CCC. As part of its advisory mandate, a report to the UK Paliament, by the Committee (CCC, 2019) is rather emphatic and remains concerned that even a zero-net effort to decarbonise the UK's built environment sector up to 60% by 2050 remains a very ambitious target. In reference to the heritage sector, the CCC report is concerned that activities on the ground confound the very thought that government is on target.

As a key driver of the UK's remit on climate change, current estimates are well too ambitious. Indeed, in its concluding statement, the May 2019 CCC report, ascertains that the heritage sector is one of its target zone with the potential for deep emission reduction. This description postcribes the sector, in ways unexpected by the UK's government. It is partly explained by the fact that the heritage sector is habitually ignored owing to the stringent nature of heritage legislation.

There is an inherent but adhoc concentration of the 'harder-to-reach' as well as 'harder-to treat' heritage stock. The CCC (2019) is uneasy about the increasing rate at which heritage buildings are now being designated as on the blink of disappearance, thus making the risk register. It is this same stock that is difficult to turn around without prohibitive intervention costs. In the main, this stock, tends to be beyond the reach of many people who owns these buildings. These issues are inherent of the heritage sector and will never go away.

Furthermore, across the UK, the current approaches and attitudes to decarbonising heritage stock conjures up the same image: of all the sectors within the built environment, it is the heritage sector that is the hardest hit. Worse still, this is also the sector with the most reduced capital spending receipts from government. The corollary to this, and given the aforesaid, is that the heritage sector is also the slowest to respond to any external demands to decarbonise its building stock. With these constraints in mind, the study sought the insights of heritage practitioners with a view to exploring variations in the perceptibility of barriers and threats to the successful and sustainable restoration of heritage buildings.

2. RESEARCH DESIGN, STRATEGY AND PROCEDURES

The heritage sector contributes in excess of £20.2 billion gross value added contribution to the UK's GDP. It is therefore an important sector vital to the treasury UK and society at large. Given this upshort, researchers felt it necessary to identfy both the apparent and the indescenible barriers with a view to understanding better, the threats to the successful and sustainable restoration of heritage buildings. However for this to happen, the views and opinions expressed by heritage practitioners were needed. For this reason, access to heritage practitioners formed a key episteological component of the study.

Practitioners are defined as professionals with a vested interests in the heritage sector and that their daily and unique experiences would enable the study to reveal some of the challenges which are intrisic yet remain deep-rooted to the heritage sector. It is from this upshort that the study collected data from 87 professional practitioners. These included building surveyors, conservation officers, designers, main heritage as well as specialist heritage subcontractors. This heterogeneous sample was subject to the same research instrument and the data generated was chiefly non-parametric.

3. FINDINGS

The study set out to explore practitioners' perception of the barriers and threats to the successful restoration of heritage buildings. A list of twenty five factors were generated from literature and as part of the exploratory work looking into the adaptation of new technology in the heritage sector. Researchers attended several workshops and these platforms, as pilot stages, assisted the researchers to reduce the twenty five factors to only eight. The eight were found to be the most recurring factors and thus worthy of subjecting to the main sample.

Threats to restoration are defined as a series of factors likely to hinder the successful restoration of a heritage asset. Kangwa and Olubodun (2010) outlined the logistical constraints likely to negate the succesful refurbishment of heritage buildings and found them to be wide ranging yet unique to a geographical location, legislative by laws. The hollistic understanding of these variables all contribute to the successful restoration of a heritage asset. Gorse and Highfield (2009) admit that unlike ordinary buildings, listed buildings are more challenging because of the unpredictability of the regulations. Taylor (2011) observed that even the sentimental decisions of project conservatioal officers tend to vary from one building to the next even when managed by the same officers. The sector has gone extenstive reviews a lot of changes post the Pinfold review. Given the aforesaid a question emerges: what do practitioners perceive as the ongoing threats to sustainable restoration of heritage buildings?

3.1 Perceptibility of barriers and threats to restoration of heritage buildings (BaTRes).

The pilot stages helped the study to reduce twenty five threats to successful management of heritage assets down to eight. Respondents were then probed to provide a rating relative to the degree of threat each factor presented. A rank order rating of 1 denoted a factor perceived to offer the greatest threat, and so forth up to 8. Factors at the bottom of the Table 1 portray areas with the least impact on restoration activities.

Table 1: Perceptibility of barriers and threats to restoration of heritage buildings (ranking at aggregate level)

Sample n = 87

Abbreviation	*Perceptibility of threats to successful restoration of heritage assets*	*Aggregate*	*Rank*	*Implied meaning*
BaTRest4	Adapting to modern technologies when establishing extent of decay/damage	2.038	*1*	*Reversibility : Avoidance of unintended structural damage*
BaTRest3	Avoidance of unintended damage to other parts of a building	3.019	*2*	
BaTRest1	Retaining the Historic value of a building	3.377	*3*	
BaTRest7	Finding a network of well reputed restoration contractors	4.113	*4*	*Micro-knowledge of a building's local heritage definition*
BaTRest6	Local significance/relevance behind listing status of a historic building	4.396	*5*	
BaTRest8	Finding reliable energy efficient retrofit technologies backed by Historical England	4.566	*6*	*Blurred technological interface*
BaTRest2	Keeping an accurate inventory of extent of ensuing work	5.283	*7*	
BaTRest5	Establishing extent of archaeological interest	6.189	*8*	

Since the respondents for the study were captured from various heritage backgrounds, with various years of working in the heritage sector a fair representation of the extent and order of perceptibility of threat was possible. Starting with the *implied meaning* (refer to Table 1) the results are now discussed in turn.

Reversibility: under listed building or scheduled monument consent heritage planning policy requires that the historial value receives the utmost consideration, whatever the proposed restoration or repair solution. All the main custodians of heritage buildings (Historical England, the Association for the Protection of Ancient Buildings, and Natural England to mention a few) are renown for insisting that restoration is not driven by 'replace' rather than *repair to retain* (RtR) value whether it is individual or a sum of building elements. This criteria drives a deeper sense of valuing a building to be a sum of individual components which in temselves define the both historical and present value of a building. In some cases, simply being able to understand the vulnerability of the original materials available at the time and effort to seek *like to like* (LtL) *materials or assembly techniques* all go some way in retaining the orignal fabric and thus the heritage value of a building. Any prognosis of repair should prioritise these issues: they echo the need for a sympathetic approach to restoration. Among conservational officers and planning officers they belive that these doctrines have been proved to be correct time after time (Gorse and Highfiled, 2011). They result in challengingly complex technical solutions but whose resulting effects allow the building to remain true to its original heritage value. In order to acquire these attributes, no amount of training is ever enough for a heritage practitioner.

Following on from here it is notable from Table 1 that indecisioness of the heritage sector is also a threat to the conservation process. In particular, obtaining listed building and ancient monument consents during planning process can take months if not years respectively. Buildings are therefore left overexposed between longer cycles of non intervention. The resulting effect is that structural damage occurs but despite this, every effort to rebuild the former structural integrity adopting the *RtR* and *LtL* are unique restoration attributes and rooted in the *'reversibility'* (Rv) doctrine.

A further inspection of Table 1 shows unanimity among practitioners that managing heritage assets hinges on getting an accurate diagnosis of structural defects but that the prognosis of the extent of decay and resulting structural damage are not cursory factors to the chosen restoration techniques. It is clear from the ranking that these are the hardest and most in dispute topics held between restoration contractors and the conservation officers. The common goal is to ensure any design efforts to restore a building's historical value.

Micro-knolwedge of local heritage definition. BaTRest 7,6

The second most severe threat relates to the almost inevitable issue associated with finding specialist heritage practitioners when you need them most. Any remedial work involves soft stripping and gradual exposure of sections or parts of a building that are beyond repair or reinstitution. Exposing the elements that are beyond repair requires an understanding of the intricate and elaborate ways in which old buildings were assembled. Inevitably, even with the greatest care of the most dextrous craftspersons, other parts of a building are bound to be damaged. This problem can also be explained by the fact that challenges that besiege the heritage sector also include the difficulties in finding specialist heritage contractors. These tend to be expensive and work can only take place when they are available and not when necessarily when the building owner needs them.

Striking a balance between immediate intervention to minise structural damage and the associated costs and restoration of the heritage value implies that one cannot succeed without the other. The custodians of heritage buildings are not necessarly the owners of the buildings protected by statute. However as heritage custodians, Historical England, The Society for the Protection of Ancient Buildings and Natural England should all focus on bolstering the skills and training critical to dealing with some of the inimitable restoration techniques which most colleges and institutions of higher learning hardly seek to provide. There is no replacement or substitutes for such skills and thus when it comes to restoration, there is no place to hide but to see their effect even among practitioners. Any lessons by the heritage contractor or the building owner can be expesive and must be avoided at all costs.

Consequently, finding bridinging initiatiives that allow tradespersonnel to develop their dexterities and encompassing the very understanding of the doctrines enshrined in reversibility: *hence Rv = RtR + LtL*. Ancient techniqure skills allow practitioners to Repair to Retain value (***BaTRest 6)*** and to adopt the use of Like to Like material and assembly techniques. These are the attributes that give credence to the doctrine of Revesibility (Rv). The knowledge and experience needed to understand the varied and conflicting needs of old buildings lies in understanding traditional methods of construction. This draws attention to the need to focus on trades training and specialist heritage skills which are all pivotal to the successful restoration of heritage buildings.

The least perceived threats shown in Table 1 are three equally very important areas of heritage management, namely:

Retrofitting Technology- BaTRest 8*;* ***record keeping of heritage work*** *-* ***BaTRest2*** *and* ***archaeological record-keeping - BaTRest5.*** all three sources are threats to the restoration process and perhaps an indication that heritage practitioners are getting used to the various technologies which target the new build sector and not necessarily the refurbishment or maintenance sector.

The call for the use of drones in the heritage sector is an interesting one; it reflects a repsonse to the challenges contractors have in providing specimen details of structural damage or most recent status of structural damage to ascertain extent of remedial work necessary. Where these may needed to confirm the cost of the work drones can reduce the drastic waiting time to confirm the status of a fledling structure in danger of collapse. Drones are a perfect match for a non destructive methodology often insisted upon by custodians. Yet as this study shows, the heritage sector has not woken up or fully embraced the drones-technology. In a sector where the time between expression of interest and the award of contract can be several years apart, the presence of drones would allow a quick update of the structural status of a building. They can inform the heritage contractor to revise their quotations and therefore their loss, a win win situation for the client as well. Even if the building were to be perlilous and about to collapse, drones would act as a non destructive method.

The reluctance in adopting these modern technologies compared the new built sector again confirms that restoration and refurbishment activitities are cinderrela activities to those of the new built sector. Given the heritage sector is characterised by very strigent archaic rules it leaves the sector disjointed and perhaps ad-hoc and with such attributes the heritage sector must be quick and ready to embrace new technologies.

3.2 Bivariate analysis: ranking of barriers and threats relative to heritage experience

The last fifteen years have seen drastic changes in the UK's regulations and planning procedures relating to refurbishment and restoration of listed buildings. The next stage therefore, was to establish extent of unanymity or concensus in the ranking of barriers and threats relative to heritage experience.

Thus as Table 2 shows, a cross tabulation between heritage experience and working purely in the construction sector was made. The table shows that up to 70% of practitioners for this study indicated to have only up to 14 years of heritage experience. Only 30% of the sample had more than 15 years and of heritage experience. Given this imbalance, it was important to use this as a criterion for determining extent of variance in the ranking attitiudes of the repsondents. The concern was that the 70% sample may have different views to the most experienced (heritage veterans) and therefore skewing or spoofing the outcomes of the study.

As a follow up Table 3, shows a bivariate analysis with practitioners split on this same basis: years spent working in the heritage sector. Therefore Respondents with between 0 to 14 years were

Table 2 Cross tabulation between construction and heritage experience

	Years in historical sector				
Construction experience	*0 to 9yrs*	*10 to 14yrs*	*15 to 19yrs*	*20+*	***Total***

Table 3: Relative ranking of BaTRest by designated heritage experience

Sample(R)	**IV1** n = 61 up to 14yrs	*Rank (X)*	**IV2** n = 26 15yrs +	*Rank (Y)*	Difference of ranks (d)	d^2
BaTRest4	1.79	*1*	2.25	*1*	0	*0*
BaTRest3	2.64	*2*	3.36	*2*	0	*0*
BaTRest1	3.12	*3*	3.61	*3*	0	*0*
BaTRest7	4.40	*5*	3.86	*4*	1	*1*
BaTRest6	4.00	*4*	4.75	*6*	-2	*4*
BaTRest8	4.92	*6*	4.25	*5*	1	*1*
BaTRest2	5.44	*7*	5.14	*7*	0	*0*
BaTRest5	5.68	*8*	6.64	*8*	0	*0*

$\sum d^2 = 6$

identified as the *X* group, whereas respondents with 15 years and above were labeled as the *Y group*. As stated above, the purpose of undertaking this bivariate study was to ascertain the degree of association in the perceived barriers and threats and whether the very experienced practitioners ranked some threats greater than those with the less heritage experience.

Spearman rank correlation was deemed the more appropriate bivariate method to help decipher the extent of the agreement or disagreement among the practitioners. It helped the study to address the following question:

> *Does heritage experience dictate practitioners' views of the prevailing barriers and threats to successful restoration of historical buildings in the UK's heritage sector?*

Kvnali et al (1999; 2016); and Kangwa (2004) Bryman and Cramer (2016) have all suggested the need to establish whether the relative mean rank for each of the eight perceived threats (BaTRest) is either high and traceable to practitioners with less experience or whether the opposite, is in effect,

In their work, using a similar approach, Yockey (2011), Yung, and Chung (2012) observed that as soon as the sample mean rank for each item was identified, the rest of the bivariate analysis was easy to conduct despite not having a central distribution,the fact that the data is generally non parametric makes the central distribution less relevant.

As shown in Figure 1, the Spearman's (r_s) rank correlation test was deduced as the most suitable bivariate analysis as it measures degree of agreement between two groups of practitioners: heritage practitioners *X*:(experience n= 61) and heritage practitioners *Y:* (experience n = 28) in e positioning of the each eight rated item as a perceived threat succesful and sustsinable restoration of heritage buildings.

3.2.1 Test of hypothesis

> H_0: No association in ranking of BaTRest factors exists between X and Y practitioners relative to heritage experience.

The Spearman rank correlation coefficient, given by the formula below was utilized to determine the degree of agreement.

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

$$r_s = 1 - \frac{6\ (6)}{8(8^2-1)}$$

$$r_s = 1 - \frac{36}{504}$$

$$\boldsymbol{r_s = 0.929}$$

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Based on this value, it is noted a significant positive relationship exists between heritage experience and perceptibility of threats to the successful restoration of heritage buildings. The value of r_s is neary 1, an indication of a higher level of unanimity in the rater-attitudes towards what are perceived barriers and threats to the restoration processs.

In order to determine whether a derived value of r_s = 0.925 was large enough to support the aforementioned conclusion, a test of the hypothesis that uses rank correlation r_s as a test statistic was set out as below.

According to Howitt and Cramer (2011) and Laer Statistics (2013), the applicable test of hypothesis is a rank correlation value r_s which the study set at a significance level of α = 0.05, with n = 8.

Table 4: Spearman's rank correlation test of hypothesis

	n = 8	
Confidence leve	95%	99%
Significant level	0.05	0.01
ChiSquare Table	0.643	0.833
Computed rs val	0.929	*Significant Reject H 0*

Table 4 summarises the test procedure, which is to reject H_0 if $r_s >$ **0.643** taken from the critical value of Spearman's Rank correlation represented at 95% confidence level where n = 8.

As noted in Table 4, the computed value of the Spearman's rank correlation coefficient is 0.929 and far exceeds the Table value **0.643. T**he study can proceed to reject the H_0 in favour of the alternative H_1 which shows that association exists between two sets of practitioners pitted against heritage experience. The ranking is undistorted, thus justifiable and credible that experience does not play a siginificant part. It also endorses the study's methodology in trying to extrapolate the extent to which the eight factors reflect the daily concerns of heritage practitioners.

Moreover, the outcome points to a higher degree of agreement between the two sets that that even when checked against the *p*-value α = 0.01 (99%); the noted chisquare value (as shown in Table 4) is siginificantly higher (0.833) than the derived calculated value.

A close look at figure 1 below shows how close the threats are ranked between X and Y respodents. It can be seen that BaTRest 7, BaTRest 6, and BaTRest 8 are the only threats where the two professionals could not possibly tie completely. The Scaterplot of Figure 1 endorses this position.

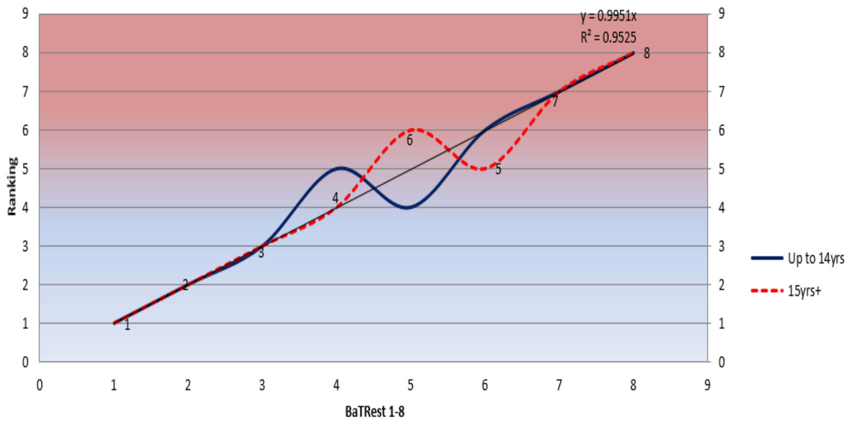

Figure: 1 Comparative ranking of BarTRest by heritage experience

As per Figure 1, the closeness in the ranking between practitioners with up to 14 years and over 15 years pitted against each other reveals a higher level of unanimity. Certainly, the two sets of ranking can hardly be seperated, an indication of the nearness in the perception of the barriers and threats. Considering there are 61 (70%) of the sample with between 0 to 14 years work experience, the imbalance is hardly a compounding factor to distort the perceiptibility of the most severe threats and thus barriers that militate the successful restoration of heritage buildings. Indeed, Figure 2 endorses that when a greater level of unanimity is registered - both in the magnitude of threat and extent of perceptibility of the rank order of the barriers – then their effect could not be a mere chance occurence. While the 70% respondents (0 to 14yrs) has a notable impact on the mean scores the results opposes the view that two camps are anything but closer. The veteran heritage practitioners (with 15 years +) have as much coners as the less experienced practitioners. The threats and barriers are sufficiently visible.

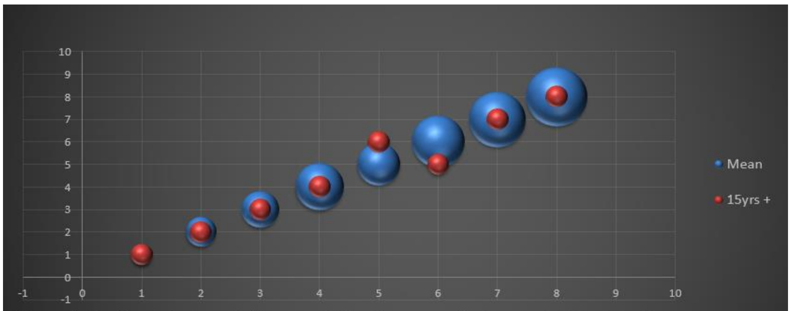

Figure 2. Scatterplot of practitioners relative to mean pitted against 15yrs+ heritage experience

4. DISCUSSION OF FINDINGS AND CONCLUSION

This study reveals the threats likely to impede the successful restoration management of heritage buildings. Further to this, the research defined threats as areas that can inform the measures necessary for ensuring the success of most restoration projects. Overall, eight threats appear to point to those areas where the practitioners are likely to find challenges and which impede their ability to operate well in the sector.

The next threat is associated with the difficulties in understanding mediaval building assemebly methods. This outcome is important in that it reflects the general constraint of skill shortage in the built environment. With heritage sector being so unique, it comes as no surprise that the shortage of well-trained professionals has emerged as one of the biggest threat.

The study concludes that the sector lacks ‘can-do’ attitudes. As a result, it is diffuclt to innovate and to find solutions to the inexorable cycle of disrepair and the enormous restoration bill, currently estimated to run into several billions of Pound sterling. Sadly, locked-in with this, is the enormous high carbon foot print resulting from the backlog of restoration and repair activity.

5. LIMITATIONS

The prevailing absence of information, on all manner of heritage activities, leads to increasing uncertainty in the diagnosis and prediction of restoration strategies. There is unanimity that these issues will, collectively, combine to allow the perceived threats and the consequences of unintended damage to heritage buildings to remain as major sources of concerns. Recently introduced legislation including governmentt reviews for the sector appear to have had little effect to ephase these concerns.

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Rainwater Harvesting: an important element of water sustainability in Bloemfontein

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ABSTRACT AND KEYWORDS

Purpose: Some major cities in South Africa have been experiencing water shortages over the years. Bloemfontein has experienced its share of water shortages over the years and looking at the rate of population growth, depending on municipal water supply alone may lead to situation where water demand will exceed supply. This study thus sought to explore the possibility of using rain water harvesting as s solution to the frequently occurring water problems in Bloemfontein.

Research methodology: Qualitative research approach was used for this study. Structured interview questionnaire made up of closed and open ended was used to collect data from purposefully selected construction professionals made up of quantity surveyors, project managers and estate developers. Excel statistical tools was used to analyse the data collected.

Limitation: The study concentrated on Bloemfontein city and data was collected from only construction professionals operating from Bloemfontein

Findings: The findings indicate that harvested rainwater can be used as an alternative water supply in conjunction with municipal water supply to ensure water sustainability for Bloemfontein in the near future and to decrease the pressure on municipal water supply. It was also revealed that estate developers do not make provision for water harvesting storage facilitate after the development because clients do not request for it; client see it as an obstruction to the aesthesis of the buildings and they not see water shortage as a serious problem in Bloemfontein.

Practical implication: the implication is that, letting go rainwater without storing them for future use will come to bite the municipal authority in the near future as the population increases causing water demand to exceed supply. It is therefore recommended that the municipal authorities should take action now and sensitize the populace and estate developers to install water storage facilities to supplement the municipal water supply.

Keywords: Bloemfontein, harvesting, rainwater, water sustainability

1. INTRODUCTION

Water using fixtures vary from plumbing (both in bathrooms and kitchens), external water installations for irrigation of the garden or landscaping. South Africa is becoming a water scarce country due to a couple of factors such as drought and the natural increase in population, engineers and architects are forced to keep water usage and energy savings in mind during the designing phase (Von Bormann and Gulati, 2014). They are forced to design in such ways because of the desire to design green systems and the increase in urbanization in larger cities such as Bloemfontein. This leads to various alternatives in the installation of water consuming fixtures such as toilets, taps and showers. These alternatives have some disadvantages such as the high capital and installation cost, maintenance and regular inspections by technicians, which ultimately have a negative influence on the operational cost of buildings (Spigarelli, 2012).

Bloemfontein is frequently dealing with water problems for a couple of years. Existing challenges that are related to this problem are ageing infrastructure, water quality, and supply constraints. There are currently two sources, supplying water to Bloemfontein, namely; Bloem Water, which supplies 70%, and The Maselspoort Water Treatment Works which supplies 30% (Macnamara, 2017). Statistics done by the Municipality indicates that if the population grows by 1.2% per year, the water demand will increase with approximately 30% over the next 20 years (Macnamara, 2017). Realising the urgency, the municipality has been seeking solutions to relieve water pressure in a bid to address the arising problem which will lead to demand exceeding supply.

Examples of successful rain water harvesting relieving the pressure on water supplied by local authorities, can be seen in many countries all over the world (Cunninghame, 2017). In South Africa, the City of Cape Town and the surrounding communities can be witness where the government took action to reduce the water consumption (Cunninghame, 2017). The advantages of rainwater are that, it can be harvested and stored for future uses when municipal supplies are limited and can also be installed to supply water to toilets, baths and gardens throughout the year (Earth Eclipse, 2018). A possible alternative relevant for Bloemfontein to relieve the water demand from consumers is by harvesting rainwater in the raining season for use during periods of water scarcity, hence the need for this research.

2. LITERATURE REVIEW

2.1 Water Harvesting

Water is the most general or main substance on the earth, covering more than 70% of its surface. Out of this 70% total volume of water on the surface of the earth, only 2% is fresh water (Dwivedi & Bhadauria, 2009). This fresh water is used by humans, for purposes such as domestic use, industrial use and agricultural use. According to Dwivedi & Bhadauria (2009), in many parts of South Africa, the quality of ground water is believed to be undrinkable and therefore rainwater harvesting may provide an alternative source of water for human survival.

Human civilization in South Africa entirely depends upon rivers, dams, and ground water to fulfil their fast growing demands for water. However, rain is the ultimate source that feeds all these supplying sources. The implication of rainwater harvesting is to make optimum use of rainwater at the place where it falls; that is to use it and benefit from it before allowing it to drain away (Dwivedi, & Bhadauria, 2009). Rainwater harvesting and storage systems are a very simple method to harvest or collect rainwater, traditionally from roofs of buildings, for an alternative water supply source and to reduce the increasing consumption of water supplied by the local authority. This can provide a very high quality of water if it is maintained and operated in accordance with the recommended guidelines (Australia Department of Water, 2011).

The harvesting of rainwater for later use is a very prehistoric technique and is becoming even more popular due to its inherent quality in terms of its smoothness, cleanliness and natural taste (African Development Bank, 2006). Rainwater nearly has a neutral Potassium Hydroxide (pH), and is free from impurities such as salts, minerals, and other natural and artificial contaminants (Dwivedi, & Bhadauria, 2009).The quality of stored rainwater may be reduced by contaminants like faecal coli, forms turbidity and insect larvae, these contaminants can be properly controlled by understanding the system operation and simple disinfection techniques if required (African Development Bank, 2006; United States of America, 2007).

2.2 Surface Run-Off Harvesting

The primary use for this type of harvesting system is for external uses such as gardening. It can be cleaned and purified if it is polluted by the catchment area and use for domestic purposes (Practical Action, 2016). The catchments' surfaces can be from various materials such as; rock surfaces, concrete channels, plastic sheets, treated soil, and paved areas. It is a very simple system for the catchment of rainwater from impervious areas.

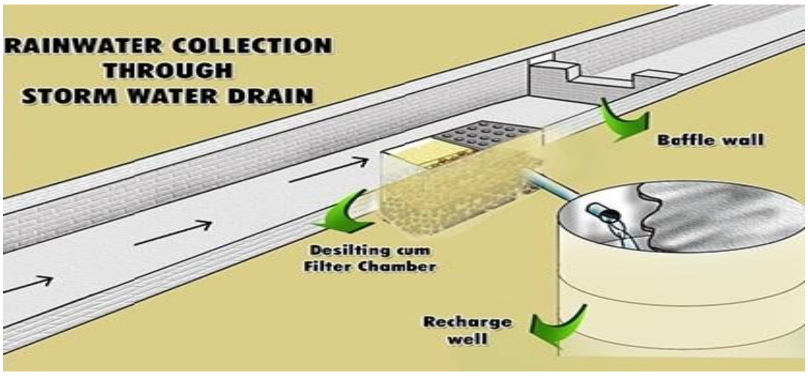

Figure 1: Surface Run-Off Harvesting (Cleanenvironment, 2018)

According Eldho (2013) the geological structure and contours must be taken into account with the ease of access when these collecting structures are installed. For example, as Cleanenvironment (2018) suggests, if the paved area is on a slope, a concrete channel can be installed at the bottom of the slope collecting rainwater and distributing it into a tank below the channels as shown in Figure 1. The tank can then be above ground level with a tap at the bottom of the tank for the use of stored rainwater. According to the African Development Bank (2006) with this type of water harvesting, the tank can be buried under the natural ground level, and pump is installed to pump out the stored water for later use. A mesh layer is also installed in the concrete channels to remove leaves and any unwanted materials before the water enters the tank. Maintenance and operation is the utmost importance for optimum harvesting and the essential quality of water (O'Brien, 2014: 37).

2.3 Roof Top Harvesting

Rooftop harvesting is a delicate process of collecting rainwater that is falling on the roofs of buildings and runs into the rainwater drainage pipes (Studer & Liniger, 2013). This water is then stored in a tank that is connected to the rainwater drainage pipes and situated next to the building as illustrated in Figure 2. Studer & Liniger (2013) suggest that the water harvested from the roof can be used by the residents of many households and the quality of the rainwater is influenced by the type and condition of the roof covering. Galvanised iron metal roof sheets provides the best quality of rainwater due to it smoothness surface and the heat of the sun on the steel helps to sterilize bacteria, provides the greatest yield of all roof covering types (Oas, 2018). Roof tile coverings that are glazed can be of good quality but contamination may exist in tile joints. On the other hand, thatch roof coverings provide poor quality water and are not preferable due to the little first flush effect that is gained from the roof (African Development Bank, 2006).

According to Dwivedi, & Bhadauria (2009), the use of the stored rainwater can be temporary (within a few days after a rainstorm), seasonal (throughout the areas rain season) or permanent (through the rain season and the dry season) except in years when the current area is experiencing adverse drought and it can be harvested and stored by the individual members of the household as it is not open to be used or wasted by members of the community. The harvesting of rainwater on roofs can be at various levels, individual, community or it can be on an institutional level, it is mainly used for domestic purposes. The quantity of rainwater that can be stored depends on that specific area's rain pattern, catchment or roof area, and then obviously the volume of the installed storage tank (United States of America, 2007).

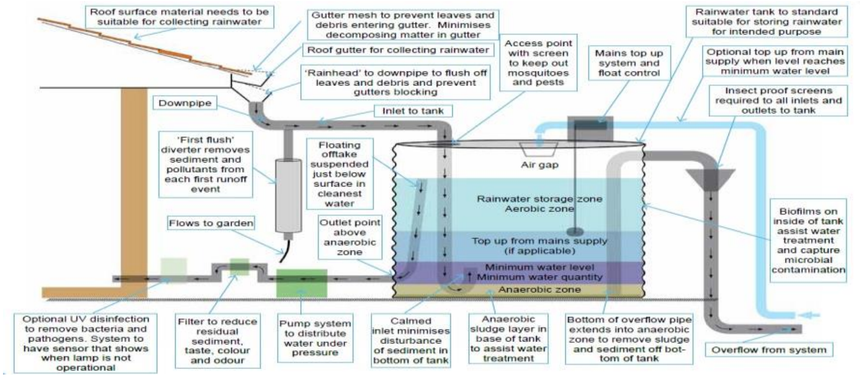

Figure 2: Roof Top Harvesting (Australia, Department of Water, 2011)

This method of rainwater harvesting can be very useful in areas with an annual rainfall of between 200 and 1000mm. If the specific areas' rainfall does not meet the favourable amount required per annum, it can still be efficient to lighten the burden of authorities supplying water (African Development Bank, 2006: 2). If one does not have the required equipment to store the harvested water, it may also be used to recharge the groundwater and water table by connecting a pipe from the rainwater downpipes to a nearby borehole (Dwivedi, & Bhadauria, 2009).

2.4 The Need for Rainwater Harvesting

Ninety-eight percent of available water in South Africa is already been allocated to the various consumption sectors, leaving South Africa with the status as a water scarce country (Von Bormann & Gulati, 2014). The need for harvesting and storing rainwater for later use has increased due to the increase in population and higher usage levels of water, thus water supply agencies are unable to cope with demand from available sources (Dwivedi, & Bhadauria, 2009; Adugna *et al*., 2018).The trend to save water is not just a question for the local water suppliers, the responsibility also rests on water consumers. When residents of a specific house take a shower, wash their clothes, or make a cup of coffee, they ignore and underestimate both the environmental as well as a financial impact of their actions (Energy Saving Trust, 2013). This financial impact refers to the water account for residential home owners as every time one opens a tap or run a water using an appliance, he/she spends money, create carbon emissions and draw on our water minerals (Energy Saving Trust, 2013).

Based on the current usage trends in South Africa, it is estimated that population's demand for water will exceed the amount of water available by the year 2025 (Department of Water Affairs, 2016). To fan the flames of the matter even more, studies shows that the Mangaung Municipality system input volume will exceed the capacity of the bulk water systems within the next two years (ISS, 2018). It is therefore critical that water conservation and water demand management initiatives be accelerated as a matter of urgency and that additional long term sources and alternatives such as harvesting rainwater be identified and implemented (Mangaung Metro Municipality, 2016; ISS, 2018). The water use in different homes, with or without meters, varies to a great extent. This depends on the utilization of water and differences in daily water use practices. The findings of a study done by the Energy Saving Trust (2013) in the United Kingdom on the average water consumption per household indicates that, the average person uses about 142 litres of water each day for different activities, whilst the average household uses 349 litres of water each day. Bathroom water usage is the biggest with showers consuming 25% and toilets using 22%. People generally spend seven and a half minutes in the shower whilst 87% of people spend 10minutes under the shower daily. Only 41% of homes had a dual flush toilet allowing the usage of less water. Eighty-six percent (86%) of residents who used a bowl when washing dishes by hand, make use of the same water as grey water in their gardens (Energy Saving Trust, 2013).

It is therefore important for South Africans to recycle more water than we do presently as more and more water in households per person are consumed which may lead to water demand exceeding supply in the near future.

2.5 Water Sustainability in Bloemfontein

Factors such as rapid population growth, industrialization and climate change are having impact on the sustainability of water management are gaining increasing attention in both South Africa and the world at large. In South Africa, cities such as Bloemfontein are under severe pressure to respond not

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only to certain water challenges, but they are also facing challenges such as economic transformation, accelerating basic service delivery, and social tension divisions (Carden & Armitage, 2012).

According to Ukwanda (2009), a distinction must be made between water availability, water withdrawals and water consumption. Water availability is the amount or quantity of renewable water resources that are available for human use for either domestic, industrial or agricultural uses whilst water withdrawals are the amount of water that is diverted from available dams and rivers and pumped from aquifers for human use, but it is not necessarily consumed. Only a part of water that is withdrawn from resources is being returned to the environment after the use thereof. Consumed Water is the volume that is not returned to the environment after use, it is usually incorporated into products and organisms so that it becomes unavailable to other users (Ukwanda, 2009). For domestic use, 10% of water is withdrawn from resources and only 3% is consumed. The difference in percentages between water withdrawn and water consumed can be due to failing water meters and leakages in pipelines (Ukwandu, 2009).

The factors that cause population growth in a city such as Bloemfontein are the natural increase in population and the migration to cities (Bhatta, 2010). A study done by the United Nations shows that South African cities have experienced population growth from the fall of the apartheid era in 1995 up to 2015, as well as a population forecast from 2015 till 2030 (Writer, 2015). The results from these studies indicate that the growth in population for Bloemfontein moved from sixth place (1995-2015) to fifth place (2015-2030) in the overall rankings of population growth in South African cities. New solutions and alternatives to improve water sustainability of these cities is inevitable and the coordination of such implementations, the monitoring thereof, reporting and verification systems are proposed ways to bring long-term accountability to both the government as well as to the local community and population (Carden & Armitage, 2012).

3. RSEARCH METHODOLOGY

In this study, qualitative research methodology was used to gather data. The data collection instruments adopted for this study was the structured interview questions made up of tick box and open ended. The interview questions were personally distributed the correspondents in the construction industry (Mechanical Engineers, Civil Engineers, Quantity surveyors, Contractors, Project managers and estate developers) operating from Bloemfontein. The department of water in the Mangaung municipality was also interviewed. A purposive sampling was used as the topic under investigation is special and hence only people with in-depth knowledge can contribute. Purposive sampling is described by Welman *et al.* (2005) as a non-probability sampling used by researchers where they rely on their experience, ingenuity and/or previous research findings to obtain units of analysis in such a way that the sample they receive will be regarded as a representative of the relevant population. The researcher personally asked respondents' questions and filled in the questionnaire based on the responses given by the respondents. In order instances, where the respondents were not available to be interviewed, the researcher left the questionnaire with the respondents. The respondents then filled the questionnaire and then emailed it back to the researcher. Respondents were encouraged to seek any clarification they might need via email or telephone call.

The research questions were made up of both closed and open-ended questions and were made easy to be answered by the respondents. As Reja *et al*., (2003), put it, the close-ended questions limit the respondent to the set of alternatives being offered, while open-ended questions allow the respondent to express an opinion without being influenced by the researcher. In all 36 respondents were contacted for an interview of which 27 responded, given a response rate of 75%. The data collected were analysed through content analysis. Content analysis is the process of analysing verbal or written communications in a systematic way to measure variables quantitatively (Polit & Hungler 1995). Welman *et al.* (2005) on the other describes contents analysis, as quantitative analysis of s qualitative data, where the researcher counts the frequencies and sequencing of words, phrases and concepts in order to identify keywords or themes. The features of the respondents are shown in Table 1:

Table 1: Profile of the respondents

Respondents Profile	Frequency	Percentage	Code
Nature of the respondent's occupation			
Quantity surveyors	10	37%	
Project Managers	6	22%	
Contractors	5	19%	
Estate Developers	2	7%	
Civil Engineering	2	7%	
Mechanical Engineering	2	7%	
Total	**27**	**100%**	
Respondents employment industry			
Private Sector	**27**	**100%**	
The participants position in the organization			
Quantity surveyors	8	30%	QS1 to QS8
Project Managers	7	26%	PM1 to PM7
Facility Manager	2	7%	FM1 & FM2
Director	4	15%	D1 to D4
Contract Manager	4	15%	CM1 to CM4
Mechanical Engineers	2	7%	ME1 & ME2
Total	**27**	**100%**	
The participants level of education			
Bachelor degree	14	52%	
Honours Degree	8	30%	
Diploma	5	19%	
Total	**27**	**100%**	
Respondents work experience			
Below 5 years	9	33%	
5 to 10 years	2	7%	
10 to 15 years	2	7%	
Over 15 years	14	52%	
Total	**27**	**100%**	

4. RESULT AND DISCUSSION

4.1 The organization's experiences of water shortages in the past

This question was asked to identify how many of the participants' respective organizations have experienced water shortages in the past.

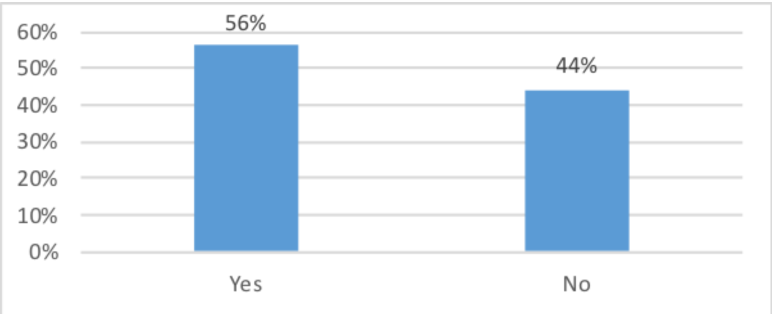

Figure 3: Experienced water shortages in the past

From Figure 3 it can be seen that 56% of the respondents have experienced water shortages in the past, while 44% of the respondents have not yet experienced water shortages.

4.2 Installation of rainwater storage facilities by the respondent's organizations.

This question was asked to determine whether the participants have installed rainwater storage facilities on their premises to date.

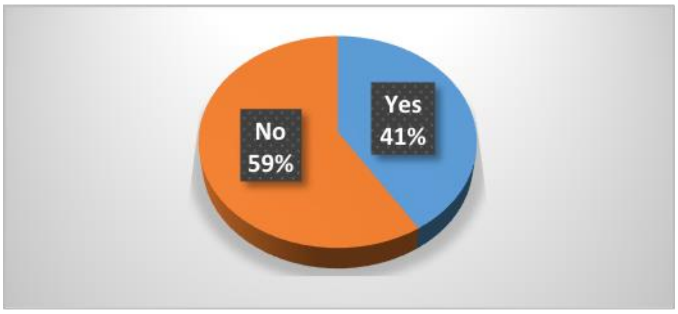

Figure 4: Installation of rainwater storage facilities by the respondent's Organizations

Figure 4 illustrates that 59% of the respondents have not installed any rainwater storage facility yet, while 41% of the respondents have installed a rainwater storage facility on their premises. The participants that answered no to this question stated the following as reasons; lack of space on their premises and infrastructure that cannot accommodate such an installation, they are currently looking into it as an alternative back up for municipal water in the near future; they are currently not consuming large volumes of water in their respective offices and the municipal water supply is enough; and the shortage is not severe yet, but they will do it in the near future as they know it is a good alternative water supply. These findings also indicate the respondents' belief in the necessity of rainwater harvesting as an alternative water supply to compliment the municipal water supply.

4.3 Involvement in property development by the respondent's organization.

This question was asked in order to determine whether the respondents are directly involved in property development.

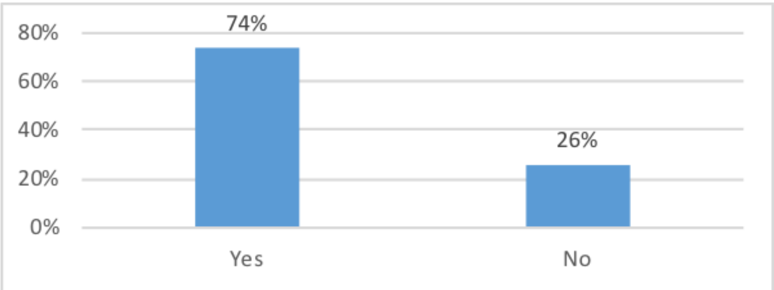

Figure 5: Respondents Involved in property development

From Figure 5, it can be seen that 74% of the respondents are directly involved in property development, while 26% of them are not directly involved in property development. Twenty-six percent (26%) of them, who are not directly involved, are consultants and are not physically involved in developments.

4.4. Making provision for rainwater storage facilities after development.

This question was asked to determine whether respondents make provision for a rainwater harvesting system after development. The result is indicated in Figure 6.

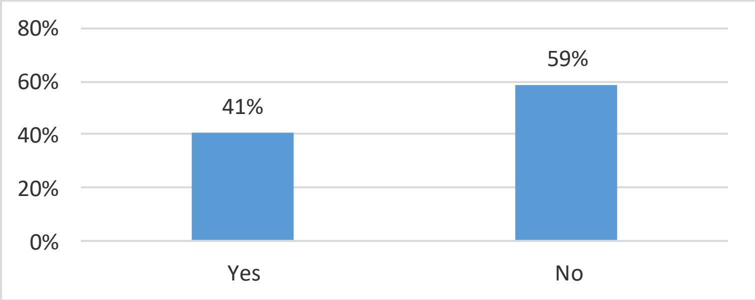

Figure 6. Rainwater storage after the development

The respondents who answered no to this question stated that, due to the bulky tanks and cost implications of a more complex type of rain water harvesting system they do even think of installing rainwater harvesting facilities after the development of the houses or offices. *FM2, CM, QS2 & QS6* stated that some clients do not want it because of the bad aesthetic appearance it has on a building and the extra costs it brings. *FM2* further stated that the installation of rainwater harvesting systems are not required by the market yet, but they are considering it in future projects. These findings clearly indicate that consumers think of the aesthetic nature of their houses more than cost saving for water by installing simple water harvesting systems such as plastic tanks. The developers also want the client to request for the installation of rainwater storage systems before they act.

4.5 Provision of rainwater storage facilities at the residential and office buildings

This question was asked to identify if the participants think that it is a good idea to make provision for such a system on their premises. All the respondents (100%) agree that it is a good idea to make provision for rainwater storage facilities at residential office buildings. Respondents are of the view that, a lot of rain water goes into drains during the raining seasons which can be better utilised in order to save water and decrease the load on the municipal water supply. Rain water will provide a cheap alternative water source in conjunction with the municipal water supply and decrease the amount money spend on water by home owners. Respondents also see the installation of rainwater storage facilities in residential and office buildings as water will become scarcer in the future due to an increase in the population as well as changes in the weather pattern with Municipal not being able to meet the demand.

4.6 Respondents opinion, on whether the Mangaung Municipality has made any provision to prevent water scarcity in Bloemfontein.

This question was asked to get the respective opinions of the respondents on whether the Metro has made any provision to prevent water scarcity in Bloemfontein in the near future. The result is shown in Figure 7.

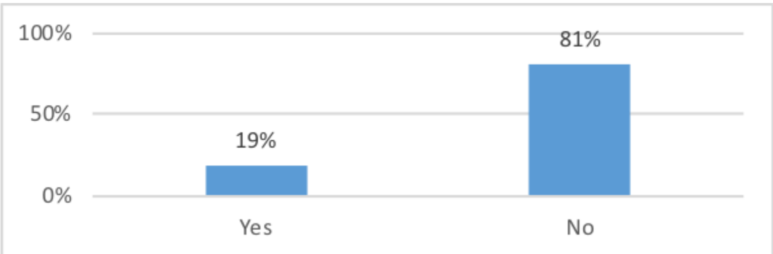

Figure 7: Whether provisions are made by the municipality regarding water shortages

Participant's, who answered yes, are of the view that there are water restrictions that the municipality have set in place and they believe that this restrictions are being followed by the consumers. The municipality has plans to build another pipeline from the Gariep dam in the next couple of years to increase the volume of water supplied to consumers, but lack of funding is delaying this project to take off. On the other hand, the respondents who answered in negative to this question stated that, the municipality do not even attend water leaks in the systems currently hence water

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shortages are eminent. *QS3 & ME2* stated that there are not enough experience personnel in the municipality to manage water resources effectively and efficiently leading to water shortages. *FM2 & PM1* are of the view that the municipality has no adequate alternative water supply in place currently to overcome any water shortages that may confront them in the near future due to financial constraints. However, in interview with the municipality, they confirmed of the construction of another dam to boost the water supply but the funding for the project is not yet secured.

4.7 Rainwater harvesting as a solution to water scarcity in Bloemfontein in future.

Respondents were asked to share their opinions on whether rainwater harvesting can be a solution to water scarcity in Bloemfontein in the near future. The responses to this question is represented in Figure 8.

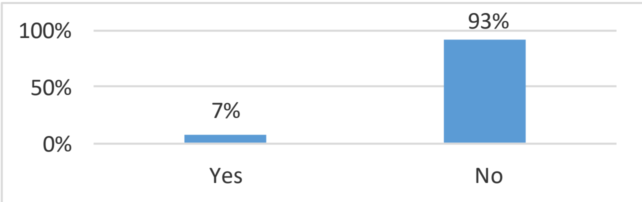

Figure 8: Whether rainwater harvesting is a solution for water scarcity in Bloemfontein

The respondents (93%) who answered in affirmative stated that if water is stored and reused, it would lessen the burden on municipal water supply. *QS1 & PM5* stated that, if rainwater is harvested and reused to their full potential, it can reduce the total water usage from the municipality and also help people to save on water bills. *FM1, CM1 & CM4* were also of opinion that, if each home or business has rainwater storage facilities, less water will be used from dams and this will reduce pressure on the municipality for increasing water supply to meet consumption levels by the households. *PM2, D1, D3 & QS3* also stated that the amount of water available is insufficient for human usage and consumption hence rain water that is collected on the correct methods can be utilized as drinking water in times of drought. On the other the 7% of the respondents who disagreed that rainwater storage cannot be a solution stated that the average rainfall of ±400mm per year in Bloemfontein is too low to make any impact and that large catch up areas is required to store enough water which is not feasible for a small residential building. Others stated that the high cost implications in terms of treating rainwater for safe use in households.

4.8 Techniques of reducing water consumption by Mangaung Municipality.

This question was asked to get opinion from respondents on how the Municipality can reduce water consumption. General answers provided by the participants are boarded on the general maintenance of the water infrastructure by the municipality. *QS2* stated that, the municipality should maintain the infrastructure and fix leaks in pipe lines immediately they occur and for this to happen, the Municipality must have more frequent inspections with qualified technicians and better staff. *ME2* also opined that, the municipality should advertise on social media platforms and channels to inform consumers on water scarcity and restrictions. They should implement penalties on late payments of water bills to encourage consumers to pay their water bills. *FM1* & *FM3* also proposed the successful installation and implementation of rain water harvesting systems for storage and re-use and that the Municipality must educate consumers on the importance of water and how to use it sparingly in conjunction with rainwater harvesting. *CM2* on the other hand suggested that, the municipality must also harvest rainwater that goes to lost in storm water channels and utilize it when the need arises.

4.9 Making it a requirement for all new buildings to install rain water harvesting facilities

This question was asked to get various opinions from the respondents on making it a requirement for all new buildings to install rain water harvesting systems and the utilization thereof during later stages. All the participants were in favour of making rainwater harvesting installations a requirement for all new buildings. Respondents were of the opinion that the rainwater harvesting system can be used in conjunction with municipal water hence if it made as a requirement in the by-laws, then it will force the developers to comply. Others are of opinion that rainwater is a good alternative and must be implemented in the South African National Building Standards (SANS).

4.10 Alternative solution for the households that cannot afford a rainwater harvesting system.

The purpose of this question was to get suggestions and alternatives from the respondents for households that cannot afford a rainwater harvesting. The participants suggested that the harvesting of rainwater can be done by using plastic container and then boil it to get rid of any germs that might be in the water and use it as drinking water. The installation of water fixtures such as hand wash basin taps with mist spraying taps and showerheads with "water saving showerheads" can also reduce the water consumption. Connecting rainwater gutters with a normal plastic pipe and use the water in their sink, wash hand basins and washing machines or gardens can also be cheaper option for households. As suggested by *FM1* stated that, "*rainwater harvesting system does not have to be expensive and complex, it merely involves installing a Jo-Jo tank that must be subsidised by the municipality that catches up rainwater and can even be used in the development of RDP-houses"*. *QS2* also suggested that the Municipality should subsidise home owners with a smaller scale rainwater harvesting mechanism and then adds a percentage to the consumer's monthly water bills till the amount is fully paid back by the customer.

5. CONCLUSIONS AND RECOMMENDATIONS

The findings of the study indicate that the successful harvesting of rainwater and the re-using thereof in conjunction with municipal water definitely is a water alternative to assure water sustainability for Bloemfontein in the near future and to decrease the pressure on the municipal water supply. The utilization of harvested rainwater will reduce the load on the municipal water supply as it can be used in many areas in the house, thereby reducing the stress on the municipal water supply and savings on the bills paid by consumers. It is therefore an ideal to install rainwater harvesting system to supply water to areas such as toilets, wash hand basins, washing machines and the gardens. The findings also indicate that consumers perceive the installation of the rainwater storage system as too expensive and will also destroy the aesthetic features of their houses. It is therefore recommended that the municipality intensify education on the rainwater harvesting as an alternative water in conjunction with municipal water to ensure water sustainability for Bloemfontein in the near future. By-laws can also be put in place to make it compulsory for all new developments to have rainwater harvesting facilities installed to decrease the pressure on municipal water consumption in time of need. The municipality can also introduce a subsidy scheme to assist the households who cannot afford the installation of a rainwater harvesting system.

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